Vantage Technical Reference

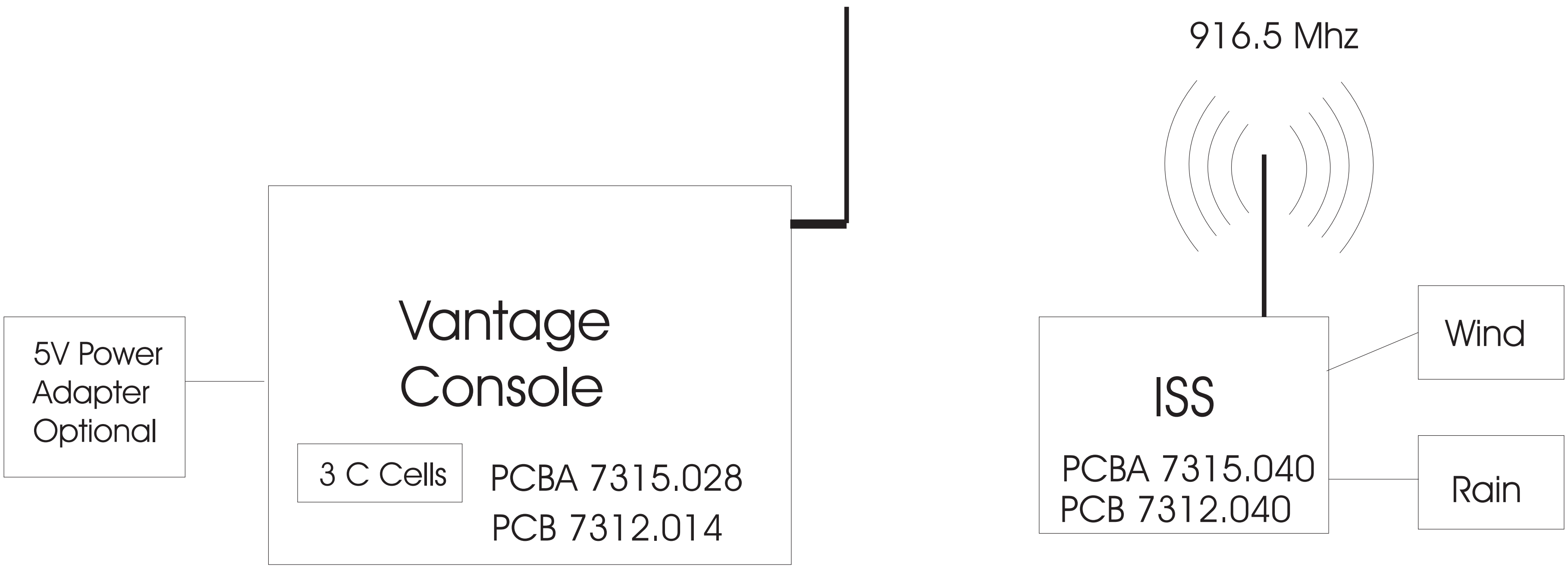
CONFIDENTIAL

For Internal Use Only

Davis Instruments
3465 Diablo Ave.
Hayward, CA 94545
Created: 9/11/01

Table of Contents

6150 Vantage Pro Station



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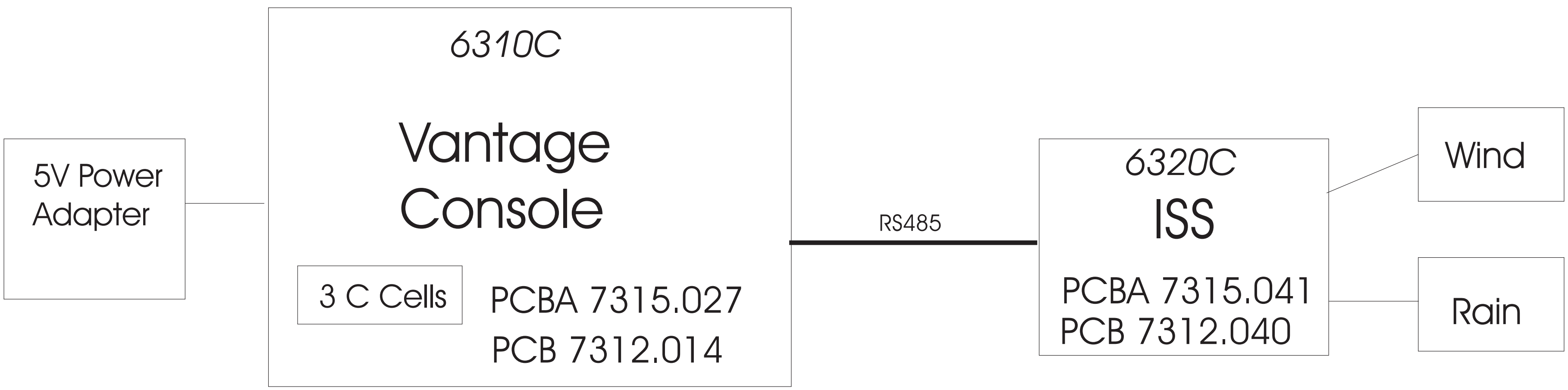
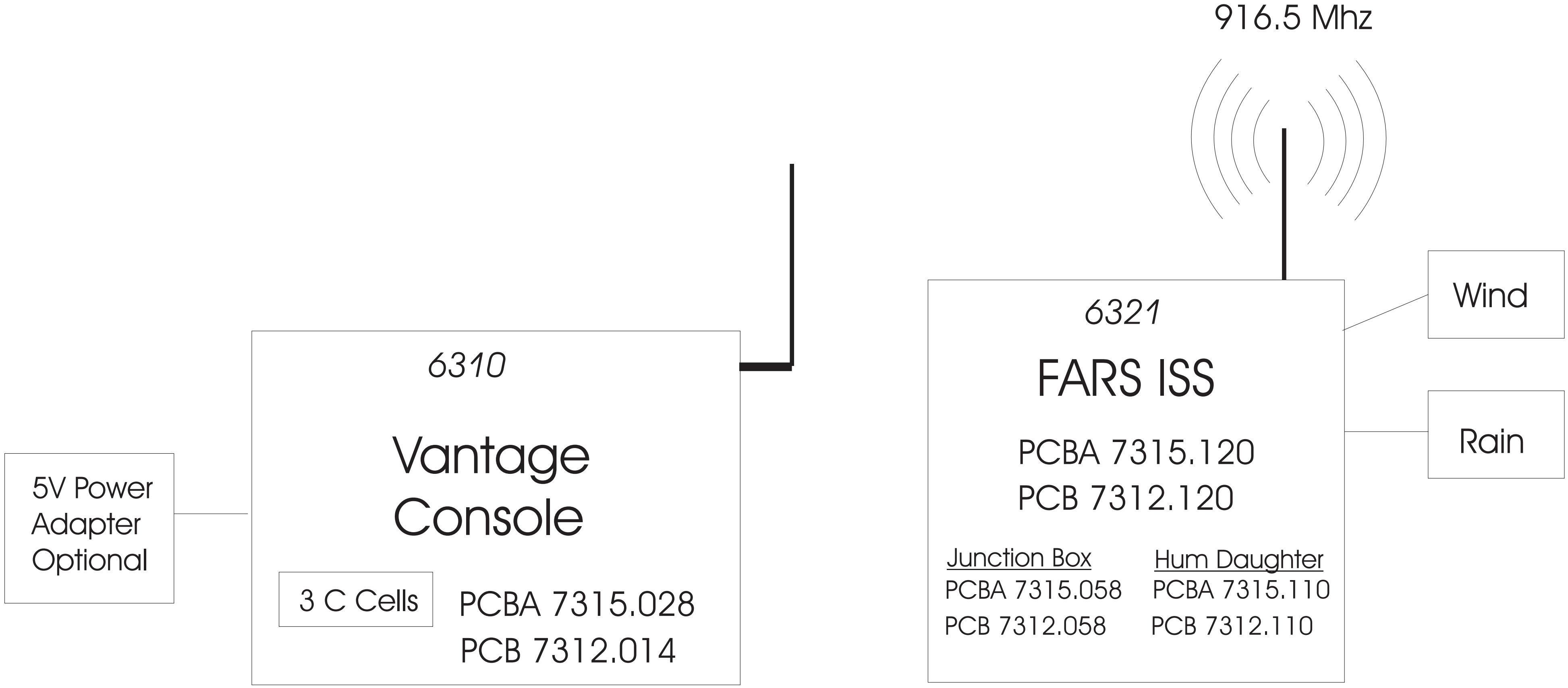


6151 Vantage Pro with FARS



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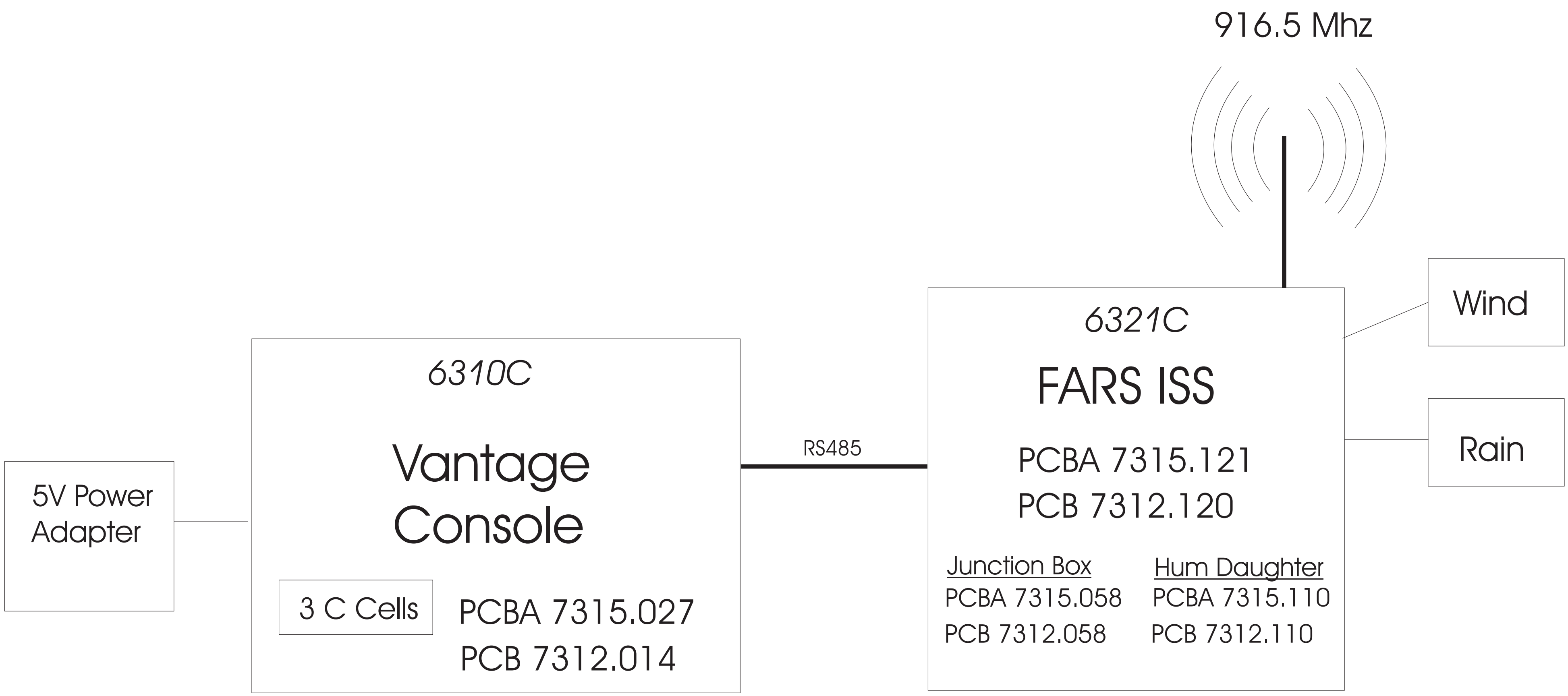

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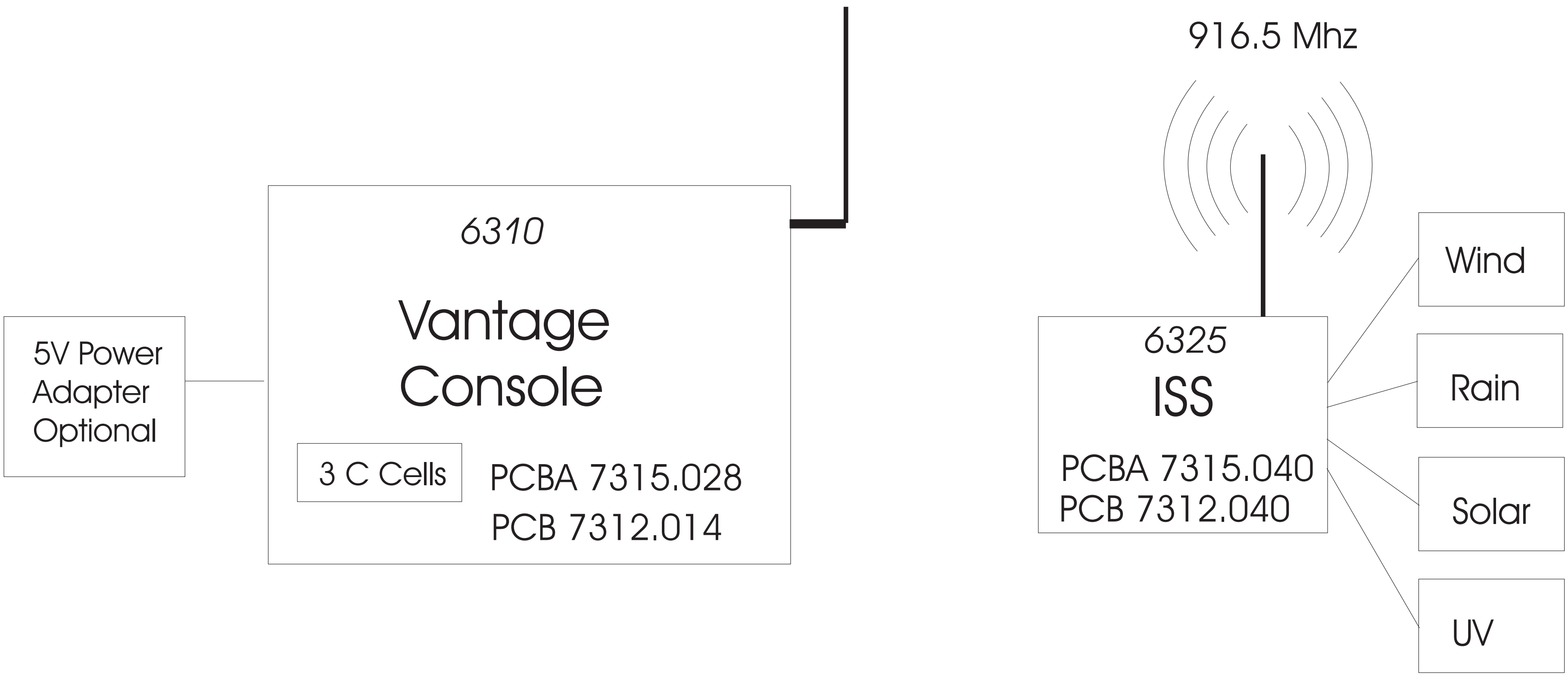

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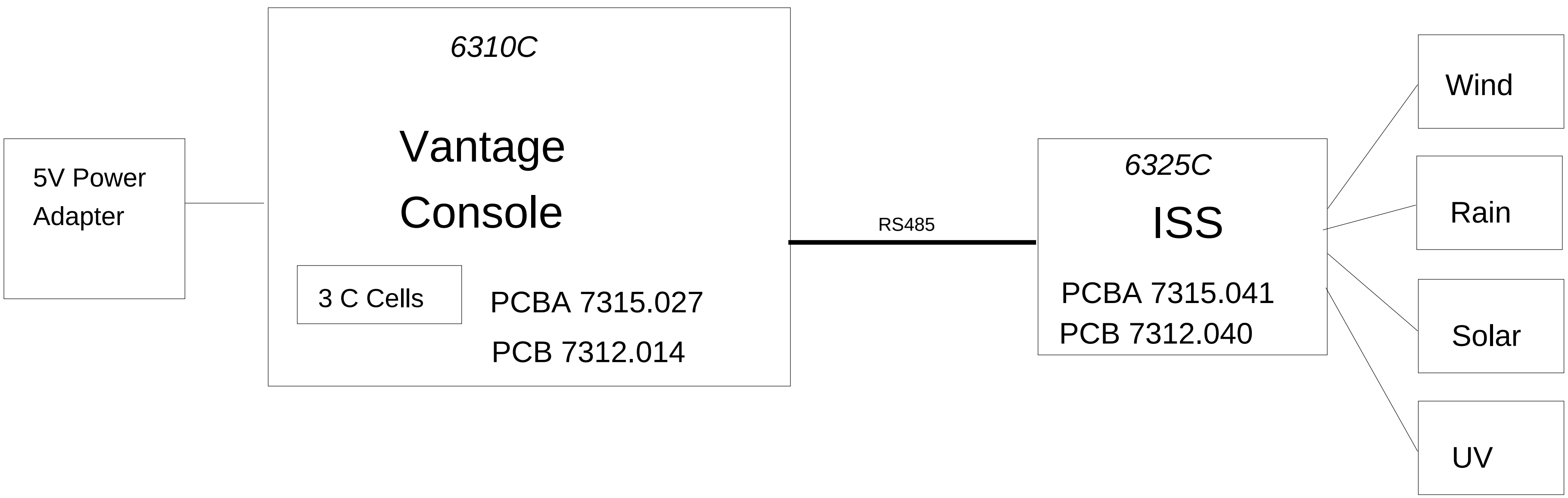

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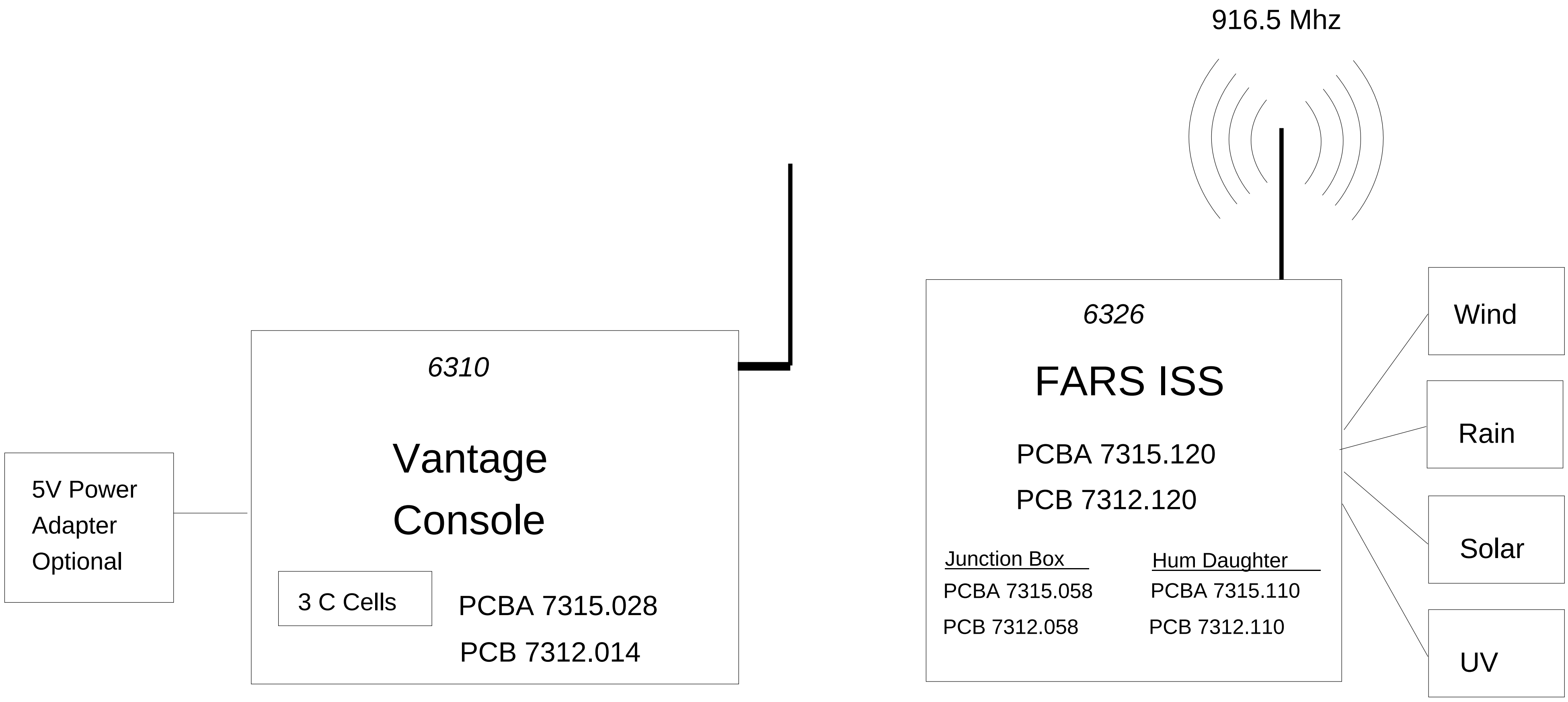

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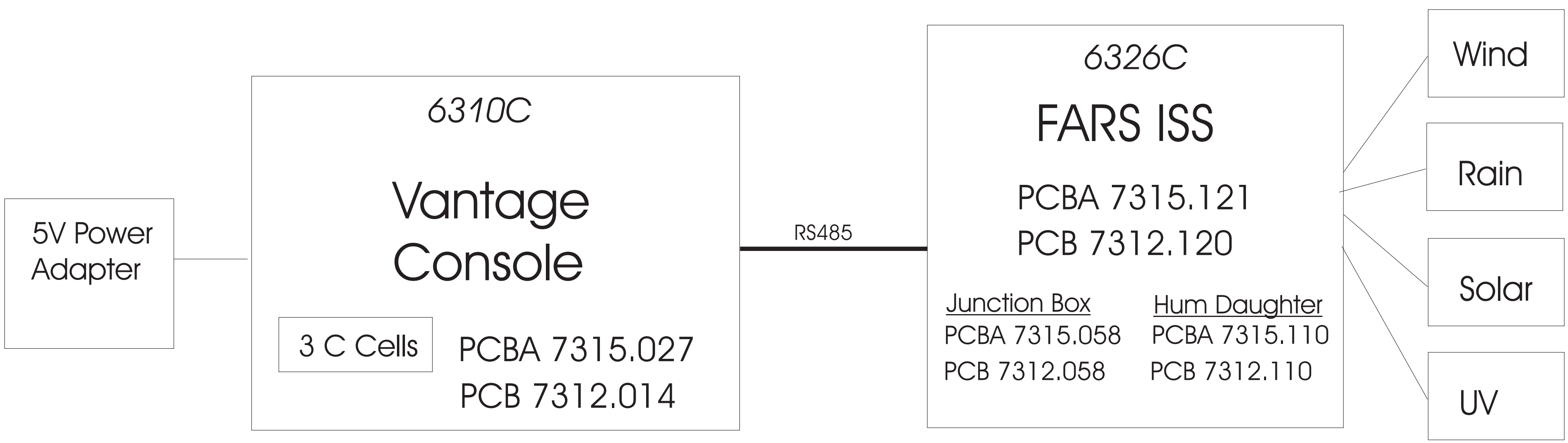

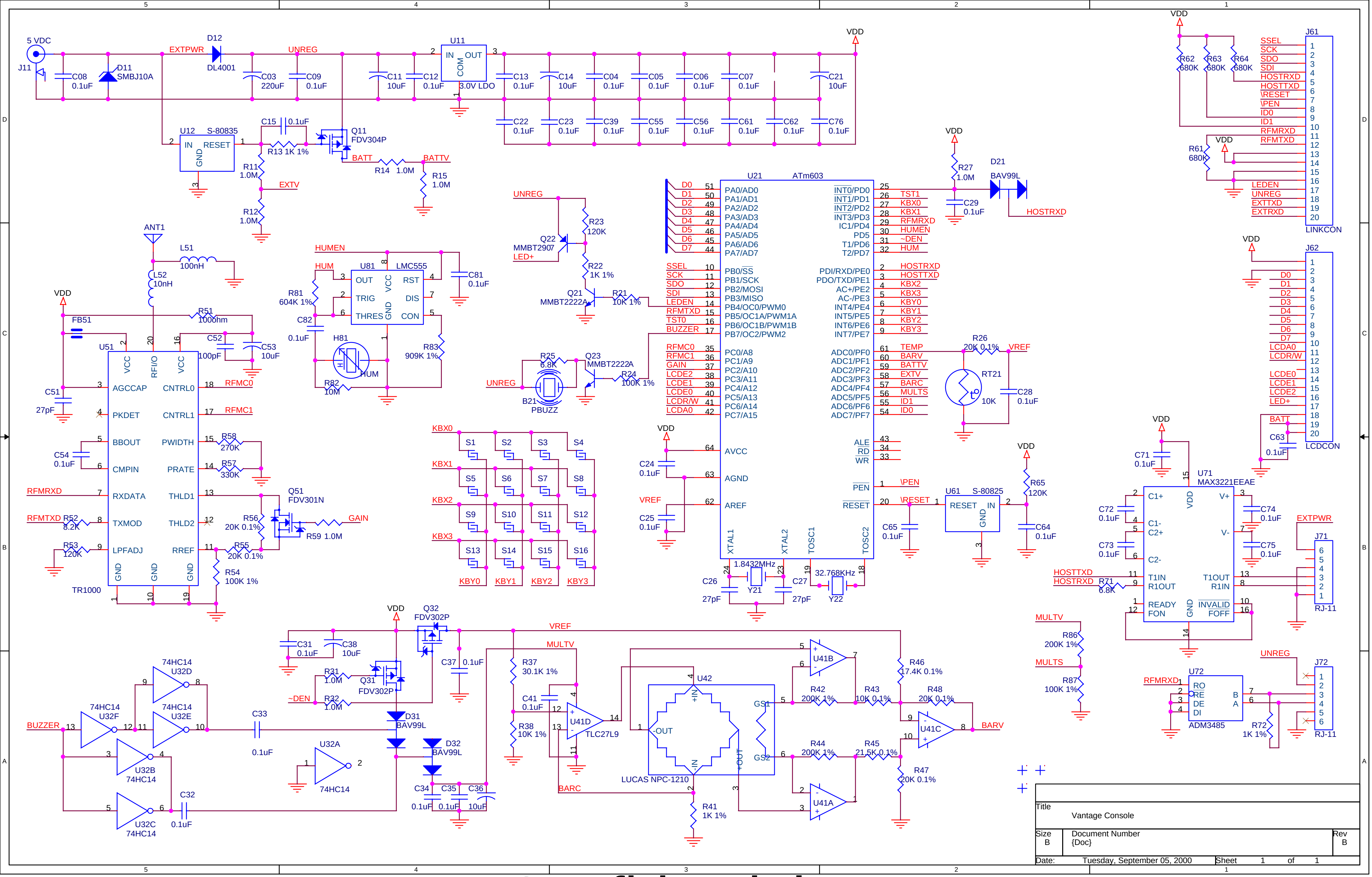

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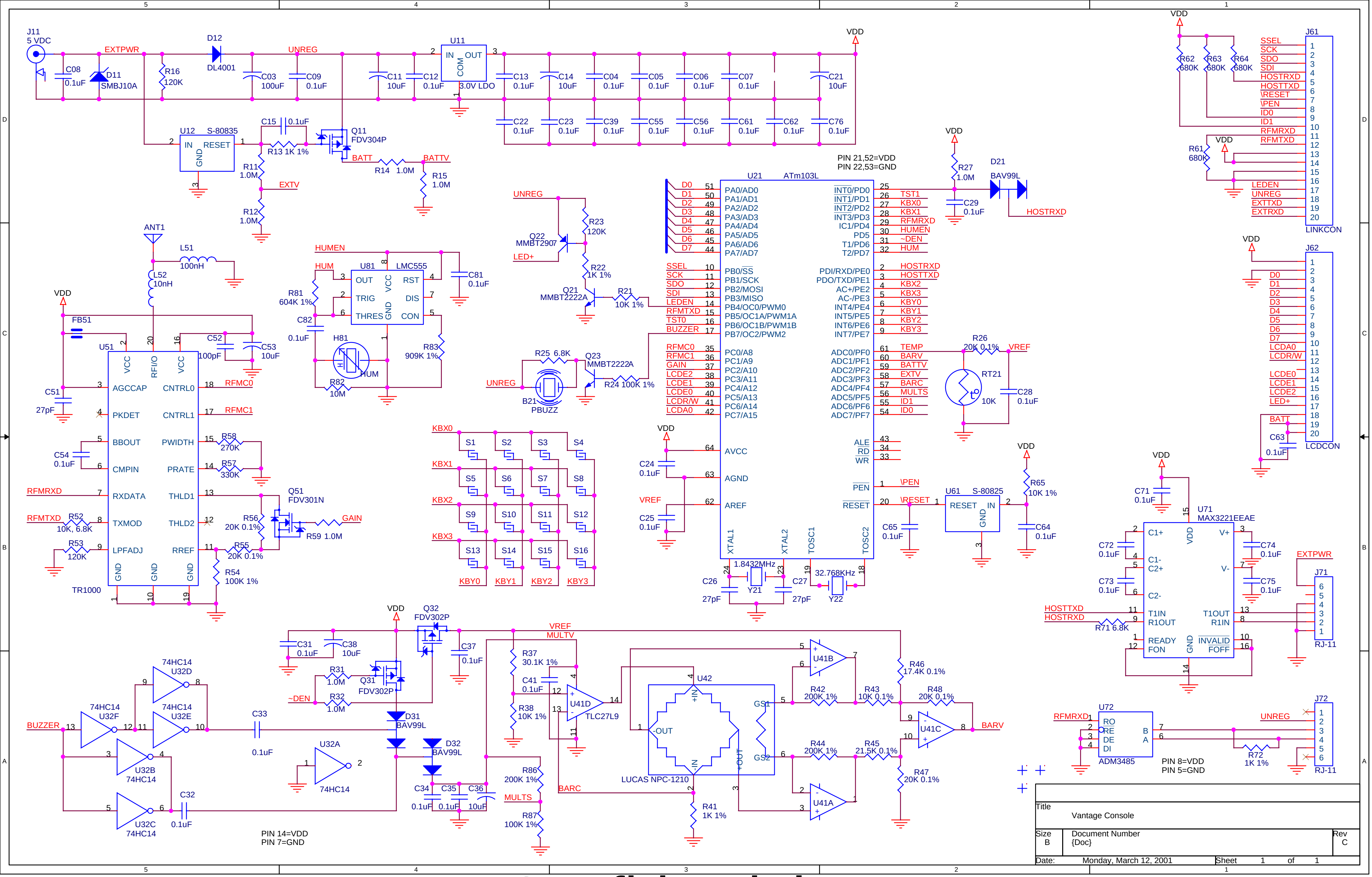

Confidential

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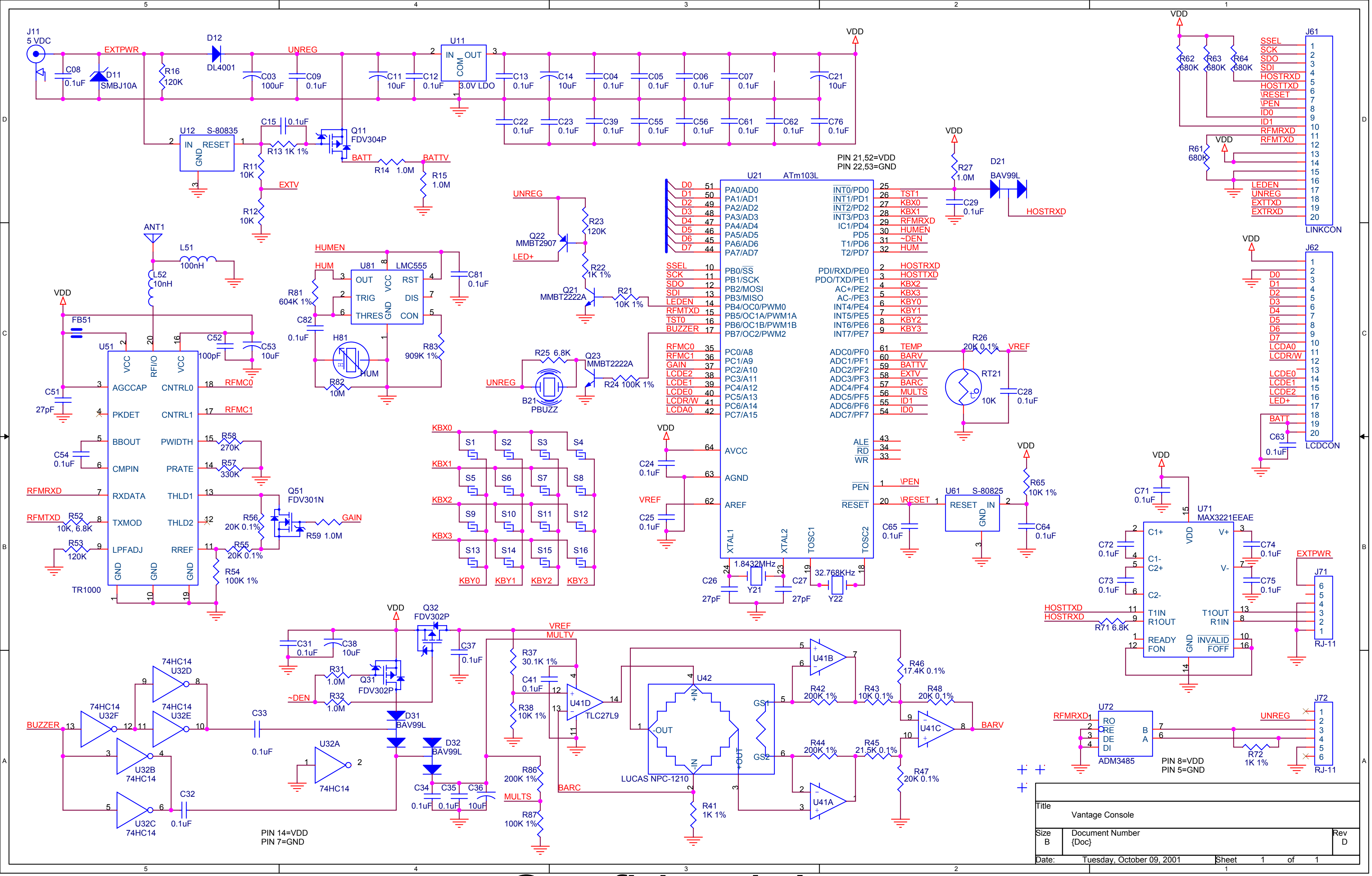

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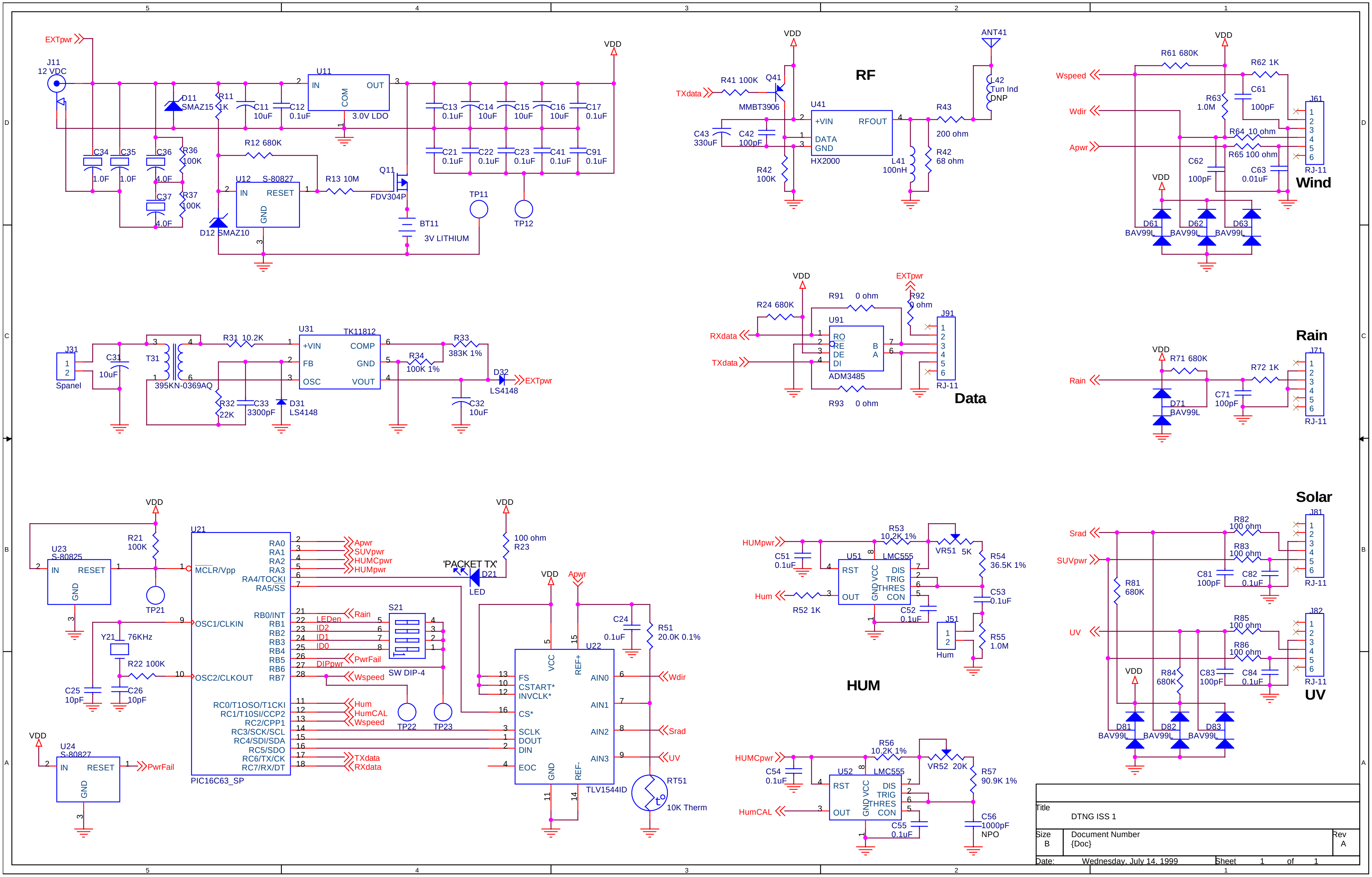

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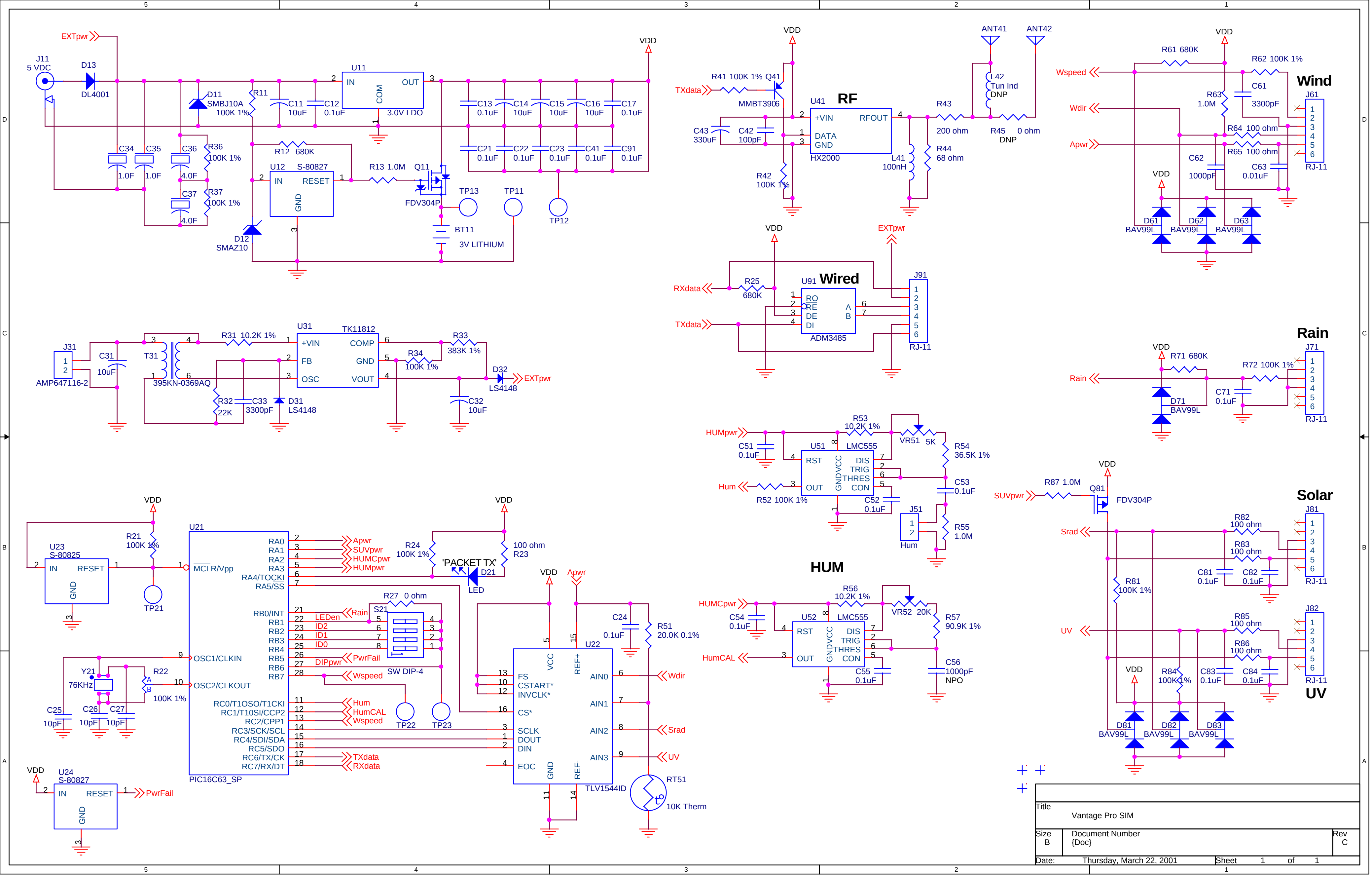

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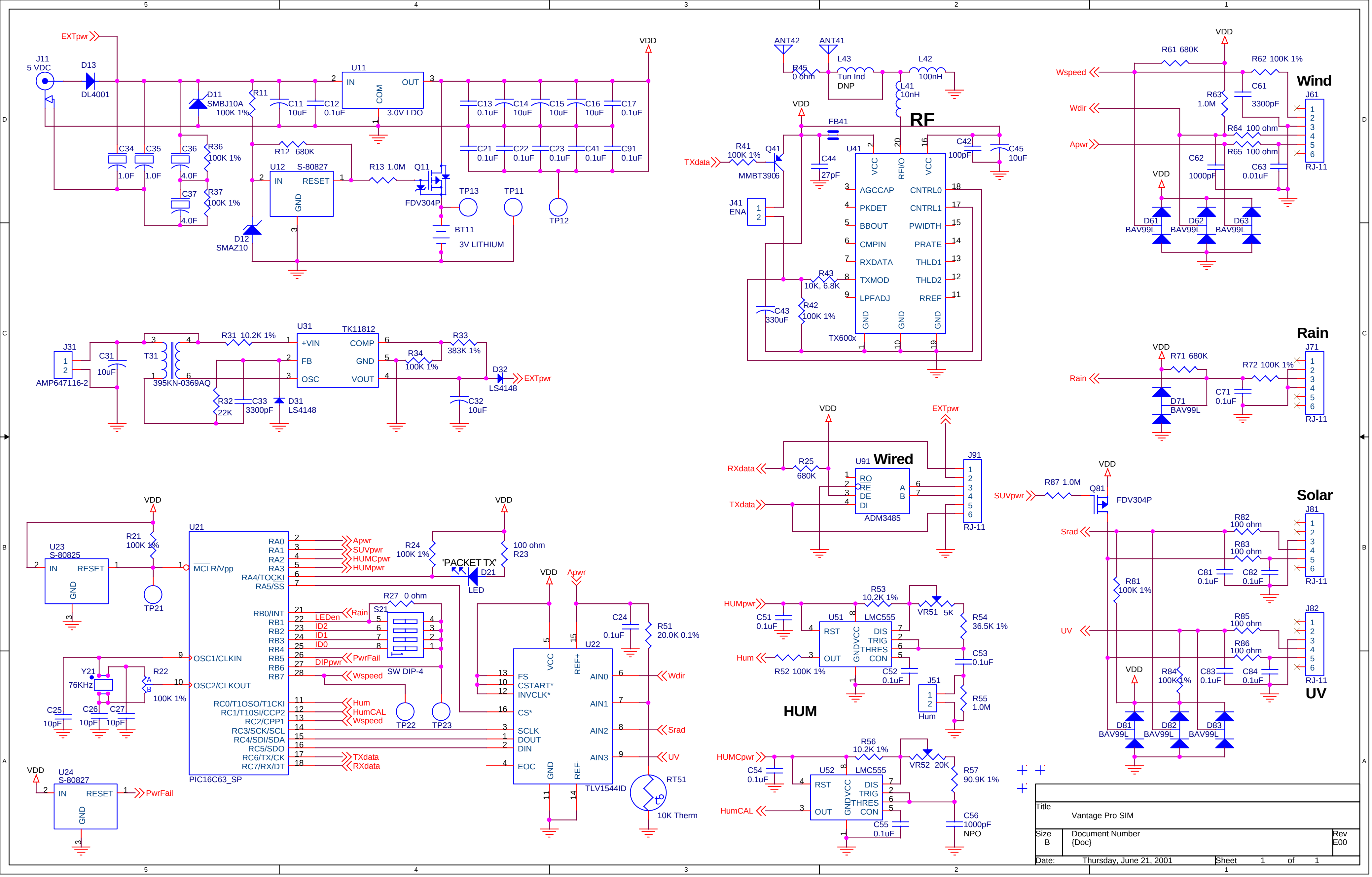

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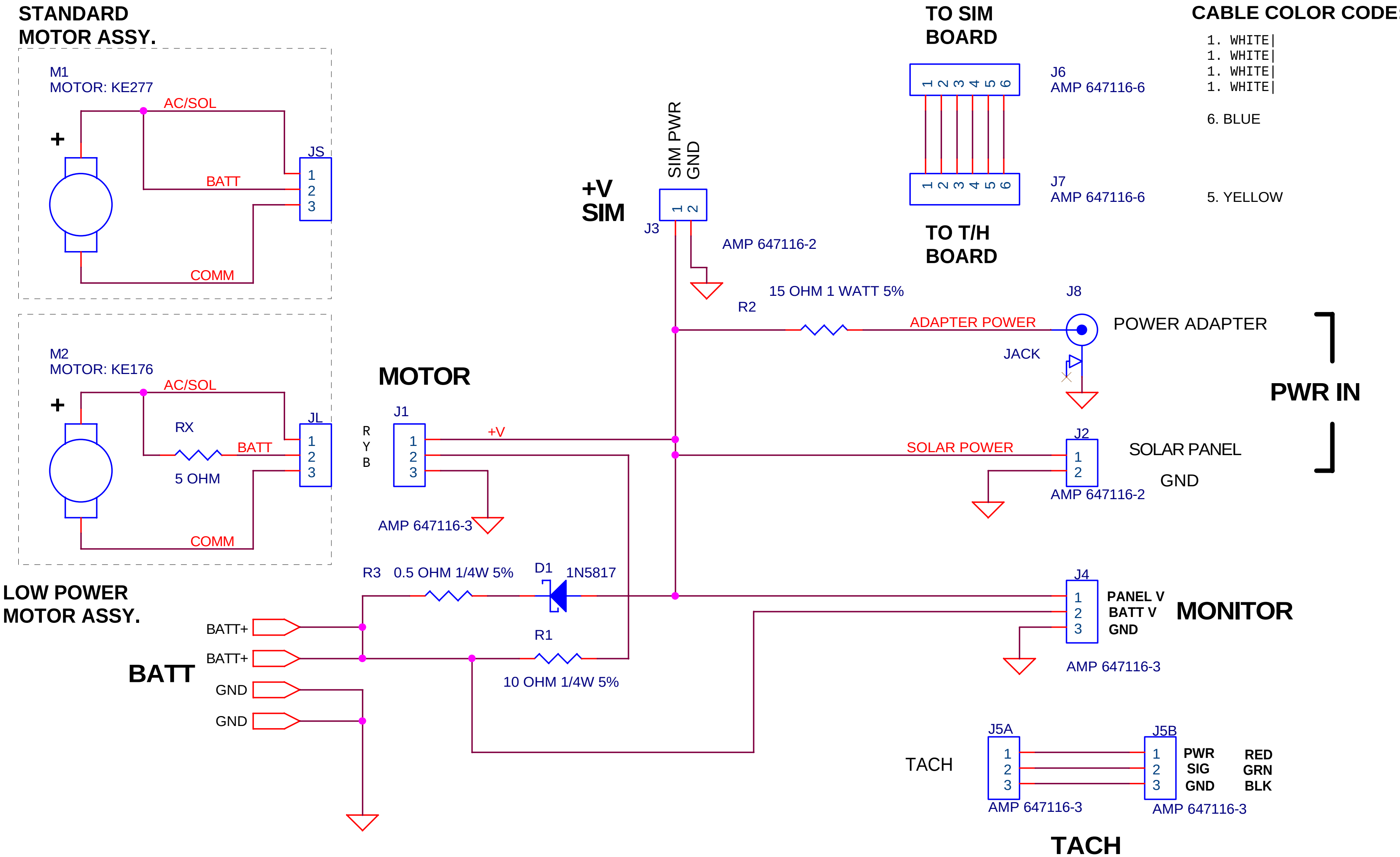

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Davis Instruments		
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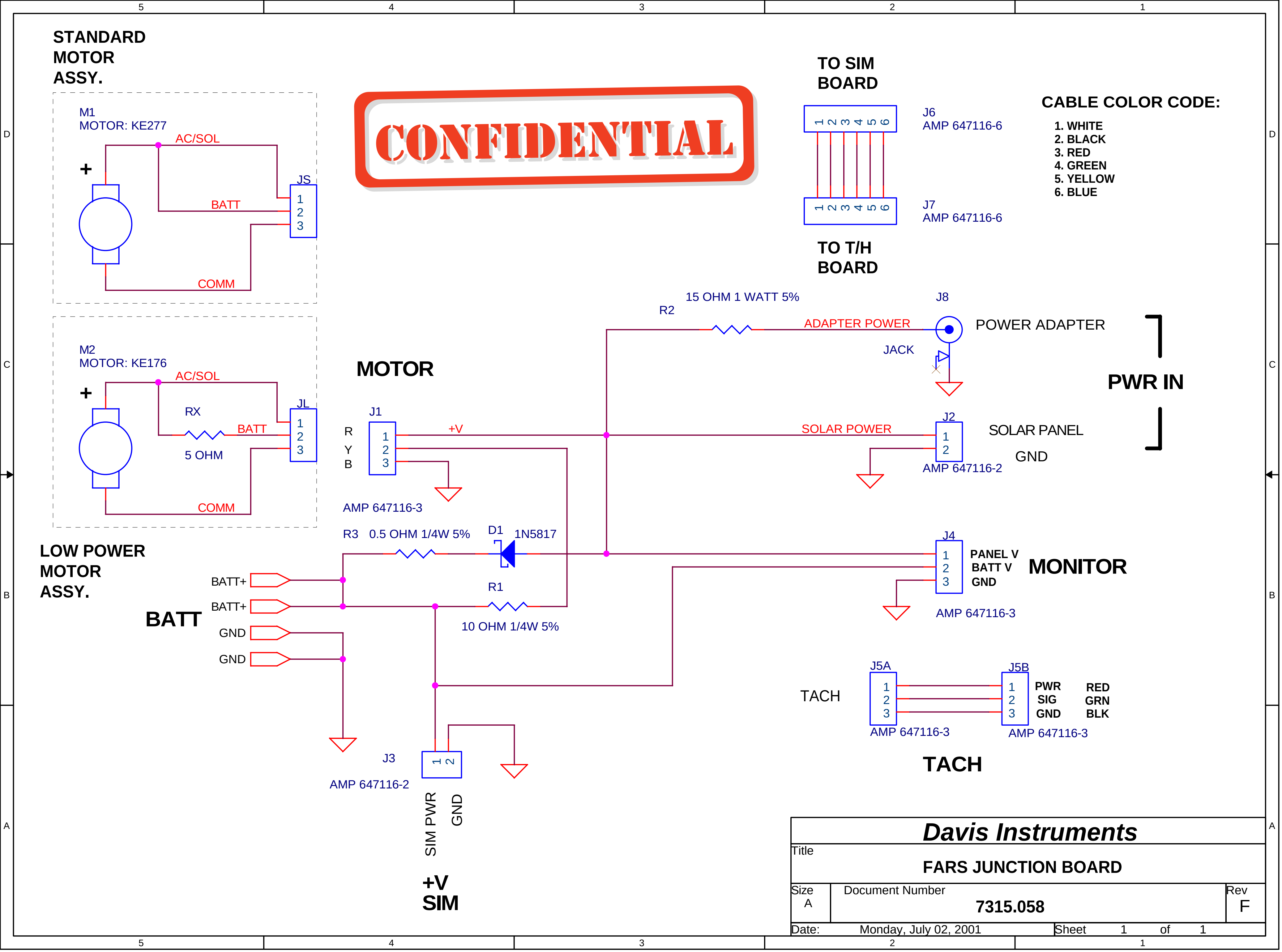
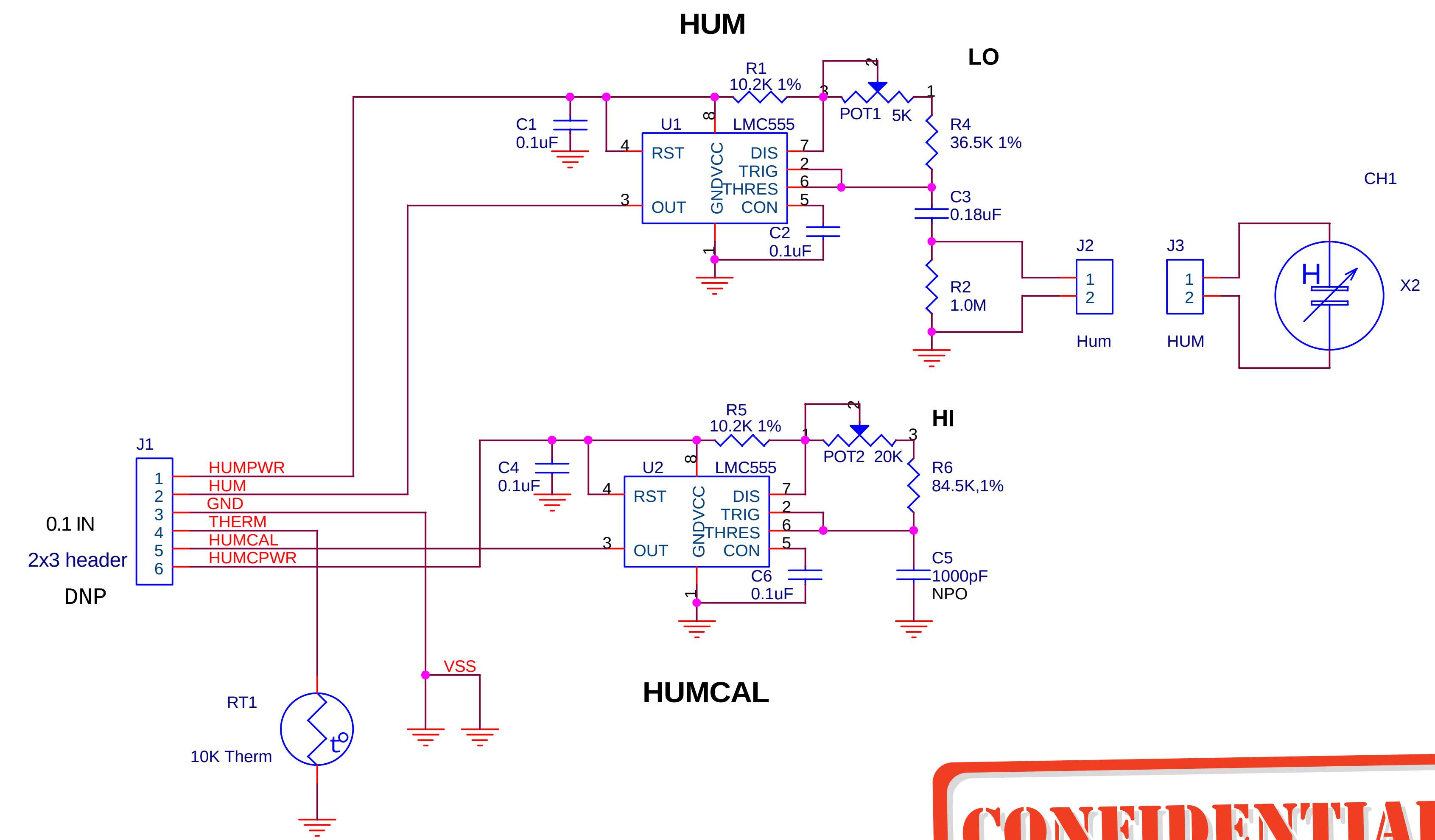
Size: A	Document Number: **7315.058**	Rev: E
Date: Wednesday, June 06, 2001	Sheet 1 of 1	


STANDARD MOTOR ASSY.
M1
MOTOR: KE277
AC/SOL
BATT
COMM
JS
1 2 3
M2
MOTOR: KE176
AC/SOL
RX
5 OHM
BATT
COMM
JL
1 2 3
LOW POWER MOTOR ASSY.
CONFIDENTIAL
TO SIM BOARD
J6
AMP 647116-6
J7
AMP 647116-6
TO T/H BOARD
CABLE COLOR CODE:
1. WHITE
2. BLACK
3. RED
4. GREEN
5. YELLOW
6. BLUE
R2
15 OHM 1 WATT 5%
ADAPTER POWER
J8
POWER ADAPTER
JACK
PWR IN
MOTOR
J1
R
Y
B
+V
AMP 647116-3
SOLAR POWER
J2
SOLAR PANEL
GND
AMP 647116-2
R3
0.5 OHM 1/4W 5%
D1
1N5817
J4
PANEL V
BATT V
GND
MONITOR
AMP 647116-3
BATT+
BATT+
GND
GND
BATT
R1
10 OHM 1/4W 5%
J5A
J5B
TACH
PWR
SIG
GND
RED
GRN
BLK
AMP 647116-3
AMP 647116-3
TACH
J3
AMP 647116-2
SIM PWR
GND
+V SIM
Davis Instruments
Title
FARS JUNCTION BOARD
Size
A
Document Number
7315.058
Rev
F
Date: Monday, July 02, 2001
Sheet 1 of 1



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Davis Instruments		
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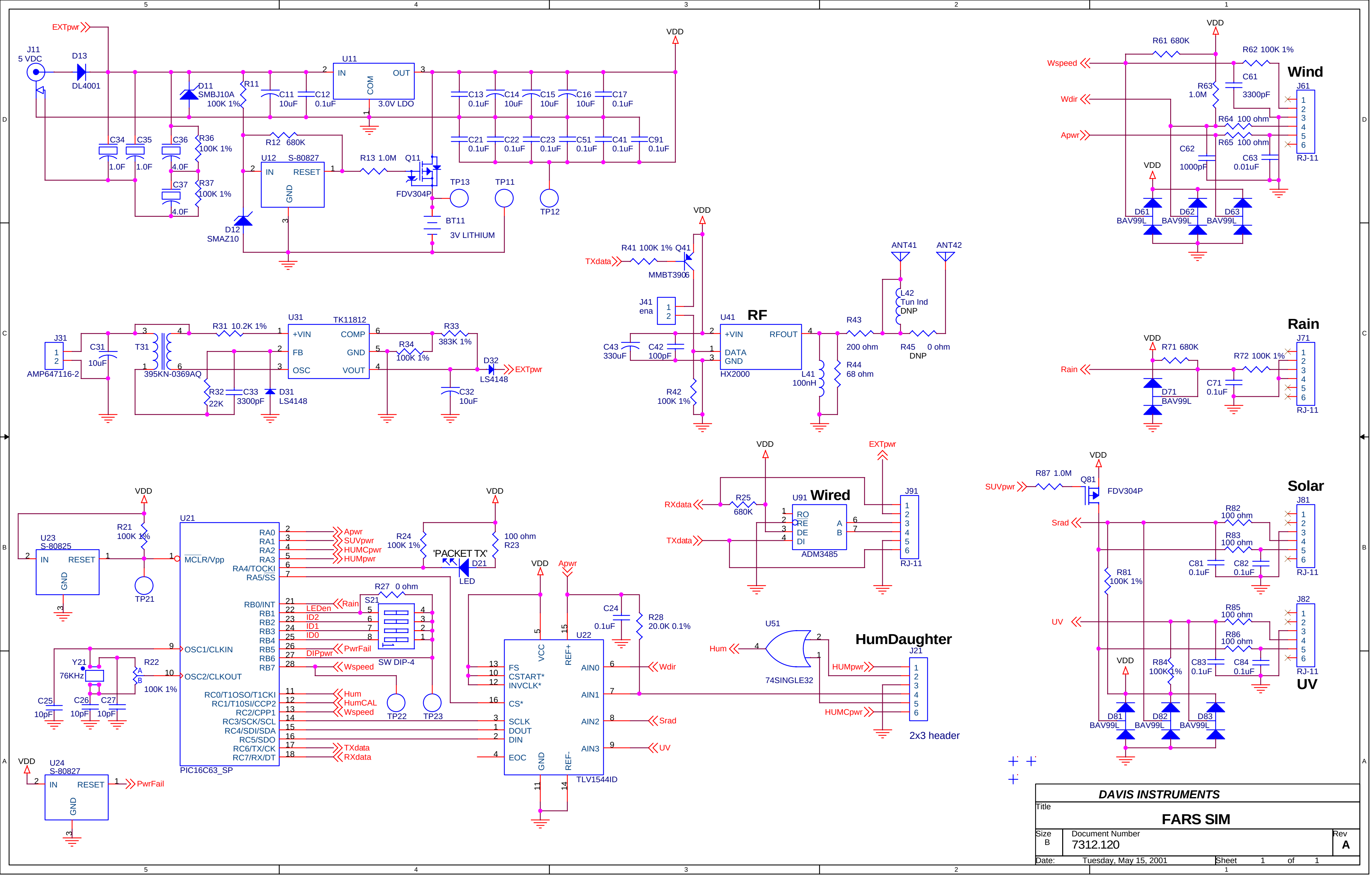
Size: A	Document Number: **07315.110**	Rev: A
Date: Monday, May 14, 2001	Sheet 1 of 1	



DAVIS INSTRUMENTS		
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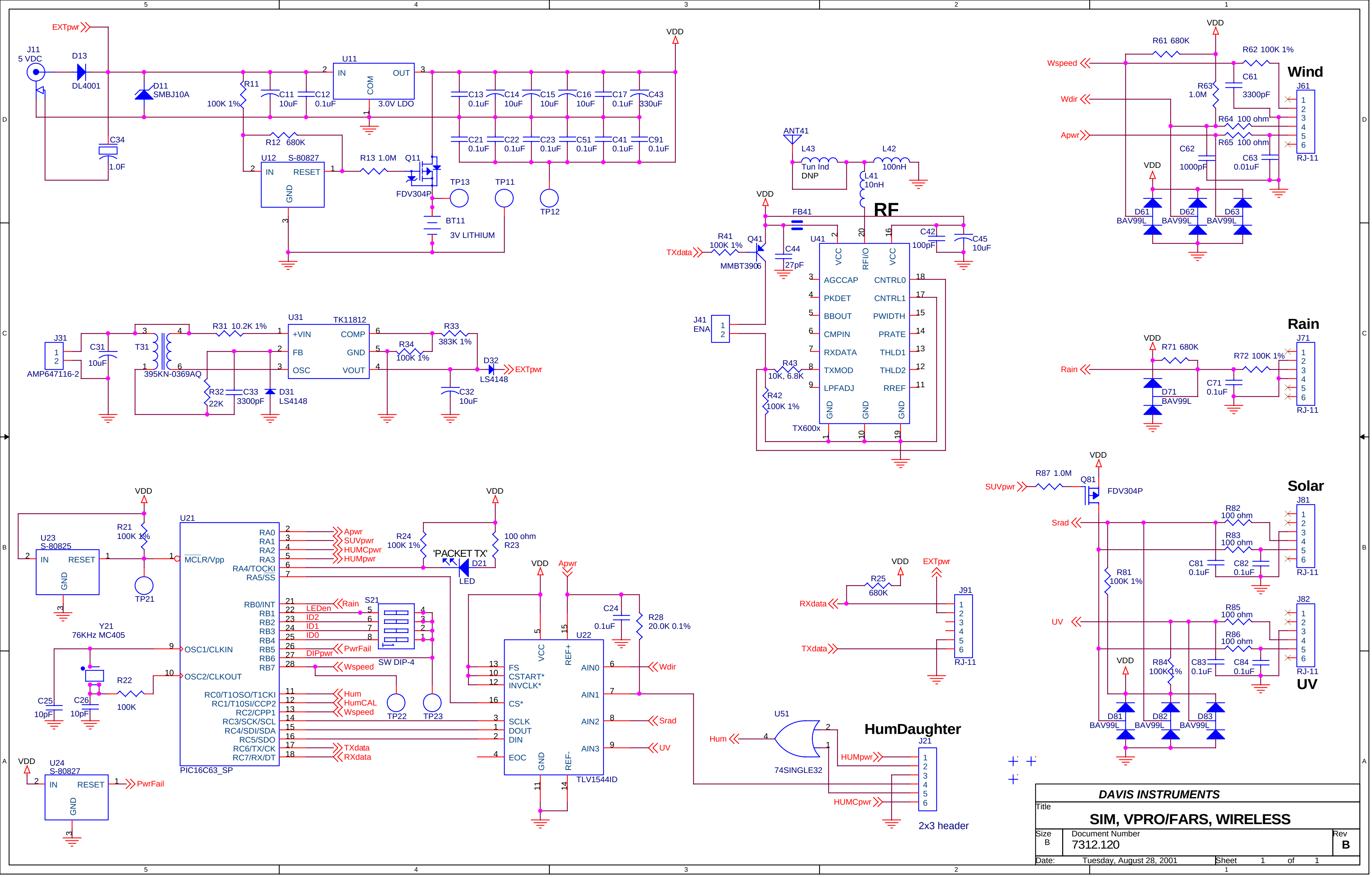
Date: Tuesday, May 15, 2001	Sheet 1 of 1	


EXTpwr
J11
5 VDC
D13
DL4001
D11
SMBJ10A
R11
100K 1%
C11
10uF
C12
0.1uF
U11
IN
OUT
COM
3.0V LDO
VDD
C13
0.1uF
C14
10uF
C15
10uF
C16
10uF
C17
0.1uF
C43
330uF
C21
0.1uF
C22
0.1uF
C23
0.1uF
C51
0.1uF
C41
0.1uF
C91
0.1uF
C34
1.0F
R12 680K
U12 S-80827
RESET
GND
R13 1.0M
Q11
FDV304P
TP13
TP11
TP12
BT11
3V LITHIUM
J31
AMP647116-2
C31
10uF
T31
395KN-0369AQ
R31 10.2K 1%
U31
TK11812
+VIN
COMP
FB
GND
OSC
VOUT
R33
383K 1%
R34
100K 1%
D32
LS4148
R32
22K
C33
3300pF
D31
LS4148
C32
10uF
ANT41
L43
Tun Ind
DNP
L42
100nH
L41
10nH
RF
FB41
C42
100pF
C45
10uF
R41
100K 1%
Q41
MMBT3906
TXdata
C44
27pF
U41
VCC
RFI/O
AGCCAP
CNTRL0
PKDET
CNTRL1
BBOUT
PWIDTH
CMPIN
PRATE
RXDATA
THLD1
TXMOD
THLD2
LPFADJ
RREF
R43
10K, 6.8K
R42
100K 1%
TX600x
J41
ENA
Wind
R61 680K
R62 100K 1%
Wspeed
Wdir
Apwr
R63
1.0M
C61
3300pF
J61
R64 100 ohm
R65 100 ohm
C62
1000pF
C63
0.01uF
RJ-11
D61
D62
D63
BAV99L
Rain
R71 680K
R72 100K 1%
J71
D71
C71
0.1uF
Solar
SUVpwr
R87 1.0M
Q81
FDV304P
J81
Srad
R82
100 ohm
R83
100 ohm
R81
100K 1%
C81
0.1uF
C82
0.1uF
UV
J82
R85
100 ohm
R86
100 ohm
R84
100K 1%
C83
0.1uF
C84
0.1uF
D81
D82
D83
U23
S-80825
R21
100K 1%
TP21
U21
MCLR/Vpp
RA0
RA1
RA2
RA3
RA4/TOCKI
RA5/SS
SUVpwr
HUMCpwr
HUMpwr
R24
100K 1%
'PACKET TX'
D21
LED
100 ohm
R23
RB0/INT
RB1
RB2
RB3
RB4
RB5
RB6
RB7
LEDen
ID2
ID1
ID0
DIPpwr
PwrFail
S21
SW DIP-4
Y21
76KHz MC405
OSC1/CLKIN
OSC2/CLKOUT
R22
100K
C25
10pF
C26
10pF
RC0/T1OSO/T1CKI
RC1/T1OSI/CCP2
RC2/CPP1
RC3/SCK/SCL
RC4/SDI/SDA
RC5/SDO
RC6/TX/CK
RC7/RX/DT
Hum
HumCAL
TP22
TP23
RXdata
PIC16C63_SP
U24
S-80827
U22
FS
CSTART*
INVCLK*
CS*
SCLK
DOUT
DIN
EOC
REF+
REF-
AIN0
AIN1
AIN2
AIN3
C24
0.1uF
R28
20.0K 0.1%
TLV1544ID
R25
680K
J91
U51
74SINGLE32
HumDaughter
J21
2x3 header
DAVIS INSTRUMENTS
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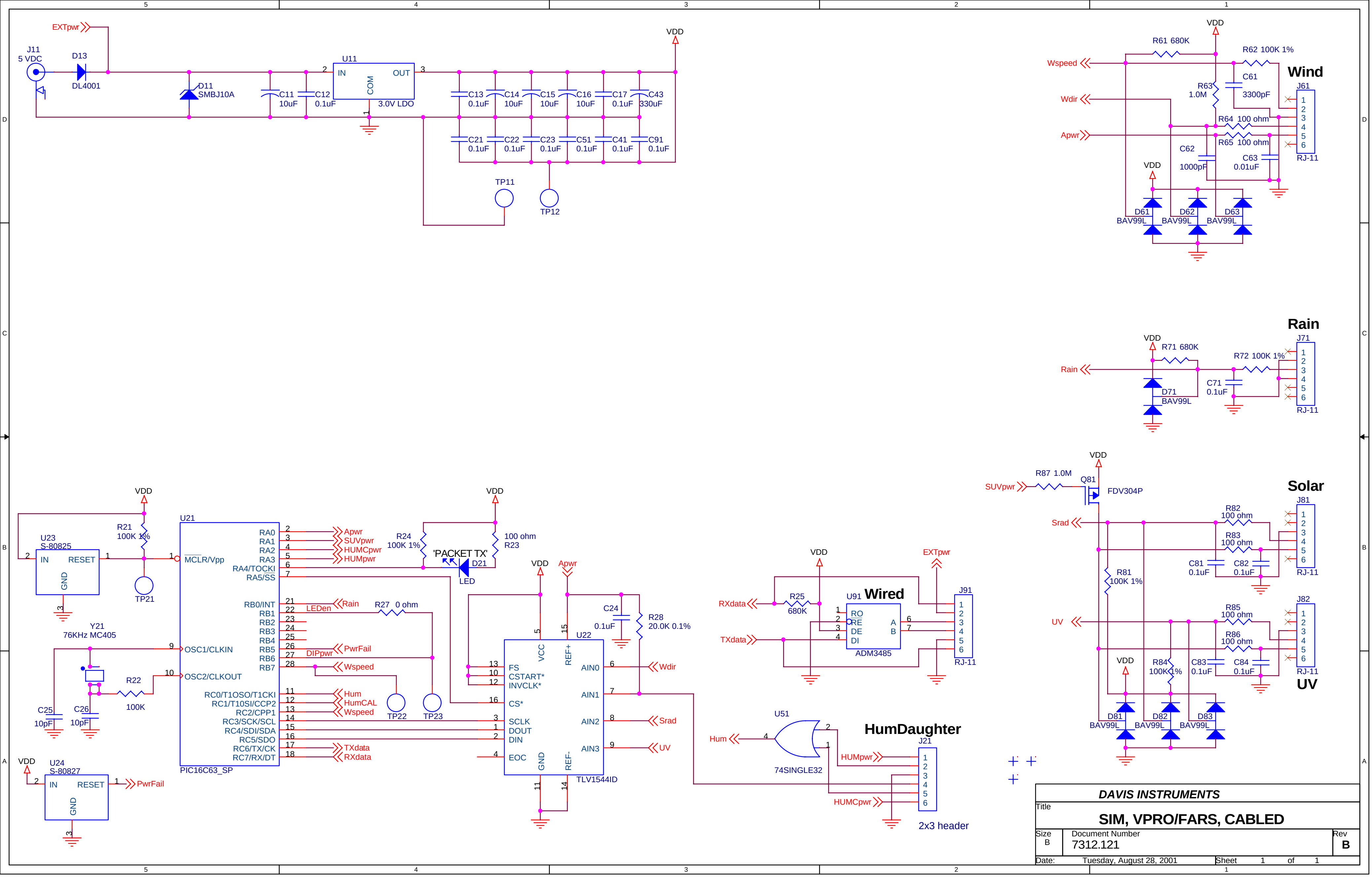
SIM, VPRO/FARS, WIRELESS
Size B
Document Number
7312.120
Rev B
Date: Tuesday, August 28, 2001
Sheet 1 of 1



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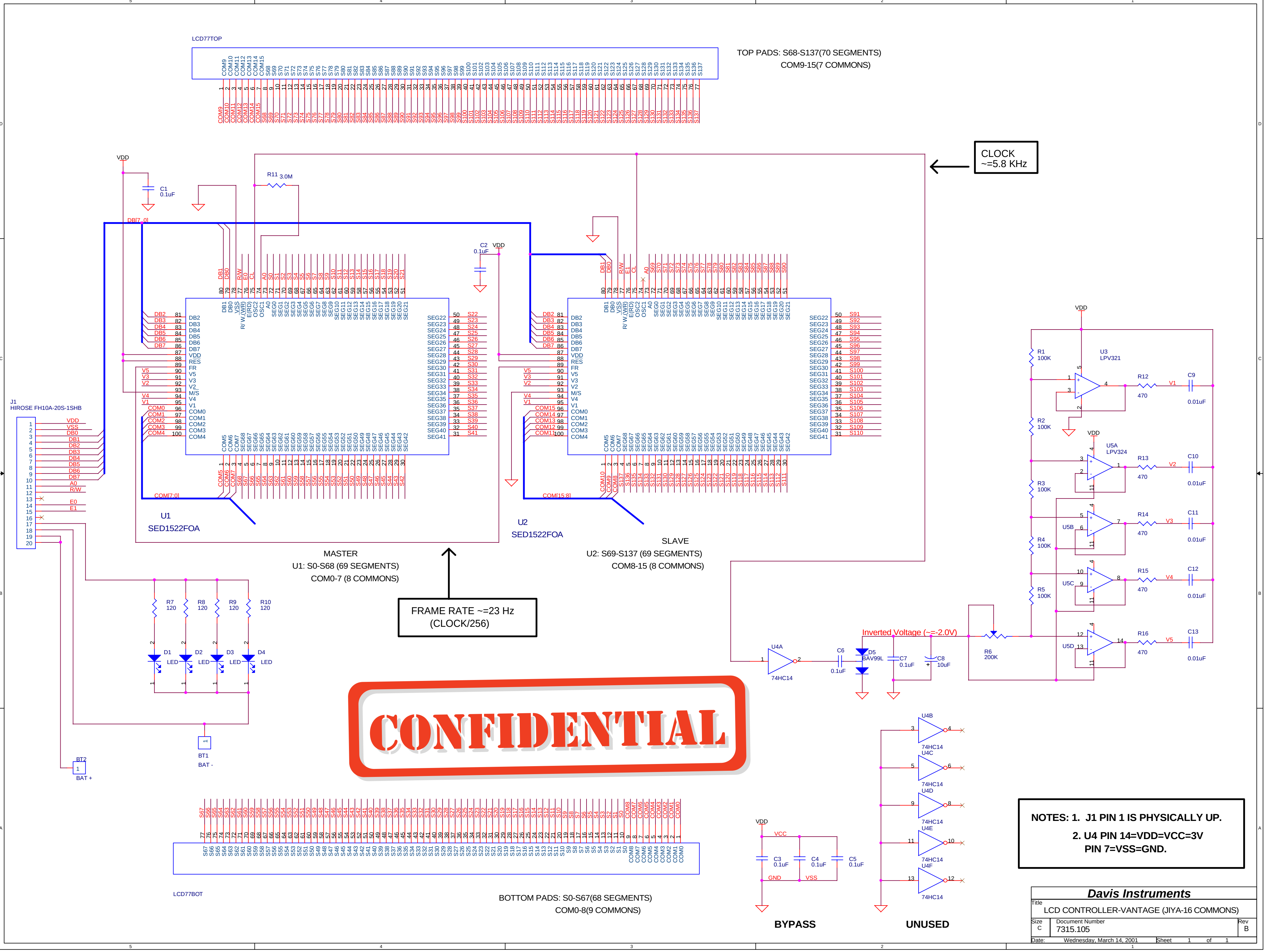
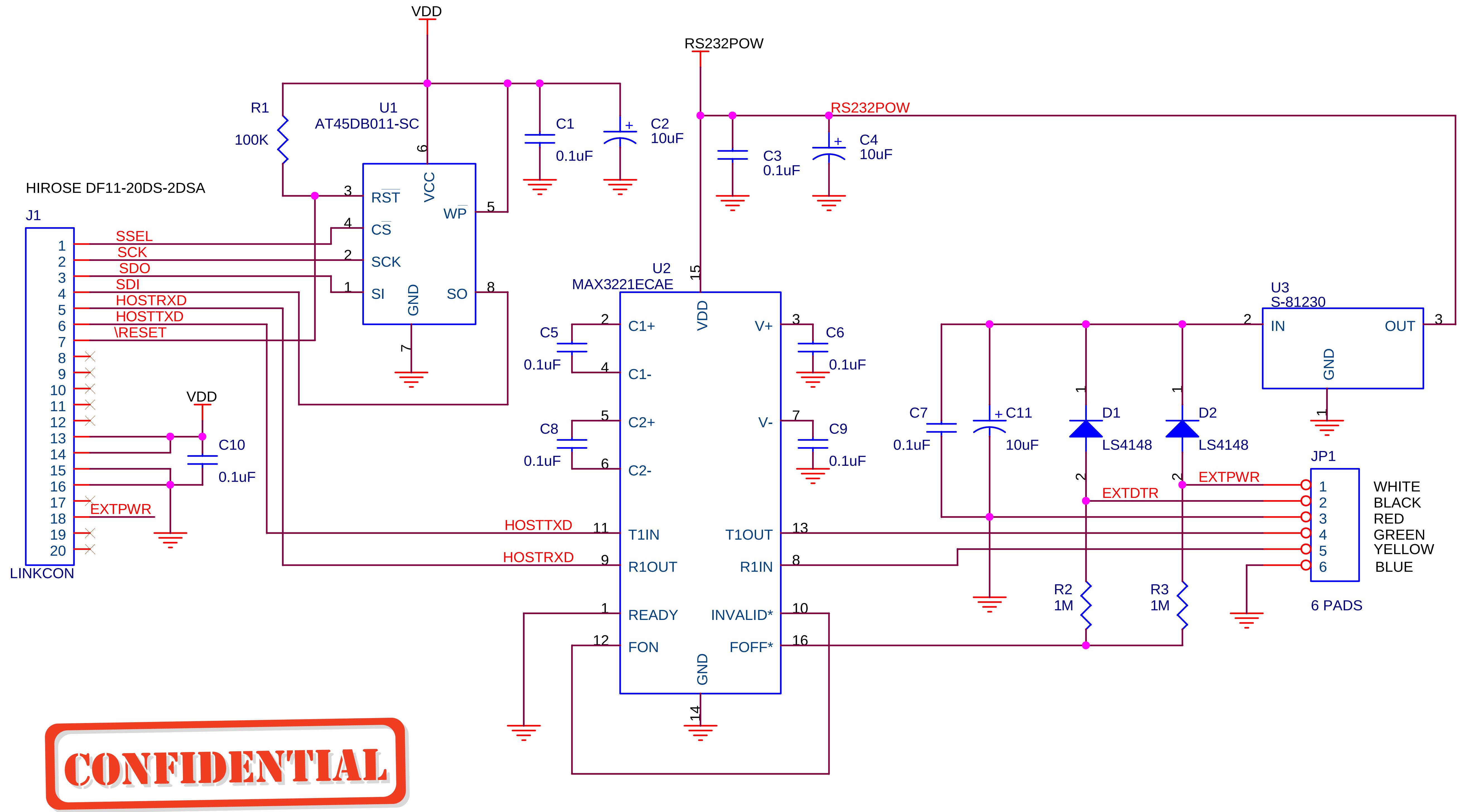

LCD77TOP
TOP PADS: S68-S137(70 SEGMENTS)
COM9-15(7 COMMONS)
CLOCK
~=5.8 KHz
R11 3.0M
C1 0.1uF
C2 0.1uF
VDD
DB[7..0]
J1
HIROSE FH10A-20S-1SHB
U1
SED1522FOA
U2
SED1522FOA
COM[7:0]
COM[15:8]
MASTER
U1: S0-S68 (69 SEGMENTS)
COM0-7 (8 COMMONS)
SLAVE
U2: S69-S137 (69 SEGMENTS)
COM8-15 (8 COMMONS)
FRAME RATE ~=23 Hz
(CLOCK/256)
CONFIDENTIAL
U3 LPV321
U5A LPV324
Inverted Voltage (~=-2.0V)
U4A 74HC14
D5 BAV99L
R6 200K
BT1 BAT -
BT2 BAT +
LCD77BOT
BOTTOM PADS: S0-S67(68 SEGMENTS)
COM0-8(9 COMMONS)
BYPASS
UNUSED
NOTES: 1. J1 PIN 1 IS PHYSICALLY UP.
2. U4 PIN 14=VDD=VCC=3V
PIN 7=VSS=GND.
Davis Instruments
Title
LCD CONTROLLER-VANTAGE (JIYA-16 COMMONS)
Size C
Document Number 7315.105
Rev B
Date: Wednesday, March 14, 2001
Sheet 1 of 1



DAVIS INSTRUMENTS

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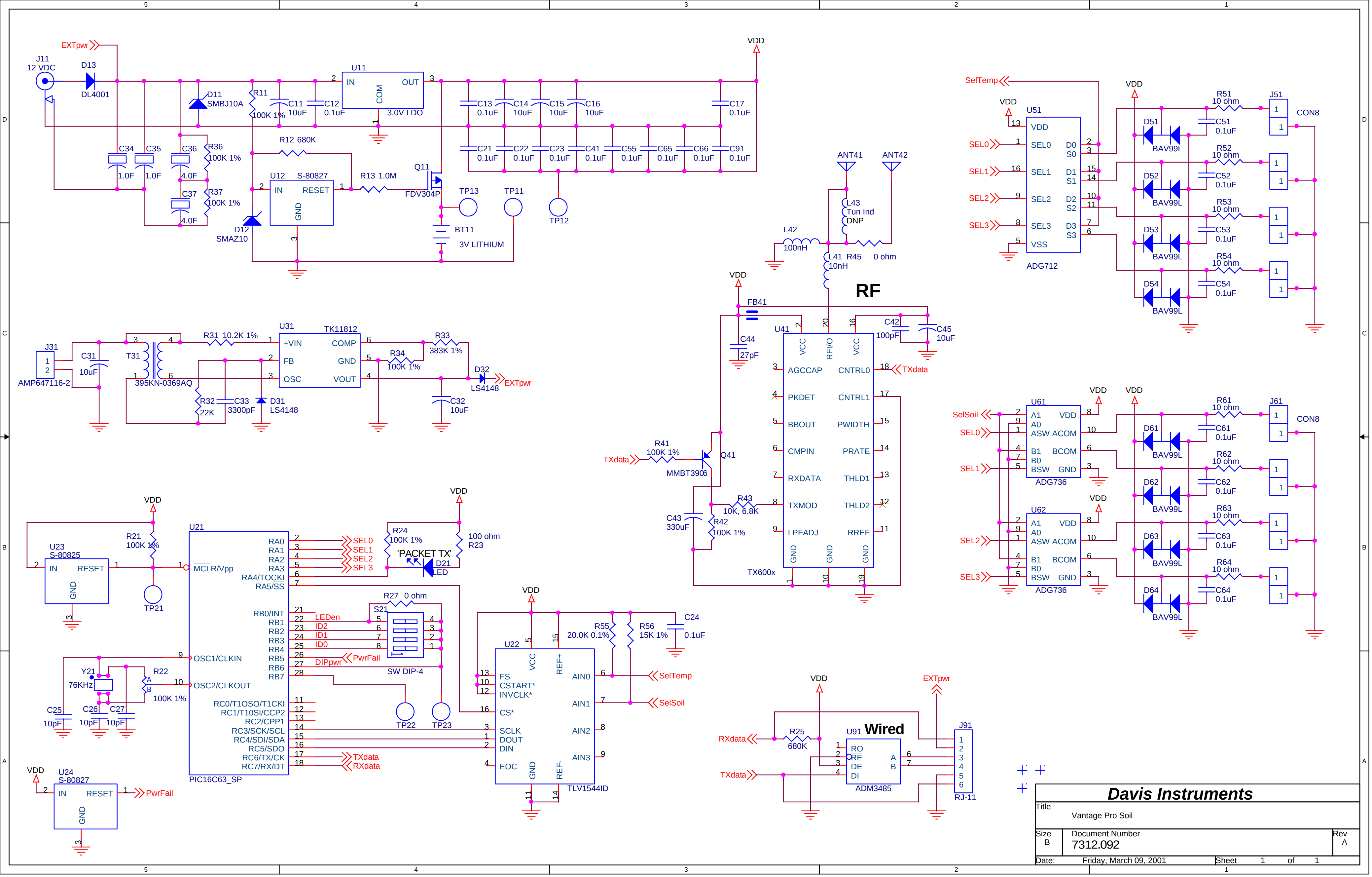
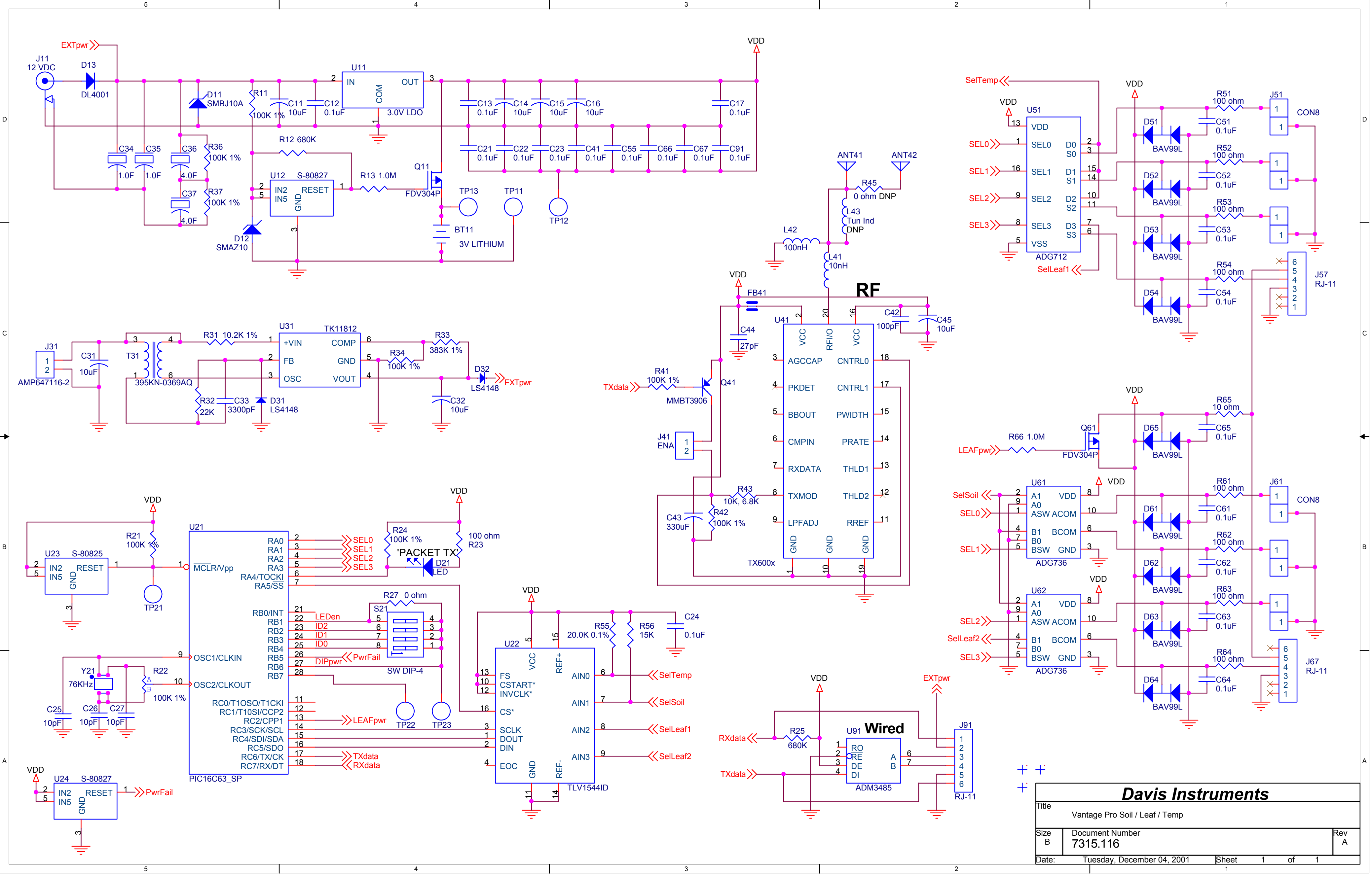
Size A	Document Number 7315.010	Rev A
Date: Tuesday, May 02, 2000	Sheet 1 of 1	



Confidential

CONFIDENTIAL



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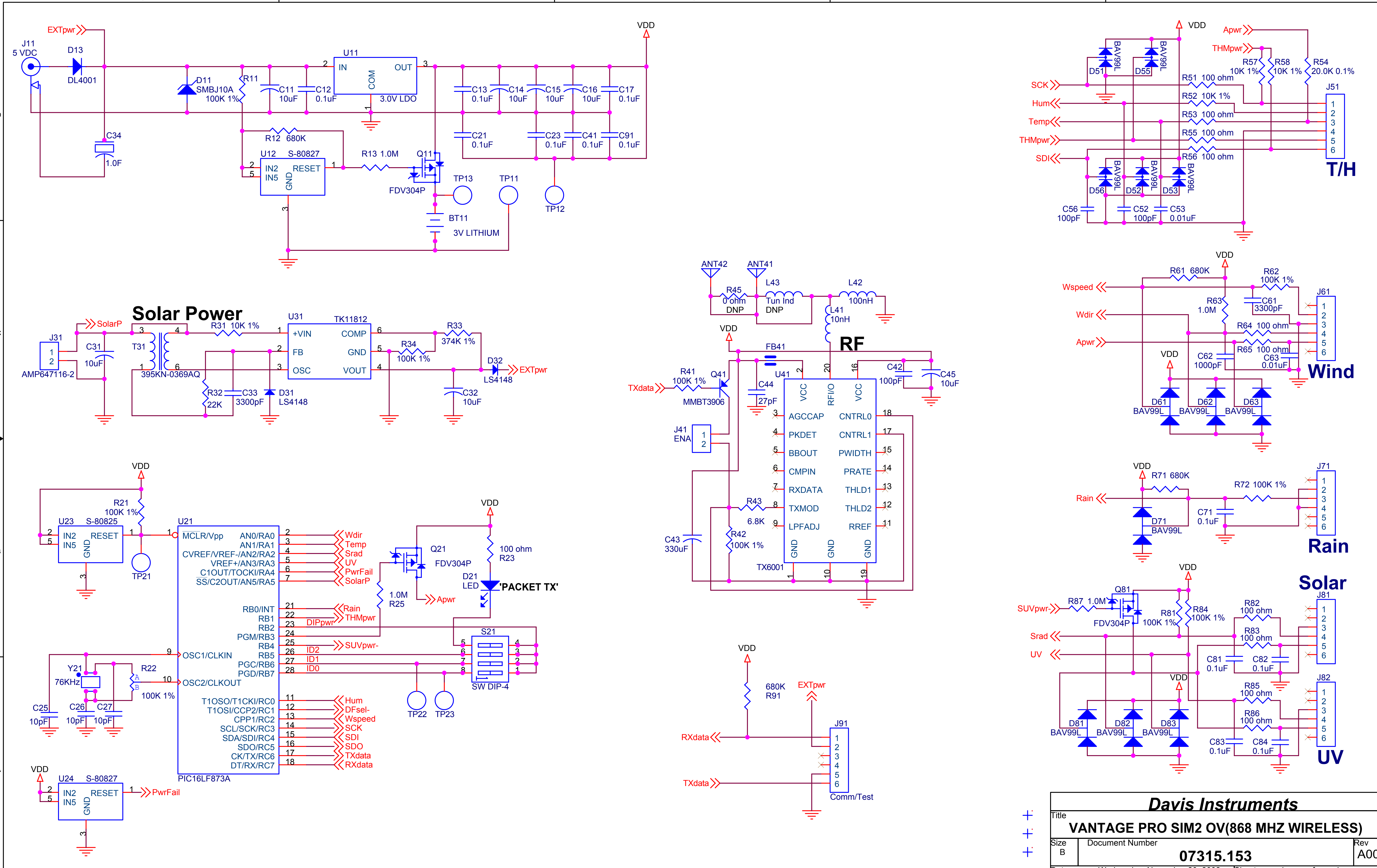
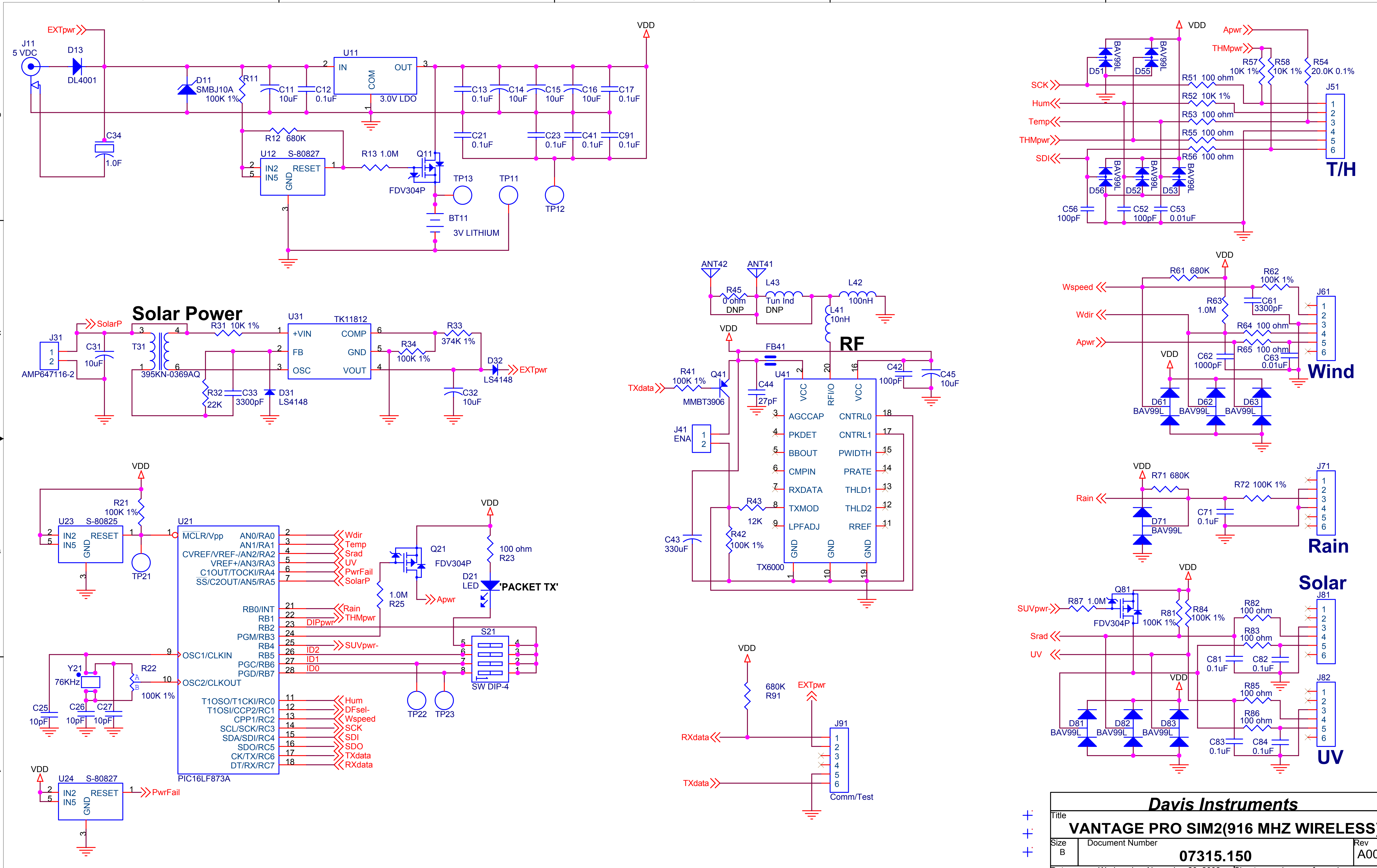


Davis Instruments

Title: VANTAGE PRO SIM2 OV(868 MHZ WIRELESS)

Size	Document Number	Rev
B	07315.153	A00

Date: Wednesday, November 20, 2002 Sheet 1 of 1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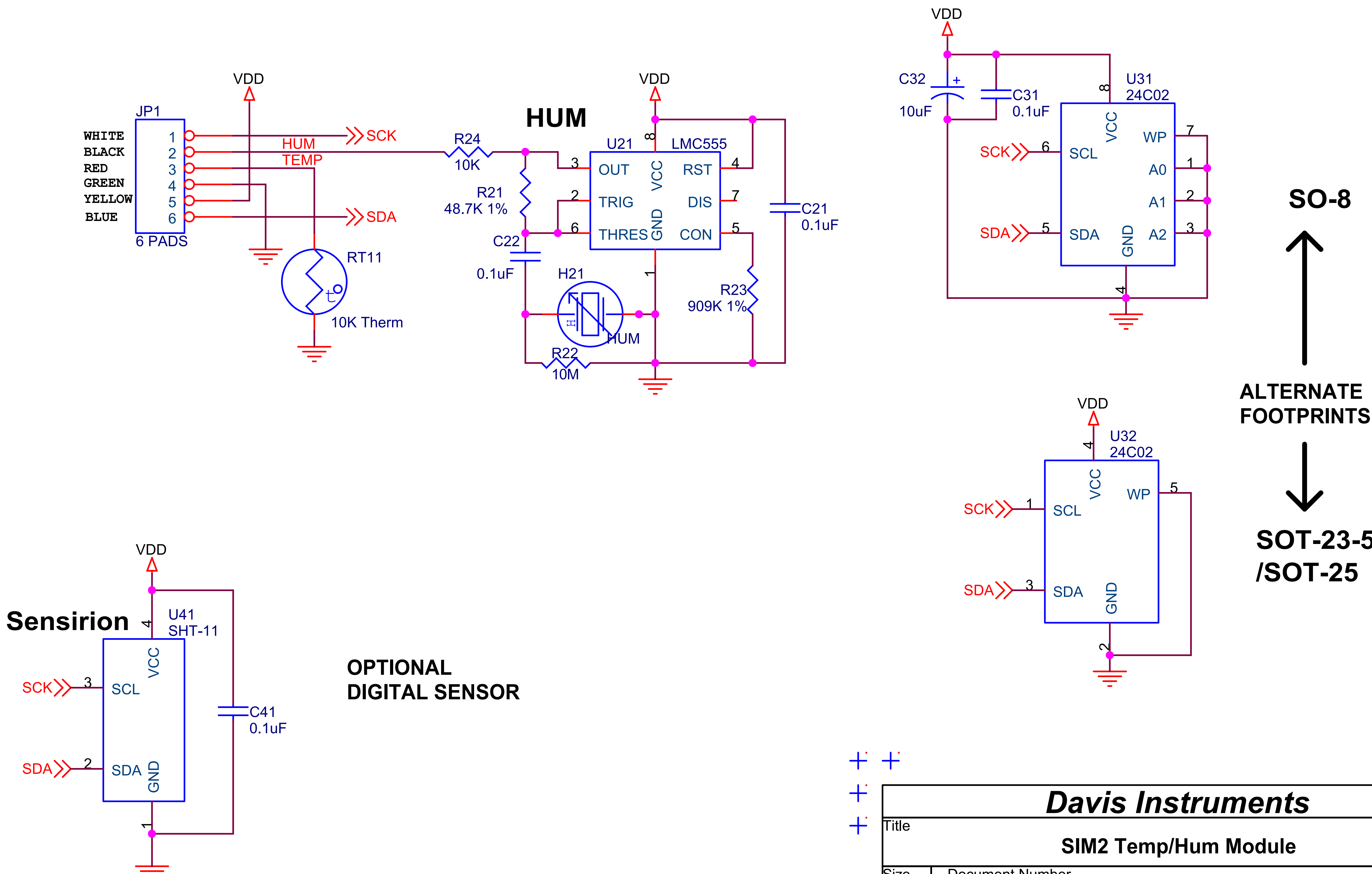
J11
5 VDC
D13
DL4001
D11
SMBJ10A
R11
100K 1%
C11
10uF
C12
0.1uF
U11
IN
OUT
COM
3.0V LDO
VDD
C13
0.1uF
C14
10uF
C15
10uF
C16
10uF
C17
0.1uF
C34
1.0F
R12 680K
U12 S-80827
IN2
IN5
RESET
GND
R13 1.0M
Q11
FDV304P
C21
0.1uF
C23
0.1uF
C41
0.1uF
C91
0.1uF
TP13
TP11
TP12
BT11
3V LITHIUM
Solar Power
SolarP
J31
AMP647116-2
C31
10uF
T31
395KN-0369AQ
R31 10K 1%
U31 TK11812
+VIN
FB
OSC
COMP
GND
VOUT
R33
374K 1%
R34
100K 1%
D32
LS4148
EXTpwr
R32
22K
C33
3300pF
D31
LS4148
C32
10uF
VDD
R21
100K 1%
U23 S-80825
IN2
IN5
RESET
GND
TP21
U21
MCLR/Vpp
AN0/RA0
AN1/RA1
CVREF/VREF-/AN2/RA2
VREF+/AN3/RA3
C1OUT/TOCKI/RA4
SS/C2OUT/AN5/RA5
RB0/INT
RB1
RB2
PGM/RB3
RB4
RB5
PGC/RB6
PGD/RB7
OSC1/CLKIN
OSC2/CLKOUT
T1OSO/T1CKI/RC0
T1OSI/CCP2/RC1
CPP1/RC2
SCL/SCK/RC3
SDA/SDI/RC4
SDO/RC5
CK/TX/RC6
DT/RX/RC7
PIC16LF873A
Wdir
Temp
Srad
UV
PwrFail
SolarP
Rain
THMpwr
DIPpwr
SUVpwr-
ID2
ID1
ID0
Hum
DFsel-
Wspeed
SCK
SDI
SDO
TXdata
RXdata
Y21
76KHz
R22
100K 1%
C25
10pF
C26
10pF
C27
10pF
Q21
FDV304P
1.0M
R25
Apwr
100 ohm
R23
D21
LED
'PACKET TX'
S21
SW DIP-4
TP22
TP23
VDD
U24 S-80827
IN2
IN5
RESET
GND
PwrFail
ANT42
ANT41
R45
0 ohm
DNP
L43
Tun Ind
DNP
L42
100nH
L41
10nH
RF
VDD
FB41
R41
100K 1%
Q41
MMBT3906
TXdata
C44
27pF
U41
VCC
RFI/O
VCC
C42
100pF
C45
10uF
AGCCAP
PKDET
BBOUT
CMPIN
RXDATA
TXMOD
LPFADJ
CNTRL0
CNTRL1
PWIDTH
PRATE
THLD1
THLD2
RREF
GND
TX6000
J41
ENA
R43
12K
R42
100K 1%
C43
330uF
VDD
680K
R91
EXTpwr
J91
RXdata
TXdata
Comm/Test
VDD
Apwr
THMpwr
SCK
Hum
Temp
THMpwr
SDI
D51
D55
BAV99L
R57
10K 1%
R58
10K 1%
R54
20.0K 0.1%
R51 100 ohm
R52 10K 1%
R53 100 ohm
R55 100 ohm
R56 100 ohm
J51
D56
D52
D53
C56
100pF
C52
100pF
C53
0.01uF
T/H
VDD
R61 680K
R62
100K 1%
Wspeed
Wdir
Apwr
R63
1.0M
C61
3300pF
R64 100 ohm
R65 100 ohm
C62
1000pF
C63
0.01uF
J61
D61
D62
D63
BAV99L
Wind
VDD
R71 680K
R72 100K 1%
Rain
C71
0.1uF
D71
BAV99L
J71
Rain
Solar
VDD
Q81
R87 1.0M
SUVpwr-
FDV304P
R81
100K 1%
R84
100K 1%
R82
100 ohm
R83
100 ohm
Srad
UV
C81
0.1uF
C82
0.1uF
J81
VDD
R85
100 ohm
R86
100 ohm
C83
0.1uF
C84
0.1uF
J82
D81
D82
D83
BAV99L
UV
Davis Instruments
Title
VANTAGE PRO SIM2(916 MHZ WIRELESS)
Size
B
Document Number
07315.150
Rev
A00
Date: Wednesday, November 20, 2002
Sheet 1 of 1



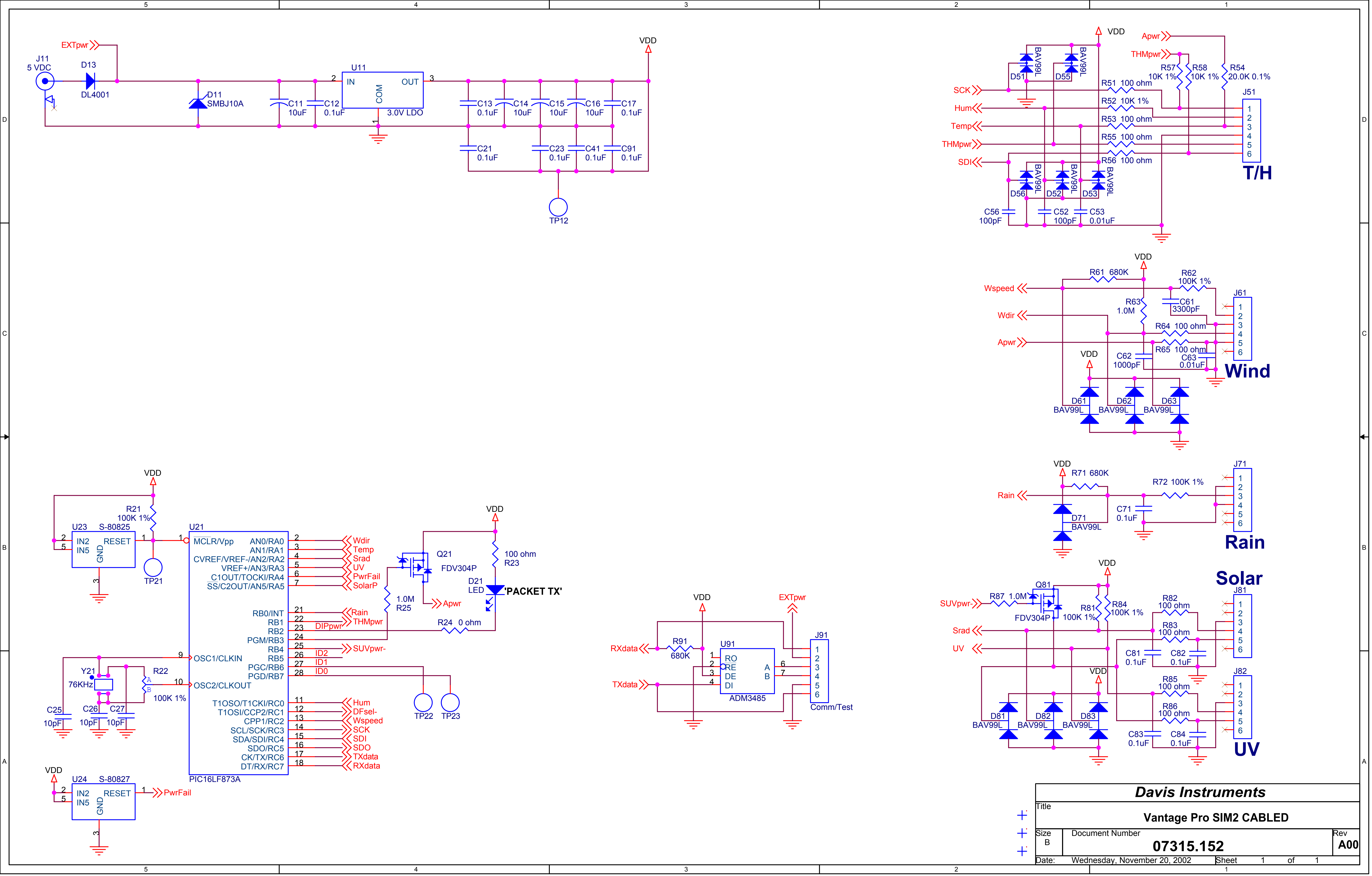
Davis Instruments

Title

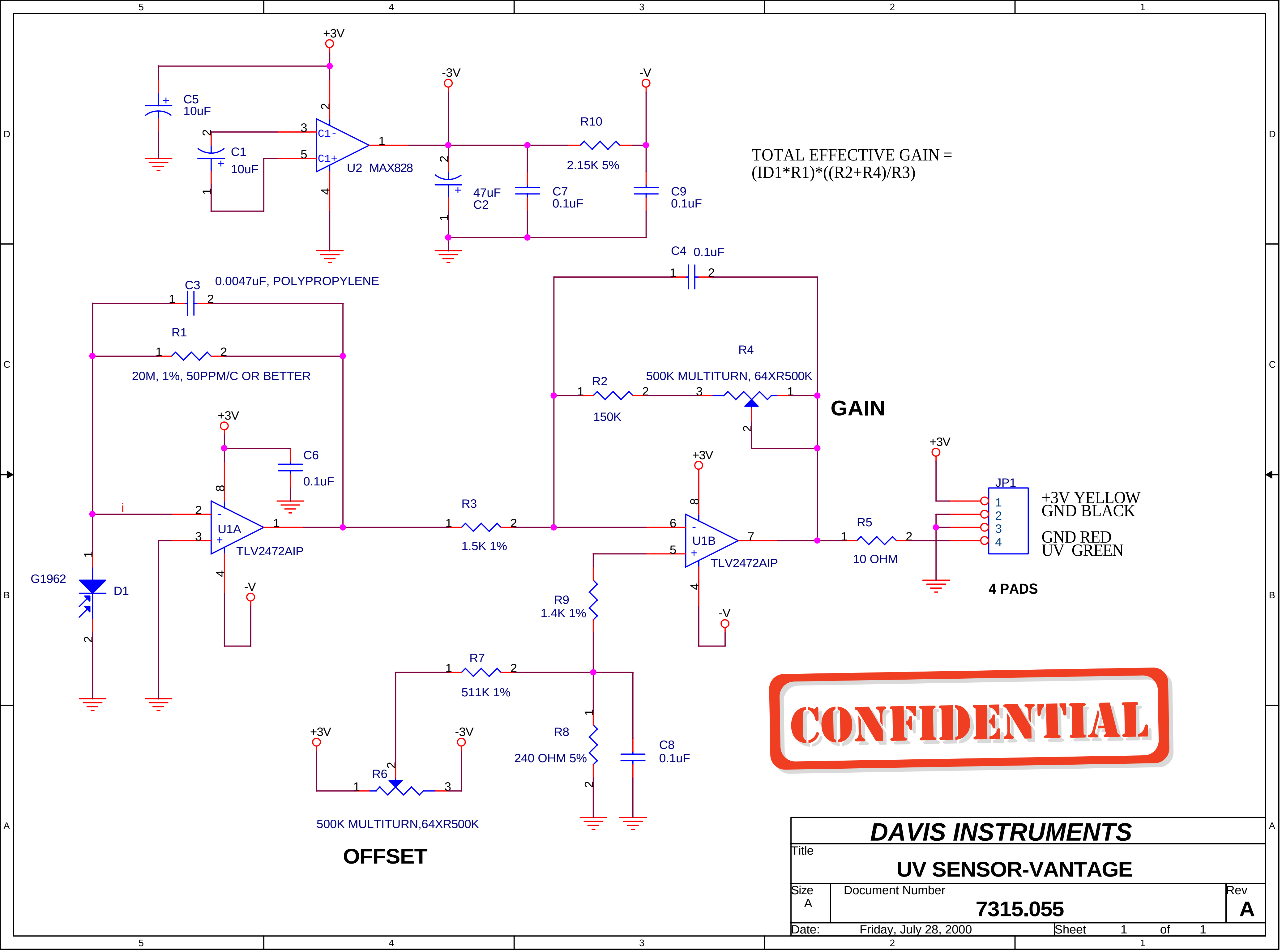
SIM2 Temp/Hum Module

Size	Document Number	Rev
A	**07315.151**	**A00**

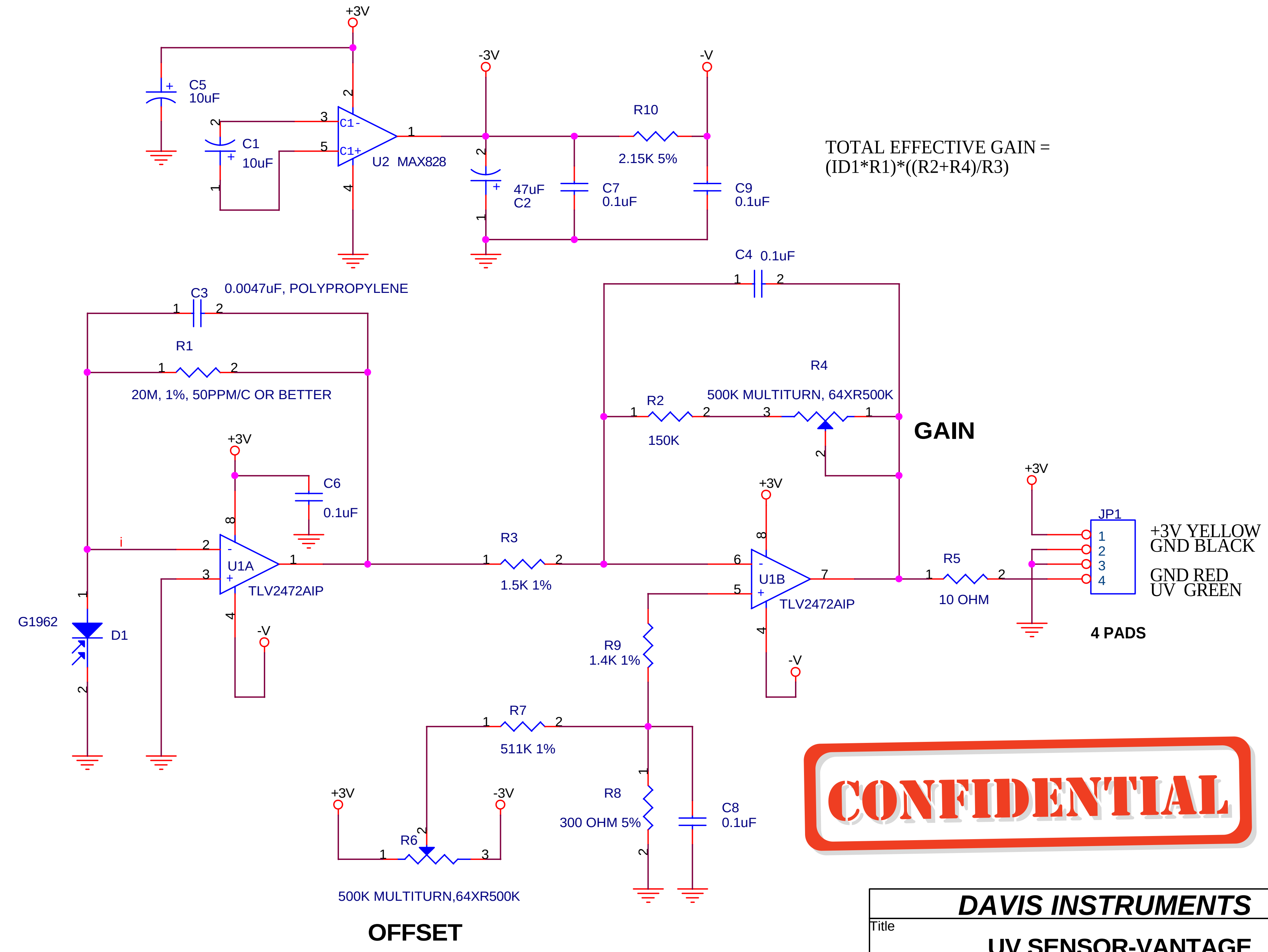
Date: Thursday, November 21, 2002 | Sheet 1 of 1



J11
5 VDC
D13
DL4001
EXTpwr
D11
SMBJ10A
C11
10uF
C12
0.1uF
U11
IN
OUT
COM
3.0V LDO
VDD
C13
0.1uF
C14
10uF
C15
10uF
C16
10uF
C17
0.1uF
C21
0.1uF
C23
0.1uF
C41
0.1uF
C91
0.1uF
TP12
SCK
Hum
Temp
THMpwr
SDI
Apwr
D51
D55
BAV99L
R51 100 ohm
R52 10K 1%
R53 100 ohm
R55 100 ohm
R56 100 ohm
R57 10K 1%
R58 10K 1%
R54 20.0K 0.1%
J51
D56
D52
D53
C56 100pF
C52 100pF
C53 0.01uF
T/H
Wspeed
Wdir
R61 680K
R62 100K 1%
R63 1.0M
C61 3300pF
R64 100 ohm
R65 100 ohm
C62 1000pF
C63 0.01uF
J61
D61
D62
D63
Wind
Rain
R71 680K
R72 100K 1%
C71 0.1uF
D71
J71
Solar
SUVpwr-
R87 1.0M
Q81
FDV304P
R81 100K 1%
R84 100K 1%
R82 100 ohm
R83 100 ohm
Srad
UV
C81 0.1uF
C82 0.1uF
J81
D81
D82
D83
R85 100 ohm
R86 100 ohm
C83 0.1uF
C84 0.1uF
J82
U23 S-80825
IN2
IN5
RESET
GND
R21 100K 1%
TP21
U21
MCLR/Vpp
AN0/RA0
AN1/RA1
CVREF/VREF-/AN2/RA2
VREF+/AN3/RA3
C1OUT/TOCKI/RA4
SS/C2OUT/AN5/RA5
RB0/INT
RB1
RB2
PGM/RB3
RB4
RB5
PGC/RB6
PGD/RB7
OSC1/CLKIN
OSC2/CLKOUT
T1OSO/T1CKI/RC0
T1OSI/CCP2/RC1
CPP1/RC2
SCL/SCK/RC3
SDA/SDI/RC4
SDO/RC5
CK/TX/RC6
DT/RX/RC7
PIC16LF873A
Srad
UV
PwrFail
SolarP
DIPpwr
SUVpwr-
ID2
ID1
ID0
DFsel-
SDO
TXdata
RXdata
Y21
76KHz
R22
100K 1%
C25 10pF
C26 10pF
C27 10pF
Q21
FDV304P
R25 1.0M
R23 100 ohm
D21 LED
'PACKET TX'
R24 0 ohm
TP22
TP23
U24 S-80827
R91 680K
U91
RO
RE
DE
DI
ADM3485
J91
Comm/Test
Davis Instruments
Title
Vantage Pro SIM2 CABLED
Size B
Document Number
07315.152
Rev A00
Date: Wednesday, November 20, 2002
Sheet 1 of 1



+3V
-3V
-V
C5 10uF
C1 10uF
U2 MAX828
C1-
C1+
47uF C2
R10 2.15K 5%
C7 0.1uF
C9 0.1uF
TOTAL EFFECTIVE GAIN =
(ID1*R1)*((R2+R4)/R3)
C4 0.1uF
C3 0.0047uF, POLYPROPYLENE
R1
20M, 1%, 50PPM/C OR BETTER
R4
R2
500K MULTITURN, 64XR500K
150K
GAIN
C6 0.1uF
U1A
TLV2472AIP
R3 1.5K 1%
U1B
TLV2472AIP
R5 10 OHM
JP1
+3V YELLOW
GND BLACK
GND RED
UV GREEN
4 PADS
G1962
D1
R9 1.4K 1%
R7 511K 1%
R8 240 OHM 5%
C8 0.1uF
R6
500K MULTITURN,64XR500K
OFFSET
CONFIDENTIAL
DAVIS INSTRUMENTS
Title
UV SENSOR-VANTAGE
Size A
Document Number 7315.055
Rev A
Date: Friday, July 28, 2000
Sheet 1 of 1



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DAVIS INSTRUMENTS		
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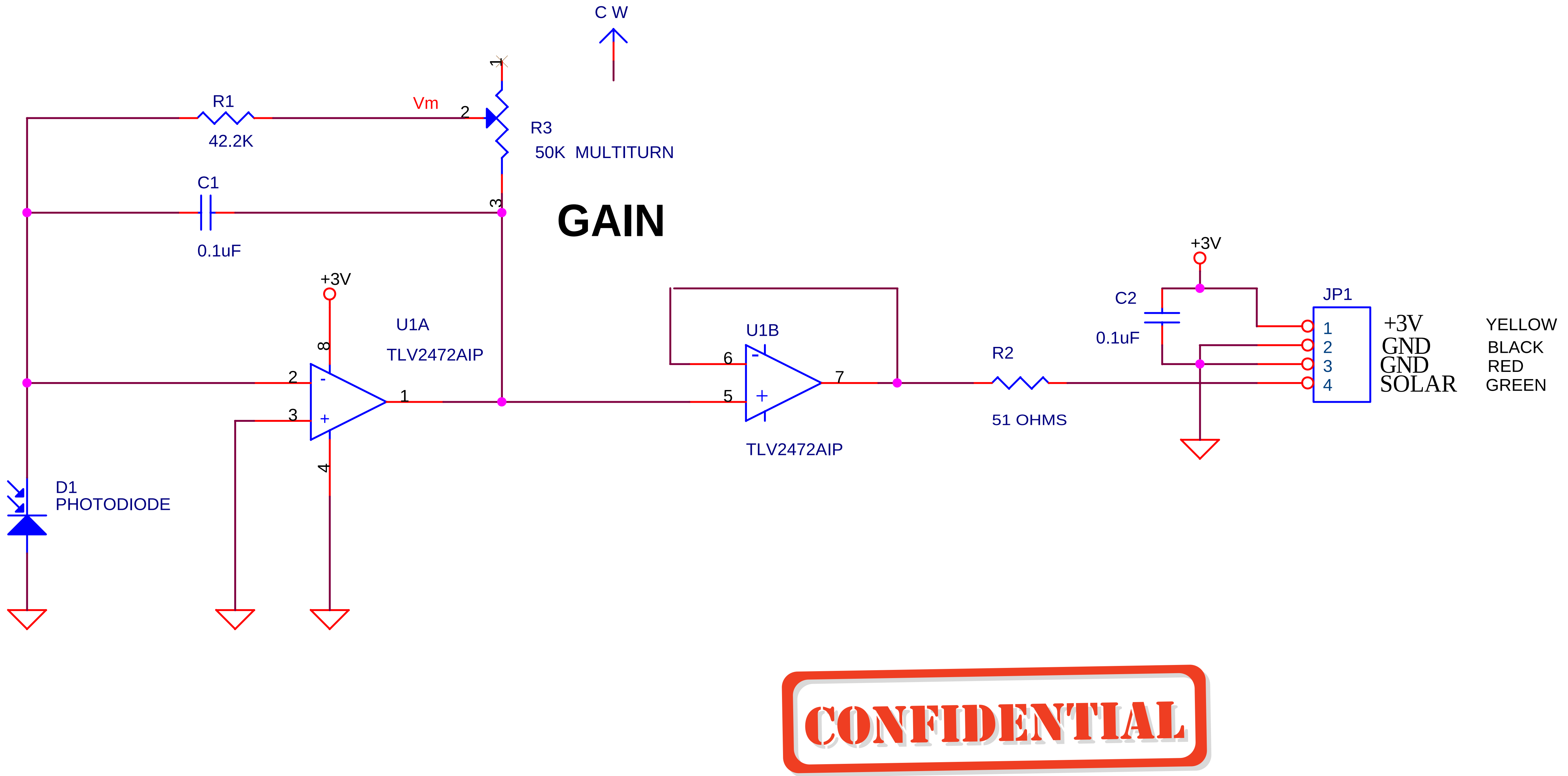
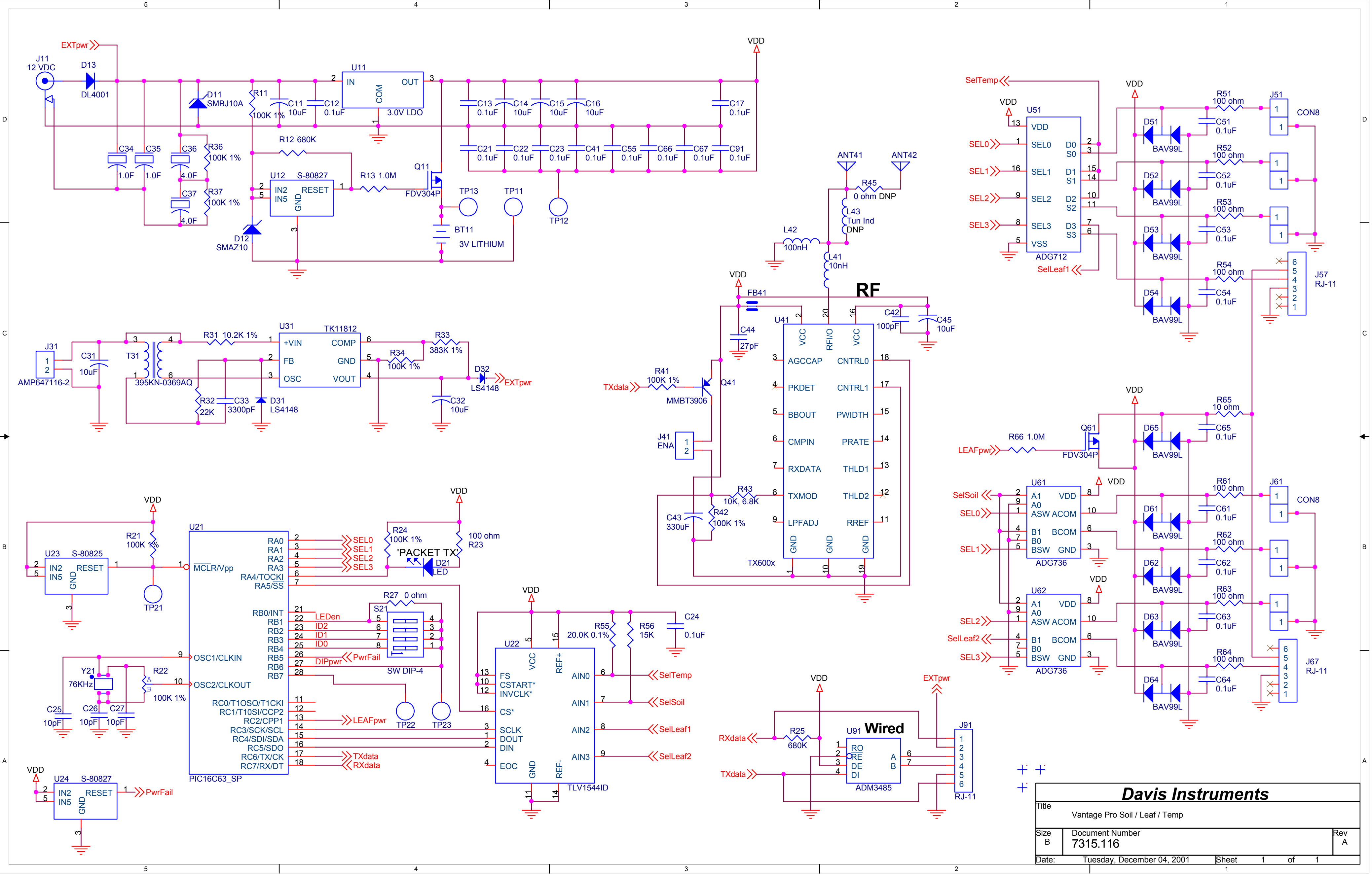
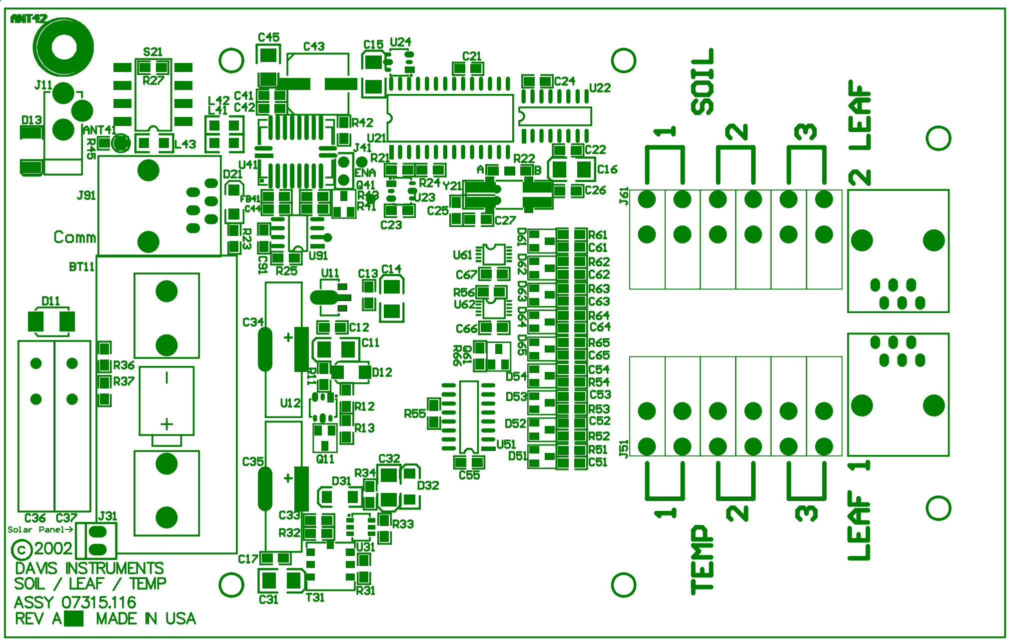
Size: A	Document Number: **7315.055**	Rev: **B**
Date: Tuesday, November 21, 2000	Sheet 1 of 1	



DAVIS INSTRUMENTS			
Title: **SOLAR SENSOR-VANTAGE**			
Size: A	Document Number: **7315.077**		Rev: **A**
Date: Tuesday, July 25, 2000		Sheet 1 of 1	

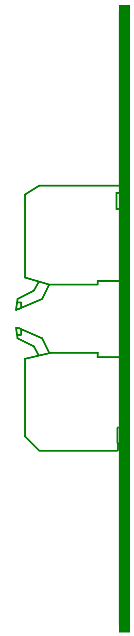


Confidential



SILKSCREEN

COMPONENT (TOP) SIDE



SIDE VIEW

NOTES:

1. MASK OFF ANT 42.
2. CHAMFERRED SIDE OF D11,D12,D13,D21,D31 & D32 SILKSCREEN DENOTES CATHODE.
3. CHAMFERRED SIDE OF CAPACITOR SILK SCREEN DENOTES + SIDE. THIS APPLIES TO C11,C14,C15, C16,C31,C32,C43 & C45.
4. SEE ATTAHED FILE tr_.pdf FOR U41 SOLDERING INSTRUCTIONS.

THIRD ANGLE PROJECTION

UNLESS OTHERWISE SPECIFIED, DIMENSIONS ARE IN INCHES, TOLERANCES ARE:

2 PLC ± | 3 PLC ± | ANGLES ±

MATERIAL:

FINISH:

CONTRACT NO.

DRAWN Mike McGlinchy | DATE 3-02

CHECKED

APPROVED

APPROVED

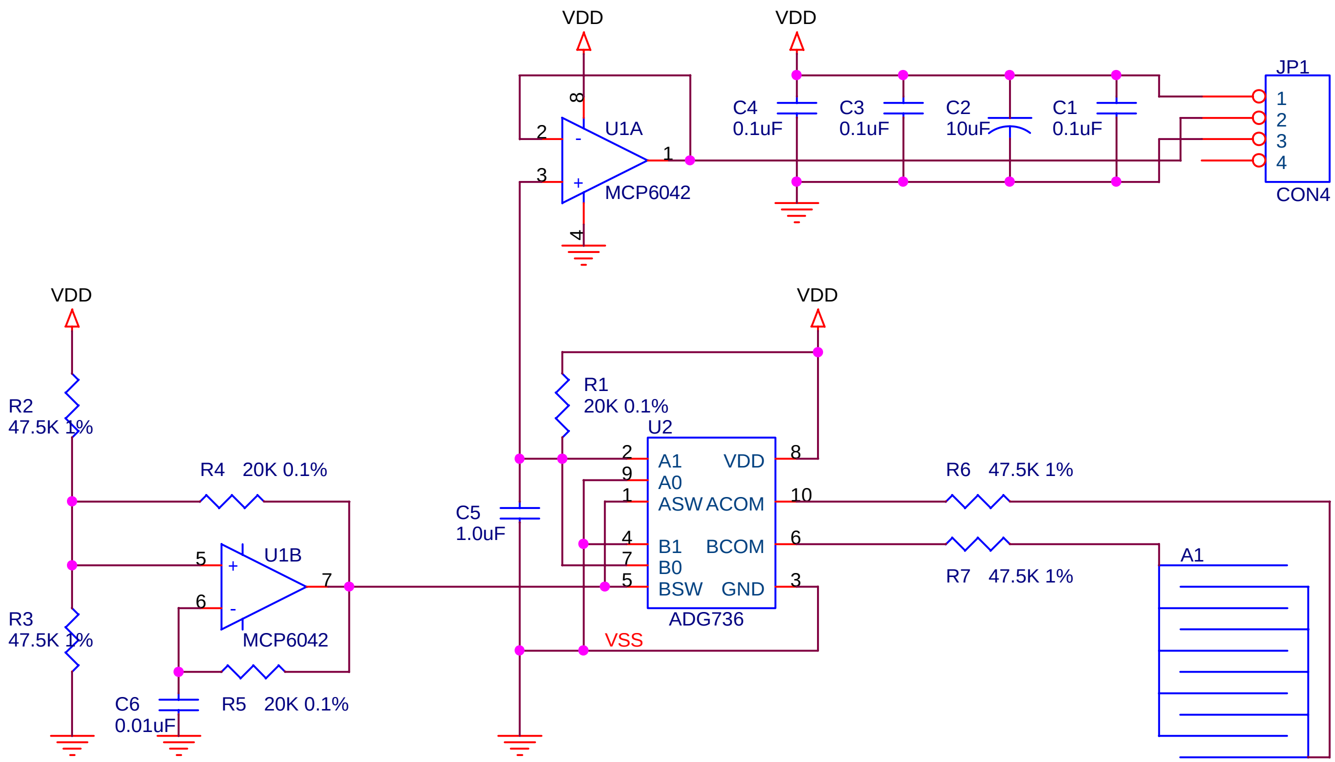
APPROVED

Davis Instruments

SOIL/LEAF/TEMP,ASSY.

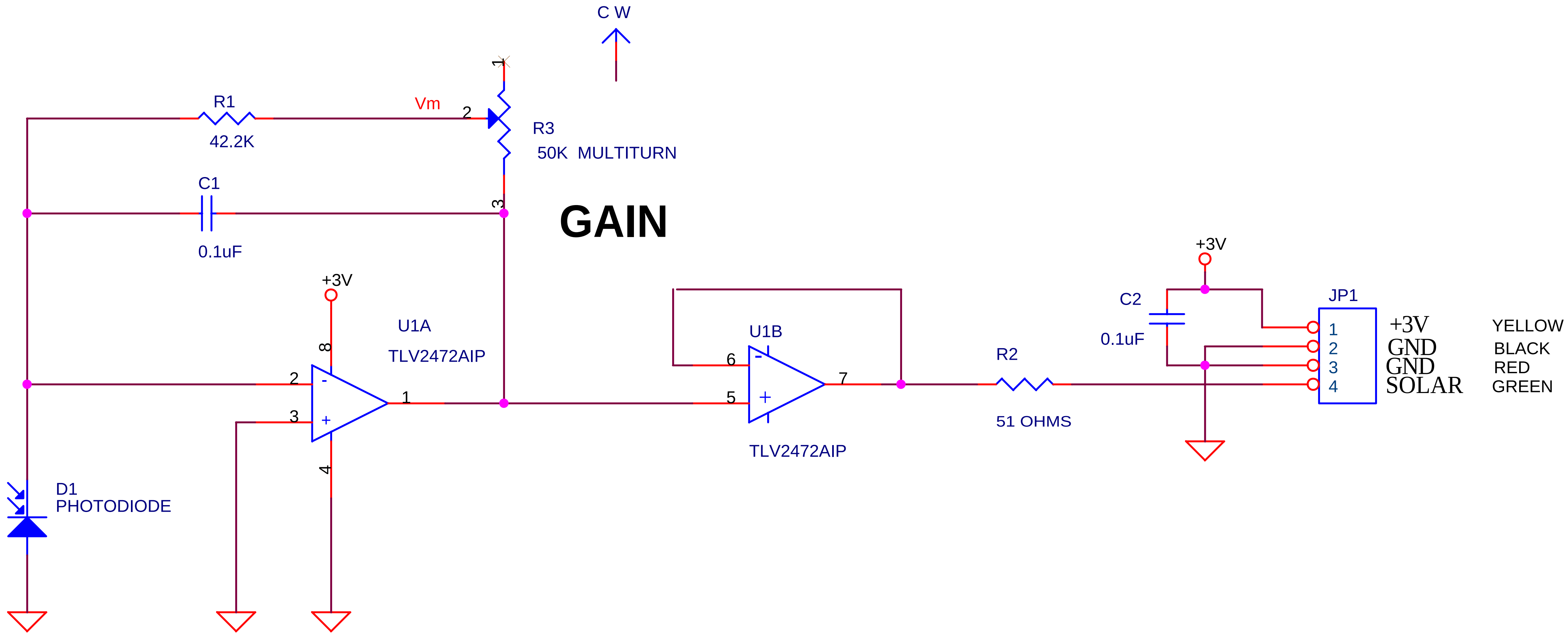
SIZE A | CODE | IDENT NO. | DRAWING NO. 7315.116 | REV A00

SCALE: | DO NOT SCALE | SHEET 1 OF 1



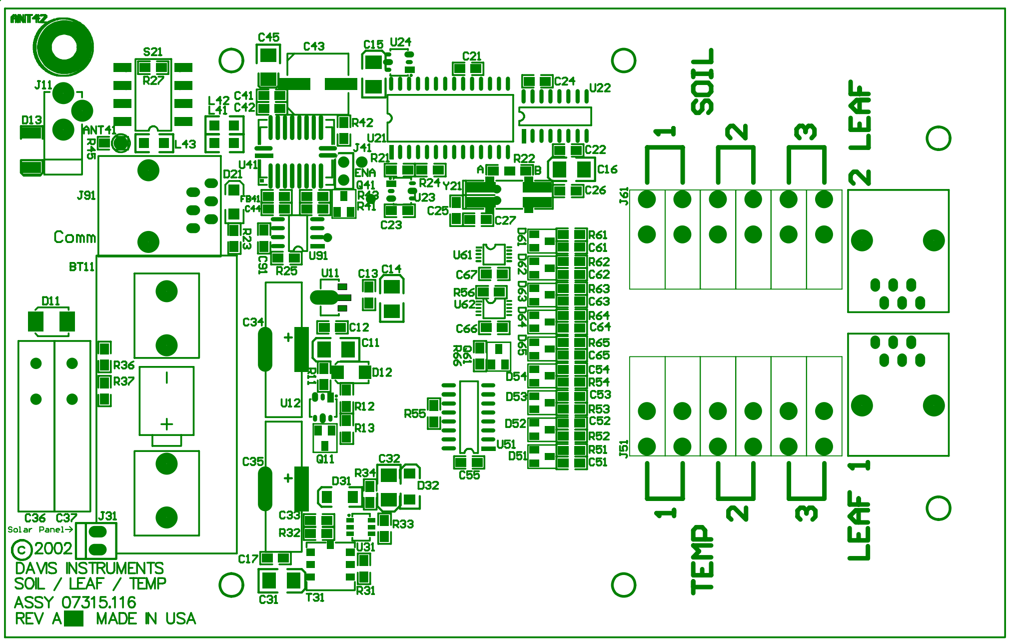
Davis Instruments

Title	Vantage Leaf Wetness Sensor	
Size A	Document Number 7315.115	Rev A
Date: Friday, April 19, 2002	Sheet 1 of 1	



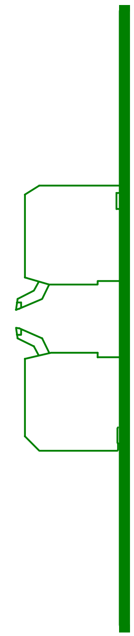
DAVIS INSTRUMENTS

Title	SOLAR SENSOR-VANTAGE	
Size: A	Document Number: 7315.077	Rev: A
Date: Tuesday, July 25, 2000	Sheet 1 of 1	



SILKSCREEN

COMPONENT (TOP) SIDE

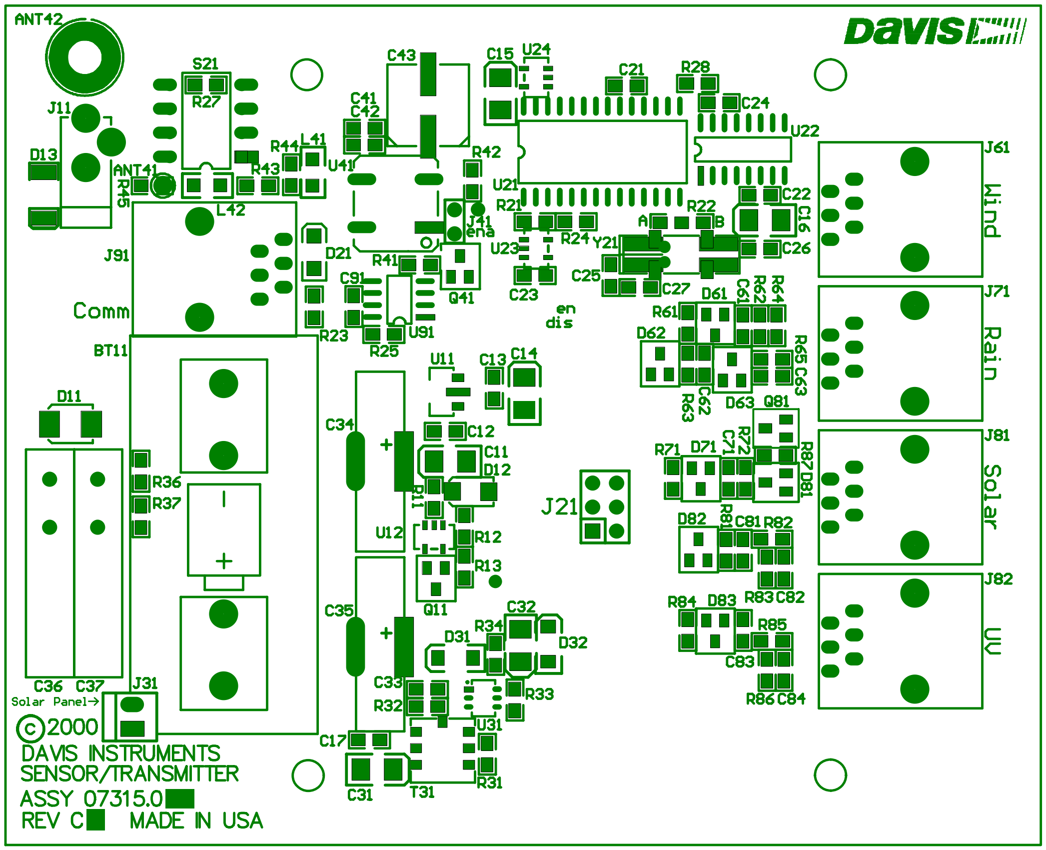


SIDE VIEW

NOTES:

1. MASK OFF ANT 42.
2. CHAMFERRED SIDE OF D11,D12,D13,D21,D31 & D32 SILKSCREEN DENOTES CATHODE.
3. CHAMFERRED SIDE OF CAPACITOR SILK SCREEN DENOTES + SIDE. THIS APPLIES TO C11,C14,C15, C16,C31,C32,C43 & C45.
4. SEE ATTAHED FILE tr_.pdf FOR U41 SOLDERING INSTRUCTIONS.

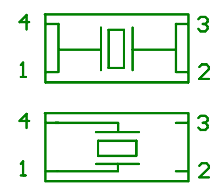
THIRD ANGLE PROJECTION	CONTRACT NO.		Davis Instruments
UNLESS OTHERWISE SPECIFIED, DIMENSIONS ARE IN INCHES, TOLERANCES ARE:	DRAWN Mike McGlinchy	DATE 3-02	SOIL/LEAF/TEMP,ASSY.
2 PLC ± / 3 PLC ± / ANGLES ±	CHECKED		
MATERIAL:	APPROVED		SIZE A / CODE / IDENT NO. / DRAWING NO. 7315.116 / REV A00
FINISH:	APPROVED		
	APPROVED		SCALE: / DO NOT SCALE / SHEET 1 OF 1



COMPONENT (TOP) SIDE

NOTES:

1. TO DETERMINE IF Y21 IS A B TYPE:
   USING AN OHMMETER, TAKE 2 MEASUREMENTS:
   MEASURE BETWEEN CRYSTAL TERMINALS 2 AND 3 AND THEN MEASURE BETWEEN TERMINALS 1 AND 4. IF BOTH MEASUREMENTS ARE LESS THAN 3 OHMS, THEN THE CRYSTAL IS A B TYPE. AS SHOWN BELOW, TERMINALS 2 & 3 AS WELL AS TERMINALS 1 & 4 ARE CONNECTED (LESS THAN 3 OHMS) ON THE B TYPE.



   IF THE CRYSTAL IS NOT A B TYPE, THEN IT IS AN A TYPE.

   IF THE CRYSTAL IS A B TYPE, THEN C25 AND C26 GET STUFFED AND R22 IS STUFFED IN THE R22B POSITION. C27 DOES NOT GET STUFFED.

   IF THE CRYSTAL IS AN A TYPE, THEN C25 AND C27 GET STUFFED AND R22 IS STUFFED IN THE R22A POSITION. C26 DOES NOT GET STUFFED.

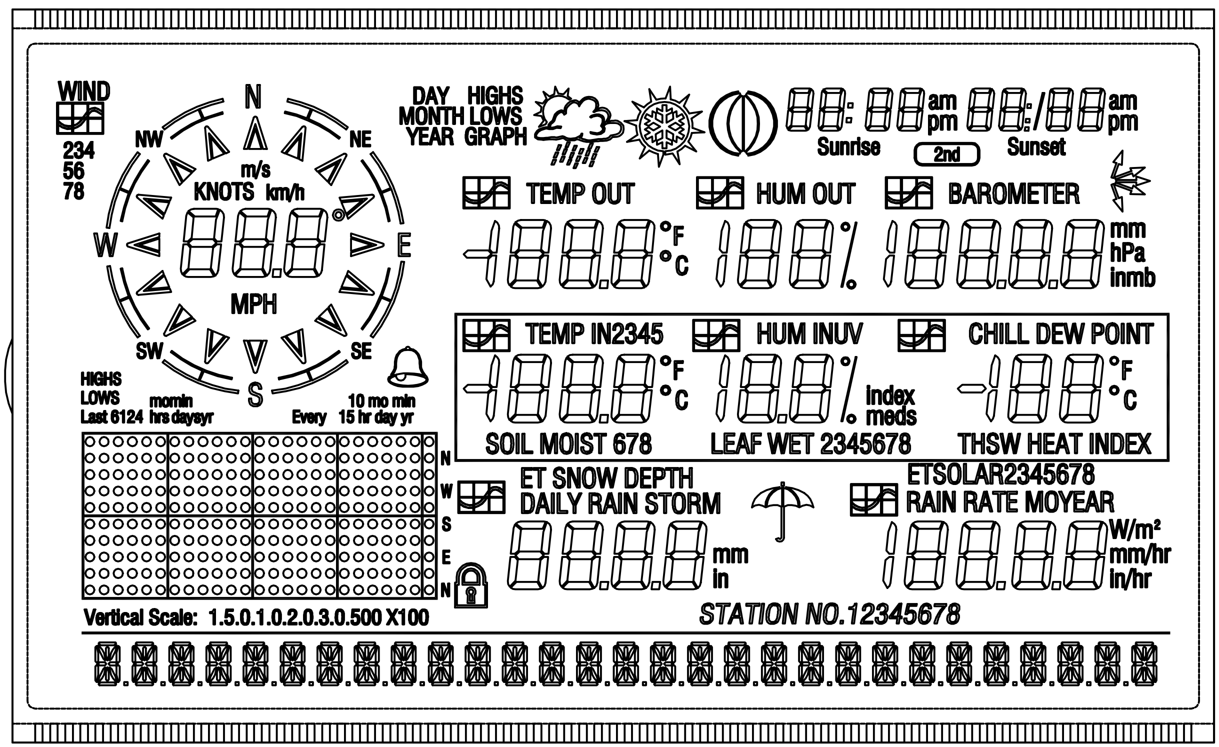
2. MASK OFF ANT41, ANT42 & J21

THIRD ANGLE PROJECTION	CONTRACT NO.	
UNLESS OTHERWISE SPECIFIED, DIMENSIONS ARE IN INCHES. TOLERANCES ARE:	DRAWN Mike McGlinchy	DATE 3–01
2 PLC ± / 3 PLC ± / ANGLES ±	CHECKED	
MATERIAL:	APPROVED	
	APPROVED	
FINISH:	APPROVED	

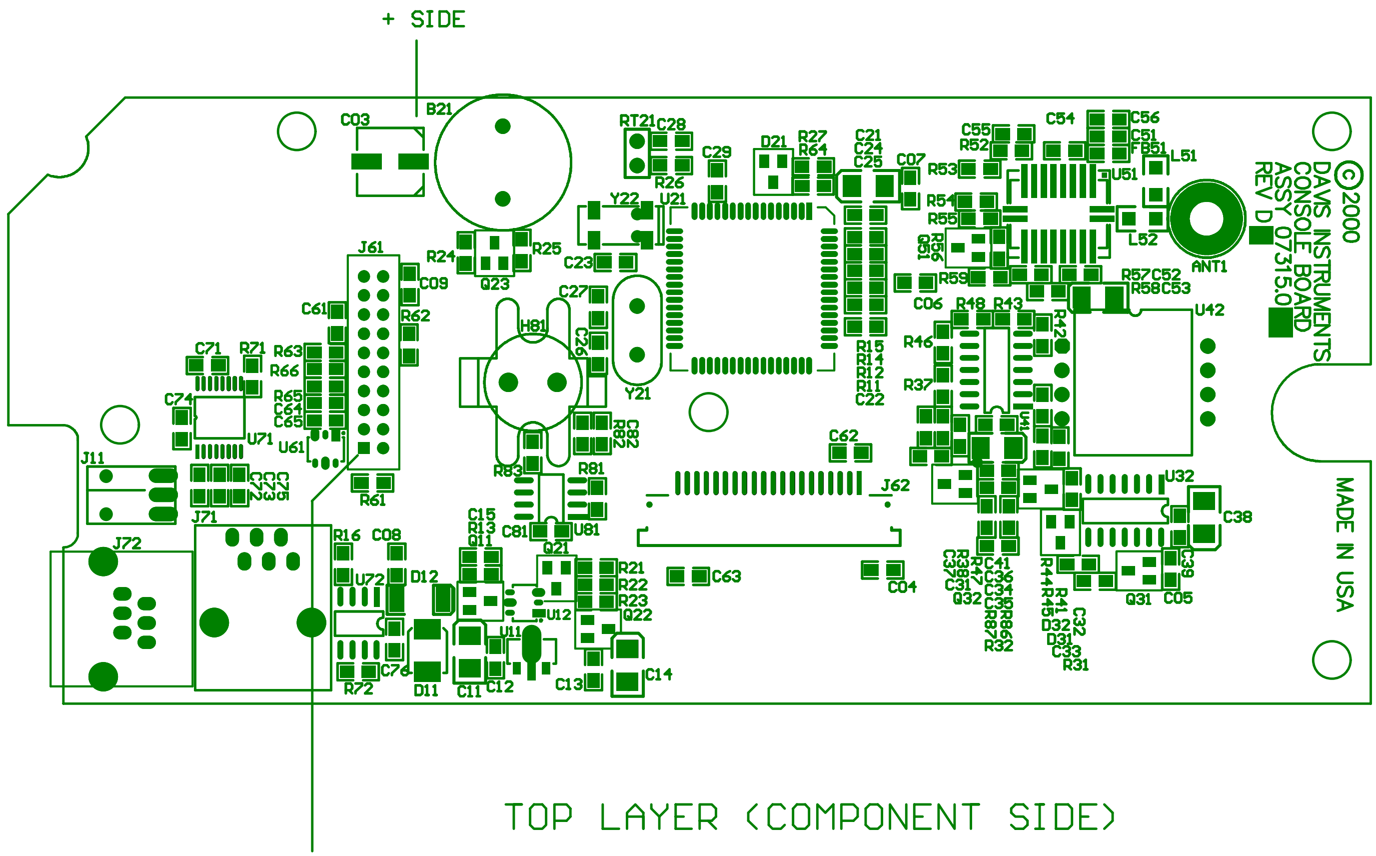
Davis Instruments

ISS BOARD, ASSY

SIZE	CODE IDENT NO.	DRAWING NO.	REV
A		7315.040	C
SCALE:	DO NOT SCALE	SHEET 1 OF 1	



WIND
234
56
78
N
NW
NE
W
E
SW
SE
S
m/s
KNOTS km/h
MPH
HIGHS
LOWS
Last 6124
momin
hrs daysyr
Every
10 mo min
15 hr day yr
DAY HIGHS
MONTH LOWS
YEAR GRAPH
am
pm
Sunrise
2nd
Sunset
TEMP OUT
HUM OUT
BAROMETER
°F
°C
mm
hPa
inmb
TEMP IN2345
HUM INUV
CHILL DEW POINT
index
meds
SOIL MOIST 678
LEAF WET 2345678
THSW HEAT INDEX
ET SNOW DEPTH
DAILY RAIN STORM
ETSOLAR2345678
RAIN RATE MOYEAR
mm
in
W/m²
mm/hr
in/hr
Vertical Scale: 1.5.0.1.0.2.0.3.0.500 X100
STATION NO.12345678



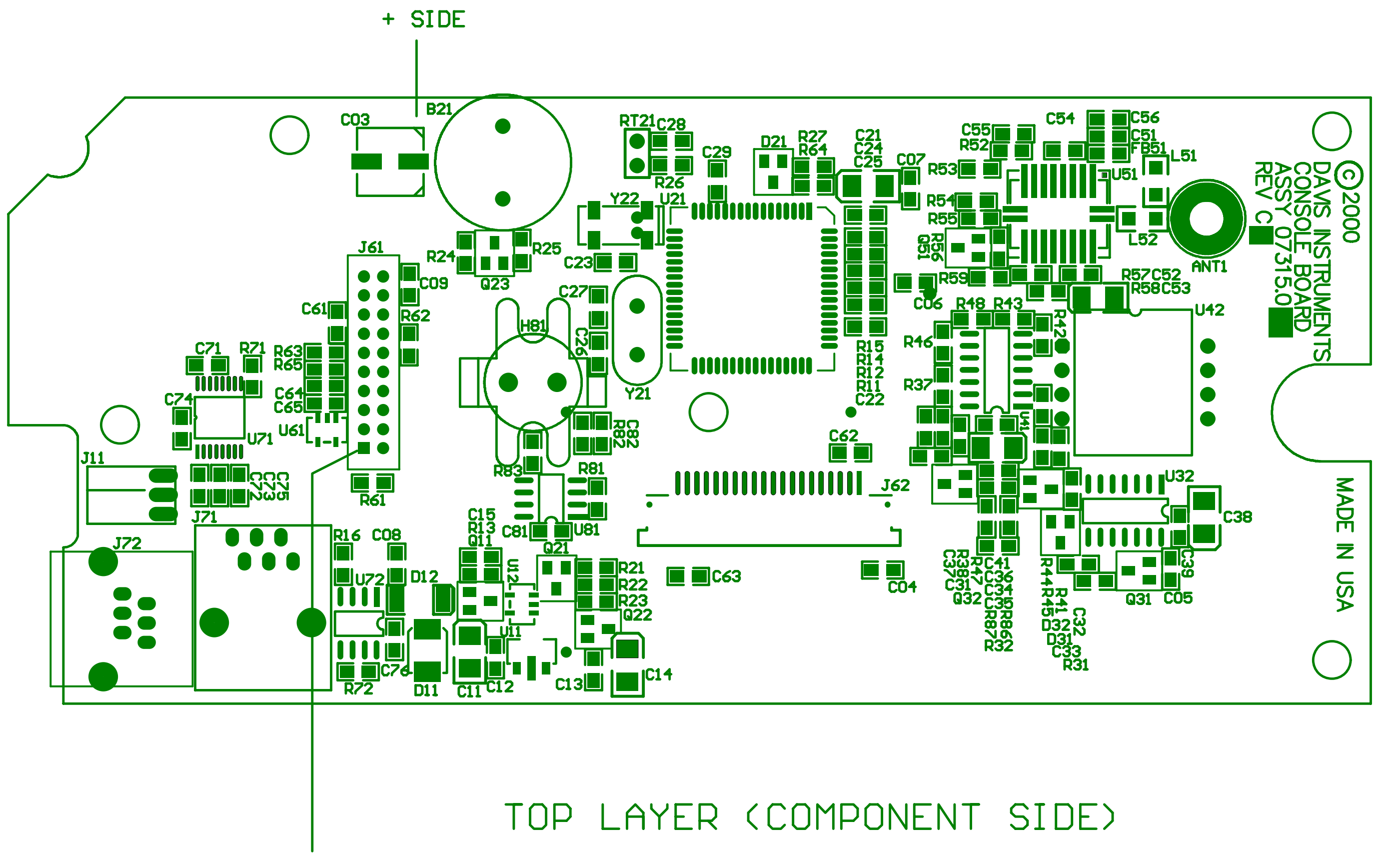
TOP LAYER (COMPONENT SIDE)

PIN 1 OF J61 (DENOTED BY SQ. PAD)
CORRESPONDS TO ARROW ON CONNECTOR

NOTES:

1. MASK OFF H81,ANT1, GOLD FINGERS & 5 MOUNTING HOLES.
2. CHAMFER ON DIODE SILKSCREEN DENOTES CATHODE.
3. CHAMFER ON CAPACITOR SILK SCREEN DENOTES +.
4. SEE ATTAHED FILE tr_.pdf FOR U51 SOLDERING INSTRUCTIONS.

THIRD ANGLE PROJECTION	CONTRACT NO.	Davis Instruments
UNLESS OTHERWISE SPECIFIED, DIMENSIONS ARE IN INCHES, TOLERANCES ARE:	DRAWN MIKE McGLINCHY — DATE 8–01	CONSOLE BOARD, ASSY.
2 PLC ± / 3 PLC ± / ANGLES ±	CHECKED	SIZE A — CODE — IDENT NO. — DRAWING NO. 7315.014 — REV D
MATERIAL:	APPROVED	SCALE: — DO NOT SCALE — SHEET 1 OF 1
FINISH:	APPROVED	
	APPROVED	



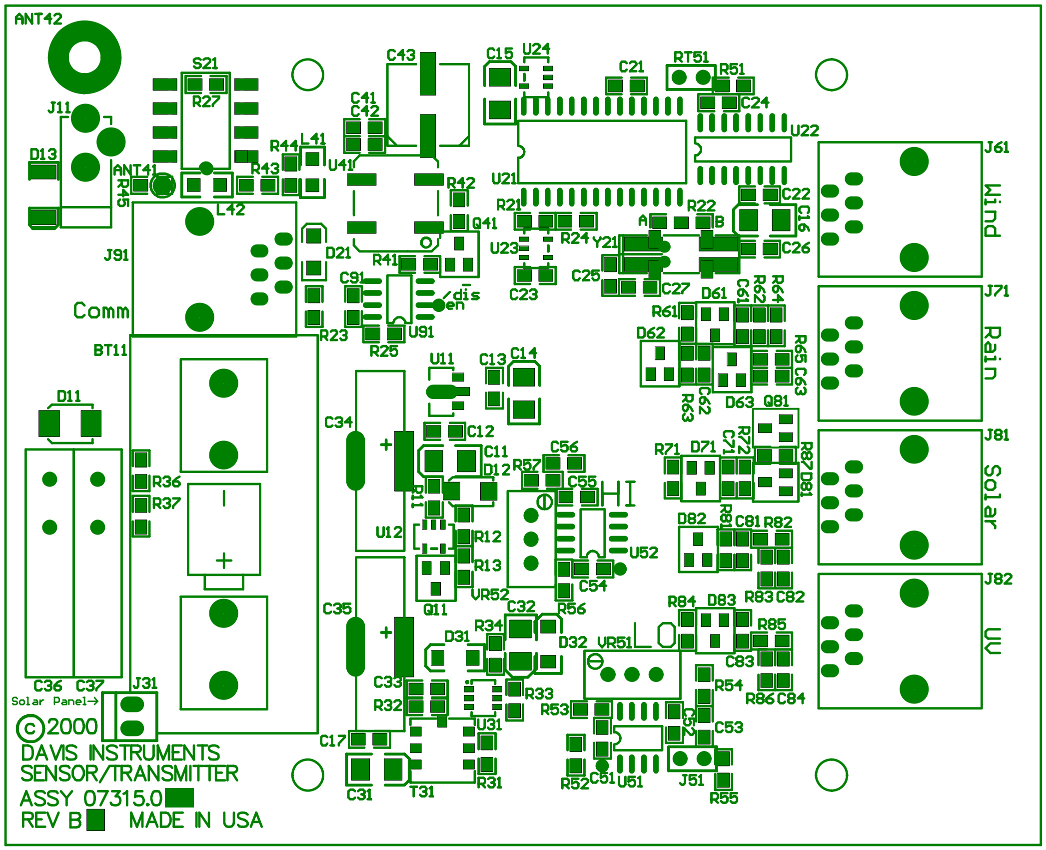
TOP LAYER (COMPONENT SIDE)

PIN 1 OF J61 (DENOTED BY SQ. PAD)
CORRESPONDS TO ARROW ON CONNECTOR

NOTES:

1. MASK OFF H81,ANT1, GOLD FINGERS & 5 MOUNTING HOLES.
2. CHAMFER ON DIODE SILKSCREEN DENOTES CATHODE.
3. CHAMFER ON CAPACITOR SILK SCREEN DENOTES +.
4. SEE ATTAHED FILE tr_.pdf FOR U51 SOLDERING INSTRUCTIONS.

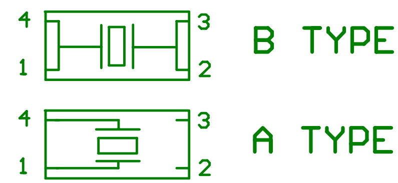
THIRD ANGLE PROJECTION	CONTRACT NO.		Davis Instruments
UNLESS OTHERWISE SPECIFIED, DIMENSIONS ARE IN INCHES, TOLERANCES ARE:	DRAWN MIKE McGLINCHY	DATE 4–01	CONSOLE BOARD, ASSY.
2 PLC ± / 3 PLC ± / ANGLES ±	CHECKED		SIZE A · CODE IDENT NO. · DRAWING NO. 7315.014 · REV C
MATERIAL:	APPROVED		SCALE: · DO NOT SCALE · SHEET 1 OF 1
FINISH:	APPROVED		
	APPROVED		



COMPONENT (TOP) SIDE

NOTES:

1. TO DETERMINE IF Y21 IS A B TYPE:
   USING AN OHMMETER, TAKE 2 MEASUREMENTS:
   MEASURE BETWEEN CRYSTAL TERMINALS 2 AND 3 AND THEN MEASURE BETWEEN TERMINALS 1 AND 4. IF BOTH MEASUREMENTS ARE LESS THAN 3 OHMS, THEN THE CRYSTAL IS A B TYPE. AS SHOWN BELOW, TERMINALS 2 & 3 AS WELL AS TERMINALS 1 & 4 ARE CONNECTED (LESS THAN 3 OHMS) ON THE B TYPE.

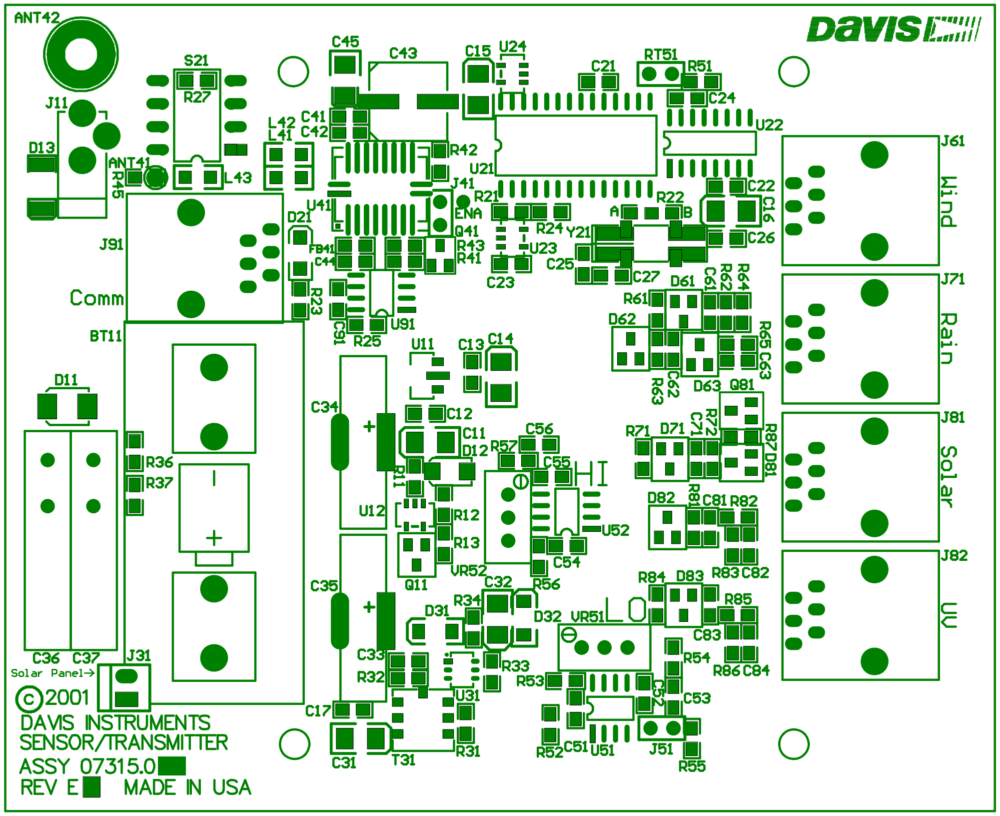


   IF THE CRYSTAL IS NOT A B TYPE, THEN IT IS AN A TYPE.

   IF THE CRYSTAL IS A B TYPE, THEN C25 AND C26 GET STUFFED AND R22 IS STUFFED IN THE R22B POSITION. C27 DOES NOT GET STUFFED.

   IF THE CRYSTAL IS AN A TYPE, THEN C25 AND C27 GET STUFFED AND R22 IS STUFFED IN THE R22A POSITION. C26 DOES NOT GET STUFFED.
2. MASK OFF ANT41,ANT42 & J51
3. JUMPER DIS
4. CHAMFERRED SIDE OF D11,D13,D21,D31 & D32 SILKSCREEN DENOTES CATHODE.
5. CHAMFERRED SIDE OF CAPACITOR SILK SCREEN DENOTES + SIDE. THIS APPLIES TO C11,C14,C15, C16,C31,C32 & C43.

THIRD ANGLE PROJECTION	CONTRACT NO.		Davis Instruments
UNLESS OTHERWISE SPECIFIED, DIMENSIONS ARE IN INCHES. TOLERANCES ARE: 2 PLC ± 3 PLC ± ANGLES ±	DRAWN Mike McGlinchy	DATE 4–01	ISS BOARD,ASSY
	CHECKED		
MATERIAL:	APPROVED		SIZE A · CODE IDENT NO. · DRAWING NO. 7315.040 · REV B
FINISH:	APPROVED		SCALE: · DO NOT SCALE · SHEET 1 OF 1
	APPROVED		



COMPONENT (TOP) SIDE

NOTES:

1. MASK OFF ANT41, ANT42 & J51
2. CHAMFERRED SIDE OF D11, D13, D21, D31 & D32 SILKSCREEN DENOTES CATHODE.
3. CHAMFERRED SIDE OF CAPACITOR SILK SCREEN DENOTES + SIDE. THIS APPLIES TO C11, C14, C15, C16, C31, C32, C43 & C45.
4. SEE ATTACHED FILE tr_.pdf FOR U41 SOLDERING INSTRUCTIONS.

THIRD ANGLE PROJECTION	CONTRACT NO.		Davis Instruments
UNLESS OTHERWISE SPECIFIED, DIMENSIONS ARE IN INCHES, TOLERANCES ARE:	DRAWN Mike McGlinchy	DATE 3-01	ISS BOARD, ASSY
2 PLC ± / 3 PLC ± / ANGLES ±	CHECKED		SIZE A / CODE IDENT NO. / DRAWING NO. 7315.040 / REV E02
MATERIAL:	APPROVED		
FINISH:	APPROVED		SCALE: / DO NOT SCALE / SHEET 1 OF 1
	APPROVED		

Outside Humidity Measurement

The X2 sensor is in a 555 oscillating circuit which is trimmed (sensor offset adjust) using VR51 to output 72khz at 33% relative humidity (rh). The "gain" of the sensor (the frequency change for every 1 percent change rh) is communicated in a second oscillator circuit which is trimmed using VR52. The actual gain frequency seen with a frequency counter can be input into the formula below to determine the sensor gain. In some documentation the gain frequency is referred to as the HI_CAL frequency. HI_CAL = F_{94} – 1000. Sensor Gain = (F_{94}- F_{33})/ (94 – 33). F_{94} is the frequency of the sensor oscillator at 94% rh and F_{33} is the frequency at 33% rh (always trimmed to be 9khz). When the sensor frequency and the HI_CAL frequency are known the rh value can be calculated using the following formula: rh = (F_{sensor}- 9000) / SensorGain + 33. Note, for the Phillips sensor the HI_CAL ≈ 6700 hz, and for the X2 sensor HI_CAL ≈ 7100 hz.

In production, the boards are soaked first at 33% and VR51 is set. Afterwards, the chamber is moved to 80% and VR52 is adjusted until they read 80%. Later, the chamber is raised to 90% to check that the circuit board is stable.

The ISS does not send the actual frequency numbers to the Vantage console, but it is a simple function of the numbers. The uP samples each frequency for ¼ of a second. It divides the sensor frequency by 8 and subtracts 1536 (0x600) to create a 10 bit number. The HI_CAL frequency is treated the same way but it is not divided by 8. If H is the 10 bits taken from the HUM packet and C is the 10 bits taken from the HUM_CAL packet the rh is calculated using the formula below.

Hum = 33 + (4500 – ((H+0x600)*2)) * (61 / (4000 - ((C+0x600)*2)))

If the Hum is 27 or less a correction factor is added in by the firmware. The correction can be calculated from the formula below.

HumCorr = 0.004 * Hum ^ 2 – 0.421 * Hum + 9.659

VANTAGE BAR CAL USING PROCOMM B.P. 6-9-00

In addition to the Vantage console, you will need a VantageLink, calculator for hexadecimal conversion, and a piece of paper.

1. Take the back off the console and connect the VantageLink.

2. Plug the unit into COM1: of the lab computer.

3. Go to the DOS prompt and do "cd \procomm".

4. Enter "procomm" at the DOS prompt. Don't worry that Microsoft will be split up.

5. Power up the Vantage console. You should see "We're off..." come up in Procomm. If not, check COM port and baud rate settings (ALT-P). Baud rate should be 19,200.

6. Read ambient bar from the bar reference and write it down. As an example, we will follow the last unit calibrated. The bar reference was 30.014 in.

7. Turn the bar circuit on with the command "BARON" and return. You should see a spade character come back. If not, enter it again. Now tell the Vantage to convert the barometer using the ADREAD command. "ADREAD 1 100". This tells it to read channel one 100 times. In our example we got back 77414 or 774.14 out of a max of 1023 counts. You should do this a few times and convince yourself that the reading is not changing by more than a couple of counts per 10,000.

8. Connect the tubing to the Vantage. If you do not know how to run the compressor see Jason, Brett, or Bob.

9. Take the pressure down to around 20.00". It is not necessary to be exact. 20, 21, 22, 23 will all work. Make sure you pressure is not leaking faster than .01" every few seconds.

10. Again read the reference and then take a reading. "ADREAD 1 1000" In our example we got back 289289 or 289.289 counts and the reference read 22.540.

11. Now you can release the pressure and calculate the gain and offset values to be entered into the Vantage EEPROM.

12. The gain is inches per count and is stored in 10,000ths. In our example the gain is (30.014-22.540)/(774.14-289.29) = .015415 or .01542 or 1542 fixed point. Convert 1542 to hexadecimal or 606h.

13. The total range of the circuit is approximately 7.5 psi or 15.24 in. The offset is 30.014 - (774.14*.01542) = 18.077 or 18077 fixed point or 469Dh.

14. Now write the gain to the EEPROM using the EEWR command.

EEWR 1 6
EEWR 2 6

Your should get an OK back after each statement. Note the least significant byte is written first. So if the number was 607h you would write the 7 first.

15. Now write the offset number you calculated.

EEWR 3 9D
EEWR 4 46

16. Now zero out any manual offset that might be in the EEPROM.

EEWR 5 0
EEWR 6 0

17. Now check what you wrote with the EERD command.

EERD 1 6

In our example you would get back:
06
06
9D
46
00
00

18. You can now reboot the unit. Hold the DONE key down to get out of setup, and your first calibrated bar conversion should be displayed in a few seconds. If it is different, double check your calculations and go back to step 16 to make sure what you wanted to write actually got written. Also, make sure your altitude is 0 in the Vantage setup.

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Bar Circuit Notes and Theory of Operation B.P. 6/5/2001

The barometer sensor is the NPC-1210 made by Lucas Nova Sensor. We are using a part that has a looser tcomp spec. than the one described in the data sheet. The new part is specified to have a thermal accuracy of +/- .75% instead of the .5% indicated. We found that this new part had acceptable performance. References are made to the data sheet for this part and the circuit schematic for the Vantage console below.

The pressure sensor is laser trimmed for both gain and offset to the specs indicated on the data sheet. The gain is trimmed to within +/- 1% and the offset is trimmed to a worst case of 2/75 and typically 2%. As you will see below the typical full scale range of the circuit is 15.51 inches. The barometer is converted every 15 minutes when the minute hand is at 59, 14, 29, and 44. The conversion takes approximately 2 seconds and 10,000 samples are averaged. The noise from the voltage doubler combined with this averaging interval result in a very high resolution barometer. The A/D is equivalent to approximately 15 bits. (ln (30,000)/ln (2)). Experiments run showed we could resolve .1 mv at about +/- .2 mv. Because our gain is .00517 in/mv or .175 hPa/mv this equates to a resolution of .0175 hPa with noise of +/- .035 hPa. This seems a bit small to me now, but I'm pretty sure about that .1 mv resolution and one can see by pressing the Bar key twice while on hPa that our barometer is very stable.

Look at the bar circuit at the bottom of the Vantage Schematic. The circuit is ratiometric with respect to the reference voltage. U41D provides the constant current source for the pressure sensor (wheatstone bridge). The voltage at the non-inverting input of U41D and R41 set the current. It was found experimentally that the more current used the better the temperature performance of the sensor. However, more current requires more supply voltage due to the voltage drops of the sensor not to mention more power. The circuit uses ¾ ma of constant current through the sensor. As the pressure changes, the voltage difference between the to arms of the bridge change. This voltage change (∇V) is multiplied in the first stage of the circuit by a gain that is trimmed by the gain set resistor in the sensor such that a full scale input pressure (15 psi or 30.54 in) gives 3.012V +/- 1%.

The first stage of our circuit is equivalent to the one given on the front of the data sheet – only the gain is slightly different. They use 1.5 ma as a reference current with gain resistors of 100k and we use .75 ma with gain resistors of 200k. This gives us a gain that is typically 1.7% lower than the circuit on the data sheet. The reason is that our voltage across the gain resistor is ½ of what their circuit gives. Their gain equation is ∇V x (1 + 2R/Rg). Our R's are twice as big and our ∇V is ½ their ∇V so our gain is ½∇V x (1 + 4R/Rg) = ∇V x (1/2 + 2R/Rg). The full scale output of the sensor is typically 100 mv (at 15 psi) and can be as low as 75 mv and as high as 150 mv. The gain reistor Rg is trimmed to make up for this change. By calculating the Rg and looking at the two formulas one can see the difference between our gain and their gain. If ∇V is 100 mv than Rg is 6.868k. Our gain would than be (1/2 + 200/6.868) or 29.62. Their gain is 30.12 or 1.017 more. If Rg is 10.48k (at 150 mv full scale output (fso)), than their gain is 1.025 times more. At full scale output their circuit puts out 3.012V or (15 psi * 2.036 in/psi)/(3.012 x 2) or 5.066 in/V. The x 2 is for our last stage that has a gain of 2. Since our gain is typically about 2% less we will require more change in pressure per volt or 5.066 x 1.02 or 5.17 in/V and since there are 341 counts to a volt using our A/D that will make .01516 in/count.

The second stage of the circuit is an instrumentation amplifier with a gain of 2 and an offset of –3x20/17.4 or –3.448 volts. Assuming an offset voltage of zero, note the TLC27L9C has low offset voltage (~900 uV), the output of the circuit at 15 psi will be (15 x 2.036)/5.17 – 3.448 or 2.46 volts. Therefore the nominal range of the circuit will be ***17.83 in to 33.34 in (0 to 3v)***. The highest recorded barometer ever was 32.01 inches. The Davis barometer will record this pressure down to -1000'. Note, the gain of the circuit can vary from this value as a result of the 1% resistors in the circuit that can affect the gain. The current set resistors R37, R38, R41 and the gain resistors R42 and R44. The combined worst case gain error of these resistors is 4.7% which combined with the 1% trim of Rg makes +/-5.7%. The gains in practice vary inside of this number I think because the odds of all the resistors being at their absolute worst case values is quite small.

Other factors to be concerened about are that the lower bridge arm GS1 does not go so low that the output of U41B reaches ground before FSO and that the upper bridge arm does not get too close to the op amp supply voltage generated by the voltage doubling circuit driven by the 32khz buzzer signal. A min sensor input impedance of 2.5k is given by the data sheet. At ¾ ma that produces a 1.87V drop across the sensor. An additional .75v can be found across the current set resistor R41 which means the lowest voltage reached by the lower bridge arm is approximately .75 + 1.875/2 - .075 or 1.61 V which will allow the first stage to record a difference of 3.2 volts. The leg will ground out at 15 x 2.036 x 3.2 x 1/(3.012 x .98) or 33.10 inches. Note, this is for the worst case sensor impedance and empirical measurments have confirmed we are pretty safe here. Because the voltage doubler puts out over 6.5 volts, we are ok on the high end. A 6k max sensor input impedance make the upper bridge sit at about .75 x 6 / 2 + .075 + .75 or 3.07 which when added to 1.61 v at FSO is not close to the op amp rail.

Some things to remember:

1. The temperature performance of the circuit is highly dependent on the constant current used. We found that .5 ma was not enough current and that 1 ma was ideal, but .75 ma gave acceptable performance.
2. The op amp used in the Vantage circuit has a better offset voltage spec. than the part in the Monitor II – ***you can not use the Monitor II part in the Vantage circuit.***
3. .1 % resistors are required in the instrumentation amp if good linearity is to be achieved.
4. The new Davis circuit has no startup drift because it uses no trim pots.
5. The gain of the circuit is trimmed within fractions of a percent on our calibration fixture.
6. Pressure hysterisis of the sensor is +/-.1% or +/- .0155 in.
7. We calibrate to the Vaisala PTB220A which has an accuracy of +/- 0.004 in Hg (over a pretty wide temp range also).

Overview

The ISS is designed as a replacement and extension of the SensorLink transmitter. Each ISS is assigned a unit ID number (via dip switches) between 0 and 7. This unit ID determines the time interval between data packets, which is nominally 2.5 seconds for unit ID 0 and increases by 1/16'th of a second for each unit ID above zero. Data is transmitted in 6 byte data packets. This includes the Unit ID, Packet type, Wind Speed (8 bits), Wind Direction (8 bits), Other data (10 bits or 12 bits) and a 12 bit CRC code. (Except for the Max Wind packet is a little different.).

All Unit ID's in this document are assumed to be between 0 and 7. The User manuals give Unit ID's between 1 and 8. This means that you need to add 1 to the unit ID's in this document when consulting the manual (e.g. when setting or examining the dip switches).

Data Sampling

A/D data

The ISS has a 10-bit A/D conversion chip with 4 channels. These are assigned as follows:

Channel #	Sensor
0	Wind Direction
1	Temperature
2	Solar Radiation
3	UV Radiation

The Wind Direction is sampled for every data packet.

If the current data packet is a temperature packet or a Solar Rad packet, other channels are sampled as well. The temperature is sampled for temperature packets, and both Solar and UV are sampled for Solar Rad packets. The UV value is saved and transmitted with the next UV packet (see Packet sequencing below).

When Wind Direction and Temperature are sampled, one 10-bit sample is taken and used. When Solar and UV are sampled, multiple samples are taken and averaged. This is done by making the number of samples taken a power of 2 and then bit shifting the result. The number of samples taken is 16 for both Solar and UV.

In order to save power when the Solar or UV sensors are not connected, or at night, a scheme is used to limit the number of times the Solar and UV sensors are sampled. This scheme is described below in SUV Power saving.

In order to accommodate future expansion, 12 bits are allocated to A/D data values (except UV) in the data packets even though only 10 bits are read by the ISS. This is accomplished by reducing the Wind Direction data to 8 bits. The field containing the lower 2 bits of the direction data in earlier versions of the data protocol now hold the lower 2 bits of analog data. Since only 10 bits are read on the ISS, these bits are filled with zeros (but see Wind Speed below for exceptions).

Humidity data

The humidity data requires 2 frequencies to determine the humidity value. One frequency represents the sensor data, and the other represents a calibration factor.

The Humidity frequency is divided by 8 internally, then measured for 1/8'th of a second. The resulting count is then multiplied by 2, and 0x600 is subtracted from it to determine the 10 bit data value to transmit. Note that the divide by 8 operation replaces a hardware divide by 8 operation on the original Davis Instruments Temp Hum sensor.

The Hum Cal frequency is processed the same way and the Humidity frequency, except that it is not divided by 8.

The Humidity frequency is measured (nominally) every 50 seconds, at the same time that the Humidity Cal packet is sent. The Hum Cal frequency is measured every 60 Hum Cal Packets or (nominally) every 50 minutes.

Humidity Calculation

To calculate the Humidity from Humidity and Hum Cal values use the following formula:

Hum = 33 + (2250 – (H+0x600)) * (61 / (2000 - (C+0x600)))

Where H is the Humidity data value, and C is the Hum Cal data value.

If (C+0x600) is less than 1750 and the Hum as calculated above is less than 27%, a correction formula is applied to correct low humidity values on the X2 sensor:

HumCorr = 0.004 * Hum ^ 2 – 0.421 * Hum + 9.659

Wind Speed data

Wind Speed is measured for every data packet. The measurement period is 1 second, and Both rising and falling edges are counted (up to 255 transitions).

Since the Davis Anemometer was calibrated so that for a measurement period of 2.25 seconds, each full revolution equals one mile per hour, the conversion formula for ISS data is:

MPH = Data * 2.25 / 2 = Data * 9/8

In some packets, where we do not anticipate a use for 12 bit analog data (or where we don't use analog data), The least significant of the two obsolete wind direction bits is used to record the state of the anemometer reed switch at the end of the speed measurement period. The receiver monitoring these bits should see approximately equal numbers of 1's and 0's over a period of time. This feature should help troubleshooting of anemometers (i.e. distinguishing always open vs. always closed conditions). The packets that include this data are: Rain, Rain Rate, and UV.

A value of 1 indicates an open reed switch. A value of 0 indicates a closed reed switch.

Rain Data

Rain data consists of a 7 bit tip count, and a rain reset bit. The purpose of the rain reset bit is to distinguish between the rain count rolling over the 7 bit count, and the ISS being reset (and starting over from zero). To determine how much rain has fallen since the last rain packet use the following table.

Previous Reset Bit	Current Reset Bit	Current Count – Previous Count	Rain Value	Comments
1	1	Positive	Cur – Prev	Normal operation
1	1	Negative	Current	ISS Reset
1	0		128-Prev + Cur	ISS Rolled over
0	1		Current	ISS Reset
0	0	Positive	Cur – Prev	Normal operation
0	0	Negative	128-Prev + Cur	ISS Rolled over

Rain Rate data

Rain Rate data consists of a 9 bit timer that indicates the "current" interval between rain tips. The 10'th bit is used to select between a high speed and low speed timer. The high speed timer has an interval of 1/8'th of a second and can measure intervals up to 63 7/8 seconds (511 x 1/8), or 1 minutes and 3 7/8 seconds. The low speed timer has an interval of 2 seconds and can measure intervals up to 1018 seconds (509 x 2), or 16 minutes and 58 seconds.

The timer selection bit is 0 for the high speed timer, and 1 for the low speed timer. In addition, time intervals less than 127 7/8 seconds will always be sent as high speed timer values. This means that you can perform greater than and less than comparisons on the 10 bit timer/selection value and that low speed timer values will always be larger than high speed timer values.

To calculate the rain rate from the timer value use the following table

Timer Selection Bit	0.01 inch Rain Collector Rate (in/hr)	Range (in/hr)	0.2 mm Rain Collector Rate (mm/hr)	Range (mm/hr)
0 (high speed)	288 / (Timer count)	288.0 – 0.56	5760 / (Timer count)	5760.0 – 11.27
1 (low speed)	18 / (Timer count)	(18.0 –) 0.56 – 0.035	360 / (Timer count)	(360.0 –) 11.27 – 0.71

Method of calculation

Under normal conditions (see packet sequencing below) rain rate data is sent with a nominal interval of 10 seconds. Every time a rain tip occurs, a new rain rate value is computed (from the timer values) and the rate timers are reset to zero.

If one or more rain tips have occurred since the last rate packet was sent, the highest rate (i.e. shortest interval) is sent.

If there have been no rain tips in the preceding interval, then either the last rain interval, or the interval since the last rain tip is sent, whichever is longer. This results in slowly decaying rate values as a rain storm ends, instead of holding a higher rate value which drops suddenly to 0 when the 17 minute timer expires.

Special Values

When there have been no rain tips in the last 17 minutes and 4 seconds, the rain rate data value 0x3FF (low speed timer with a count value of 511) is sent. This should be displayed as a rain rate of 0.0.
When the first rain tip occurs, the rain rate data value 0x3FE (low speed timer with a count value of 510) is sent until the next rain tip. This should be displayed as a rate of 0.01 in/hr.

Rain Rate filtering

In order to protect against rain bursts apparently associated with lighting storms reported by customers, all rain clicks, and rate calculations, are validated before they are accepted. In order for a click to be valid, it must be proceeded and followed by and interval of at least 7/16 second with no other clicks.

When a rain click occurs, the rate timers are saved, but not reset (if they are active), and a validation timer is started. If the validation timer expires without any further rain clicks, the rain total is incremented, the saved rate is recorded and the rate timers are initialized to the value of the validation timer.
If a rain click occurs during the validation interval, the clicks are considered invalid, and the rain total is not incremented. The validation timer is reset, and must expire before we can allow any rain clicks to be considered valid.

The rain rate timers remain active during a rain burst event, and will correctly calculate the time interval between valid rain clicks, even if there is an intervening rain burst.

There can be slight anomalies in the rain rate data if a rate packet is sent during a validation interval. In this case, the data sent is based on the time interval since the last valid click, instead of the click that has already happened, but hasn't been validated yet. The maximum amount of error is 3/8 second, or 2 seconds if the low speed timer is active.

Battery Level

The battery level value uses 2 bits to provide 4 levels of battery status. Originally, on the SensorLink transmitter, the battery voltage was read by the A/D chip to determine the level. Unfortunately, this did not work very well. As a result, the ISS uses a power monitor chip to determine the battery state.
A value of 0 indicates a working battery.
A value of 3 indicates a low battery.
Values of 1 and 2 are not used, but if encountered, should be treated as low battery conditions.

The alternate form of the Temperature packet, used by Temp Only TX and Temp/Hum TX station, encodes the battery state in the least significant bit of the wind direction field. The value has the same polarity as the 2 bit version:
A value of 0 indicates a working battery.
A value of 1 indicates a low battery.

Maximum Wind data

Once every 50 seconds, the Maximum wind data packet is sent which contains the speed and direction of the fastest wind over the previous 12.5 – 15 minutes. In order to fit this data into one data packet, both wind direction values are sent as 4 bit sector codes, instead of as 10 bit A/D values. These sector codes are calculated by using the 4 most significant bits of the A/D reading. If the 5'th most significant bit is a 1, the 4 bit sector code is incremented by one (i.e. we are rounding the A/D reading to 4 bits).

As wind speed measurements are made in the course of sending packets, a "current" maximum value and direction is kept. We also keep a table of the past 10 maximum values.

When the Max Wind packet is sent, the value in the "current" max entry is fixed and added to the top of the table (at index 0). All the previous entries are shifted by one (the oldest one being dropped off the end). After this, the table is searched for the largest value. The index of the largest value is the "age" of the maximum wind speed, with ties decided in favor of the most recent entry. The age parameter is also included in the data packet.

Communication protocol

The communication protocol is the same whether the ISS is a wired or radio unit.

Baud Rate: 4800
Data Bits: 8
Parity: None
Start Bits: 1
Stop Bits: 1
Logic Levels: Non inverted (LOW = 0, HIGH = 1)

Data Packet Formats

Each packet consists of 6 bytes. The packet format allows up to 16 different packet types, but only 8 are used on this ISS.

Packet ID's

Packet ID assignments

ID #	Packet Type	ISS Use	ID #	Packet Type	ISS Use
0	Message Data		8	Temperature	*
1			9	Max Wind	*
2			10	Outside Humidity	*
3	Inside Temperature		11	Barometer	
4	UV Data	*	12	Humidity Cal #	*
5	Rain Rate	*	13	Average Wind Speed	
6	Solar Radiation	*	14	Rain / Battery	*
7	Inside Humidity		15	Extended Data Packet	(*)

Packet ID's not used by the ISS are used by the Echo, or by future transmitter products.
ID 0 is for use when instructions, or commands, are transmitted. ID 15 is for extra sensor data.

Common elements

The following elements are found in all of the ISS data packets, except the Max Wind packet.

	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Byte 0	1	4 bit packet ID				3 bit Unit ID		
Byte 1	8 bit Wind Speed data							
Byte 2	8 bit Wind Direction Data							
Byte 3	Packet Specific data							
Byte 4	Packet data				CRC <11 – 8>			
Byte 5	CRC bits <7 – 0>							

Tier 1 Packets

These data packets are sent every 10 seconds

Temperature Packet

	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Byte 0	1	1	0	0	0	3 bit Unit ID		
Byte 1	8 bit Wind Speed data							
Byte 2	8 bit Wind Direction data							
Byte 3	Temperature Data bits <11 – 4>							
Byte 4	Temp Data <1-0>		Temp Data <3-2>		CRC <11 – 8>			
Byte 5	CRC bits <7 – 0>							

Temperature Packet – Temp only Tx or Temp/Hum Tx

	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Byte 0	1	1	0	0	0	3 bit Unit ID		
Byte 1	8 bit Wind Speed data (0)							
Byte 2	7 bit Wind Direction data (0)							Batt Stat
Byte 3	Temperature Data bits <11 – 4>							
Byte 4	Temp Data <1-0>		Temp Data <3-2>		CRC <11 – 8>			
Byte 5	CRC bits <7 – 0>							

Rain / Battery Packet

	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Byte 0	1	1	1	1	0	3 bit Unit ID		
Byte 1	8 bit Wind Speed data							
Byte 2	8 bit Wind Direction data							
Byte 3	R Reset	Rain Count Data <6 – 0>						
Byte 4	0	Wsp State	Battery Status		CRC <11 – 8>			
Byte 5	CRC bits <7 – 0>							

Rain Rate Packet

	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Byte 0	1	0	1	0	1	3 bit Unit ID		
Byte 1	8 bit Wind Speed data							
Byte 2	8 bit Wind Direction data							
Byte 3	Rain Rate Counter bits <7 – 0>							
Byte 4	0	Wsp State	Rate Timer Selection	Rate <8>	CRC <11 – 8>			
Byte 5	CRC bits <7 – 0>							

Tier 2 Packets

These data packets are sent every 50 seconds

Hum Cal Packet

	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Byte 0	1	1	1	0	0	3 bit Unit ID		
Byte 1	8 bit Wind Speed data							
Byte 2	8 bit Wind Direction data							
Byte 3	Humidity Cal Data bits <7 – 0>							
Byte 4	0	Wsp State	Hum Cal<9 – 8>		CRC <11 – 8>			
Byte 5	CRC bits <7 – 0>							

Humidity Packet

	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Byte 0	1	1	0	1	0	3 bit Unit ID		
Byte 1	8 bit Wind Speed data							
Byte 2	8 bit Wind Direction data							
Byte 3	Humidity Data bits <7 – 0>							
Byte 4	0	Wsp State	Hum <9 – 8>		CRC <11 – 8>			
Byte 5	CRC bits <7 – 0>							

Solar Radiation Packet

	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Byte 0	1	0	1	1	0	3 bit Unit ID		
Byte 1	8 bit Wind Speed data							
Byte 2	8 bit Wind Direction data							
Byte 3	Solar Rad Data bits <11 – 4>							
Byte 4	Sun <1 – 0>		Sun <3 – 4>		CRC <11 – 8>			
Byte 5	CRC bits <7 – 0>							

UV Radiation Packet

	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Byte 0	1	0	1	0	0	3 bit Unit ID		
Byte 1	8 bit Wind Speed data							
Byte 2	8 bit Wind Direction data							
Byte 3	UV Radiation Data bits <9 – 2>							
Byte 4	0	Wsp State	UV <0 – 1>		CRC <11 – 8>			
Byte 5	CRC bits <7 – 0>							

Max Wind Packet

	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Byte 0	1	1	0	0	1	3 bit Unit ID		
Byte 1	8 bit Wind Speed data							
Byte 2	Wind Direction Sector				Max Wind Direction Sector			
Byte 3	8 bit Max Wind Speed data							
Byte 4	Age of Max Wind				CRC <11 – 8>			
Byte 5	CRC bits <7 – 0>							

Other Data Packets

These data packets are not part of the regular ISS packet stream, but are used by other "Davis Talk" devices. The Device ID packet is the first packet sent by the ISS when it is powered up. Afterwards, the normal packet sequence is used.

Inside Humidity Packet

	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Byte 0	1	0	1	1	1	3 bit Unit ID		
Byte 1	8 bit Wind Speed data							
Byte 2	8 bit Wind Direction data							
Byte 3	Inside Humidity Data bits <7 – 0>							
Byte 4	0	0	In Hum <9-8>		CRC <11 – 8>			
Byte 5	CRC bits <7 – 0>							

Barometer Packet

	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Byte 0	1	1	0	1	1	3 bit Unit ID		
Byte 1	8 bit Wind Speed data							
Byte 2	Wind Direction Sector				Barometer Data bits <3 – 0>			
Byte 3	Barometer Data bits <15 – 8>							
Byte 4	Barometer Data bits <7 – 4>				CRC <11 – 8>			
Byte 5	CRC bits <7 – 0>							

Average Wind Speed Packet

	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Byte 0	1	1	1	0	1	3 bit Unit ID		
Byte 1	8 bit Wind Speed data							
Byte 2	Wind Direction Sector				Average Wind data <3 – 0>			
Byte 3	???				Average Wind Direction Sector			
Byte 4	Average Wind data <7 – 4>				CRC <11 – 8>			
Byte 5	CRC bits <7 – 0>							

Inside Temp Packet
Provisional packet definition for re-transmitting Inside Temp from a vantage console

	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Byte 0	1	1	0	1	1	3 bit Unit ID		
Byte 1	8 bit Wind Speed data							
Byte 2	Wind Direction Sector				Temp Data F x10 bits <3 – 0>			
Byte 3	Temp Data F x10 bits <15 – 8>							
Byte 4	Temp Data F x10 bits <7 – 4>				CRC <11 – 8>			
Byte 5	CRC bits <7 – 0>							

Message Packets

Message Packet

	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Byte 0	1	0	0	0	0	3 bit Unit ID		
Byte 1								
Byte 2								
Byte 3								
Byte 4					CRC <11 – 8>			
Byte 5	CRC bits <7 – 0>							

Extra Data Packets

This packet ID is used for sending non-standard data. For example future sensors or additional sensors on the same transmitter. In most cases, no Wind speed or direction data is included because we need the space to indicate what type of data the packet contains. First we give the general format of the packet, then examples of the currently defined sub-types. Only packets in use by current products are given in detail.

Extra Data Packet

	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Byte 0	1	1	1	1	1	3 bit Unit ID		
Byte 1	Sensor ID				Sensor Type			
Byte 2	Data							
Byte 3	Data							
Byte 4	Data		Data		CRC <11 – 8>			
Byte 5	CRC bits <7 – 0>							

Sensor Type ID assignments

ID #	Sensor Type	ID #	Sensor Type
0	Transmitter Identification	16	
1	Extra Wind Sensor	17	
2	Extra Temperature Sensor	18	
3	Extra Hum Sensor	19	
4	Extra Rain Sensor	20	
5	Extra UV Sensor	21	No Data
6	Extra Solar Rad Sensor	22	
7		23	
8		24	
9	Soil Moisture/Temp	25	
10	Leaf Wetness/Temp	26	
11		27	
12		28	
13		29	
14		30	
15		31	

Transmitter Identification Packet

	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Byte 0	1	1	1	1	1	3 bit Unit ID		
Byte 1	Not Used (000)				Sensor Type = 0			
Byte 2	Code Page				Transmitter Type			
Byte 3	Transmitter Version					Transmitter Sub-version		
Byte 4	5 = 0101				CRC <11 – 8>			
Byte 5	CRC bits <7 – 0>							

Transmitter Type ID assignments

ID #	Transmitter Type
0	Sensor Link Tx
1	Repeater
2	Console Link Tx
3	ISS
4	Soil Moisture Tx
5	Leaf Wetness Tx
6	Temp-Only Tx
7	Temp-Hum Tx
8	Leaf-Soil Tx
9	

Code Page indicates where in memory the code is installed.

Soil Moisture Packet

	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Byte 0	1	1	1	1	1	3 bit Unit ID		
Byte 1	Sensor ID			Sensor Type = 9 = 01001				
Byte 2	Soil Moisture data <9 – 2>							
Byte 3	Temperature data <9 – 2>							
Byte 4	Soil <1 – 0>		Temp <1 – 0>		CRC <11 – 8>			
Byte 5	CRC bits <7 – 0>							

Leaf Wetness Packet

	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Byte 0	1	1	1	1	1	3 bit Unit ID		
Byte 1	Sensor ID			Sensor Type = 10 = 01010				
Byte 2	Leaf Wetness data <9 – 2>							
Byte 3	Temperature data <9 – 2>							
Byte 4	Leaf <1 – 0>		Temp <1 – 0>		CRC <11 – 8>			
Byte 5	CRC bits <7 – 0>							

No Data Packet (used by repeater when received packet is missing)

	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Byte 0	1	1	1	1	1	3 bit Unit ID		
Byte 1	Sensor ID = 0			Sensor Type = 21 = 10101				
Byte 2	0x55							
Byte 3	0x55							
Byte 4	5 = 0101				CRC <11 – 8>			
Byte 5	CRC bits <7 – 0>							

Packet Sequencing

The ISS has two modes of operation, Normal Mode and Single Sensor Mode. Single Sensor mode is only used for testing and sensor calibration and is described in more detail below.

Packet Intervals

Although the nominal time interval between packets is 2.5 seconds, this is only true if the unit ID equals 0. For other Unit ID's the packet interval is longer to help diminish the number of collisions if multiple transmitters are in operation. This table shows the exact packet intervals for each Unit ID and the time interval between two packets of the same type. Tier 1 and Tier 2 are defined in the next section. Also shown is the time over which the Maximum Wind data is sampled.

Packet Interval Table

Unit ID	Packet Interval	Tier 1 Interval	Tier 2 Interval	Max Speed Interval
0	2.5 sec	10.0 sec	50 sec	8 min 20 sec
1	2.5625 sec	10.25 sec	51.25 sec	8 min 32 sec
2	2.625 sec	10.5 sec	52.5 sec	8 min 45 sec
3	2.6875 sec	10.75 sec	53.75 sec	8 min 58 sec
4	2.75 sec	11.0 sec	55.0 sec	9 min 10 sec
5	2.8125 sec	11.25 sec	56.25 sec	9 min 22 sec
6	2.875 sec	11.5 sec	57.5 sec	9 min 35 sec
7	2.9375 sec	11.75 sec	58.75 sec	9 min 48 sec

Normal Mode Packet Sequencing

The data packets have been divided into two groups based on how frequently their data should be reported. There are 3 Tier 1 data packets that are sent every 10 seconds, along with one Tier 2 packet. There are 5 Tier 2 packets that are sent every 50 seconds. The tables below show the order that the packets are sent.

When the unit is powered up, a single Transmitter Identification Packet is sent before the normal operation packet. This is used primarily by manufacturing test and calibration fixtures to determine what tests to run on the device.

Tier 1 Packets

Sequence #	Packet Type	Measurement Interval	Notes
1	Temperature	10 sec	Measured every time this packet is sent.
2	Rain / Batt	10 sec	Measured every time this packet is sent.
3	Rain Rate	10 sec	Highest value since last rate packet
4	Next Tier 2 Packet		

Tier 2 Packets

Sequence #	Packet Type	Measurement Interval	Notes
1	Hum Cal	50 min	Measured every 60'th Hum Cal Packet
2	Humidity	50 sec	Measured when a Hum Cal packet is sent.
3	Solar Rad	50 sec	Both Solar and UV are read at the same time. See below for information on Solar and UV power saving operations
4	UV	50 sec	
5	Max Wind	50 sec	

Single Sensor Packet Sequencing

Single Sensor Mode allows testing and debugging of single sensor information. Since we are in a test mode, we are assuming that the unit has an adequate power supply for a faster than normal packet interval. Instead of a uniform packet interval, the interval depends on the amount of time it takes to measure the selected data values. As in Normal Mode, an additional (Unit ID * 1/16'th) second should be added to the nominal packet interval.

Wind Direction data is valid for all Single Sensor modes, but Wind Speed data is only valid in Wind Speed Mode. Other than for wind speed, all data in a packet is measured every time a packet is sent. In Humidity single sensor mode, both Hum and Hum Cal are measured for every packet. In the Solar and UV single sensor modes, both Solar rad and UV are measured for every packet.

In the Humidity and Rain Single Sensor modes, two packets types are alternated, as given in the following table. For all other single sensor modes, the same packet is sent every time.

To set a single sensor mode, send the character given in the table (either uppercase or lowercase is OK) to the wired input jack. The format is the same as the data transmitted by the ISS (i.e. 4800 baud, 8 data bits, no parity, 1 stop bit, Logic HIGH = 1, etc.).

Single Sensor Mode operation

Command Character	Sensor	Nominal Packet Interval	Packets sent
T	Temperature	0.5 sec	Temperature
H	Humidity	0.625 sec	Humidity, Hum Cal
R	Rain	0.5 sec	Rain/Batt, Rain Rate
W	Wind Speed	1.5 sec	Rain/Batt

S	Solar Radiation	2.5 sec	Solar Rad
U	UV Radiation	2.5 sec	UV
N	Normal Operation	2.5 sec.	All
@	Radio Test Mode	---	"U" (0x55) transmitted continuously

Normal Mode Packet Sequencing for Temp TX and Temp/Hum TX

For the Temperature Only TX station and Temperature/Humidity TX station, packets are only sent at a nominal interval of 10 seconds.

For the Temperature Only TX station, only Temperature packets are sent, after the initial Transmitter ID packet. These packets are the alternate form that encodes the battery status in the lowest bit of the wind direction data.

The only Single-Sensor commands recognized by the Temp Only TX are: "T", "N", and "@".

For the Temp/Hum TX station, the following packet sequence is used:
Temperature, Hum Cal, Temperature, Humidity, Temperature, Humidity, Repeat

The temperature packets in the above sequence are all the alternate form that includes the battery status in the least significant bit of the wind direction. Hum measurements are taken when the Hum Cal packet is sent (every 60-70.5 seconds). Hum Cal is measured every 60 Hum measurements (every 60-70.5 minutes).

The only Single-Sensor commands recognized by the Temp/Hum TX are: "T", "H", "N", and "@".

Normal Mode Packet Sequencing for Leaf/Soil TX

The Leaf/Soil unit has three soil moisture sensors, three temperature sensors, and two leaf sensors. The first two temperature sensors are transmitted as both “soil temperature” and “leaf temperature” values. The Rain packet is transmitted so that the console can keep track of the battery status.

Packet Sequence:
Soil 0/Temperature 0 Soil 1/Temp 1 Soil 2/Temp 2 Leaf 0/Temp 0 Leaf 1/Temp 1 Rain/Battery

Calculations of Derived Variables

The following parameters do not have any sensors or circuitry. They are calculated from measured variables. Any conditions that affect the functions of the measurements that are used to calculate these variables will affect the readings of these variables. This includes the Setup Screen settings.

Note: In each case unless otherwise noted, the software uses the exact formula and the console uses a lookup table that closely approximates the formula.

Wind Chill

Parameters Used: Outside Air Temperature and Wind Speed

What is it:
Wind chill takes into account how the speed of the wind affects our perception of the air temperature. Our bodies warm the surrounding air molecules by transferring heat from the skin. If there's no air movement, this insulating layer of warm air molecules stays next to the body and offers some protection from cooler air molecules. However, wind sweeps that comfy warm air surrounding the body away. The faster the wind blows, the faster heat is carried away and the colder the environment feels.

The new formula was adopted by both Environment Canada and the U.S. National Weather Service to ensure a uniform wind chill standard in North America. The formula is supposed to more closely emulate the response of the human body when exposed to conditions of wind and cold than the old formula did.

Formulas:
Older versions of software (Versions 5.0 and earlier) and firmware (Vantage firmware revisions before Sept. 7, 2001 and all non-Vantage products including Echo) are based on the following formula (Siple and Passel, 1945):

$$0.0817 * (3.71V^{0.5} + 5.81 - 0.25V) * (T - 91.4) + 91.4$$

where V is the wind speed in mph and T is the outside air temperature in °F. Wind speeds above 55 mph are set to 55 mph. For wind speeds below 5 mph or temperatures above 91.4°F, the wind chill is set equal to the air temperature.

Newer product revisions (WeatherLink version 5.1 and Vantage Pro consoles with Sept 7, 2001 firmware and later) are based on the following formula:

$$35.74 + 0.6215T - 35.75 * (V^{0.16}) + 0.4275T * (V^{0.16})$$

As with the old formula, any place where the result yields a wind chill temperature greater than the air temperature, the wind chill is set equal to the air temperature. This always occurs at wind speeds of 0 mph or temperatures above 76°F. This also occurs at lower wind speeds with temperatures between 0°F and 76°F.

The new formula takes into account the fact that wind speeds are measured "officially" at 10 meters (33 feet) above the ground, but the human is typically only 5 to 6 feet (2 meters) above the ground. So, anemometers still need to be mounted as high as possible (e.g., rooftop mast) to register comparable wind speed readings and wind chill values.

The Vantage Pro console uses the "10-minute average wind speed" to determine wind chill, which is updated once per minute. When 10-minute of wind speed data is unavailable, it uses a running average until 10-minutes worth of data is collected. The Vantage Pro software uses the 10-minute average wind speed also. If it is unavailable, it uses the current wind speed (which updates every 2.5 to 3 seconds). All other products use the current wind speed to determine wind chill.

The reason an average wind speed is employed in the Vantage Pro to calculate wind chill is as follows: The human body has a high heat capacity, thus high wind speeds have no effect on the body's thermal equilibrium. So, an average wind speed provides a more accurate representation of the body's response than an instantaneous reading. Also, "official" weather reports (from which wind chill is calculated) provide average wind speed, so using an average wind speed more closely matches the results that are seen in weather reports.

REFERENCES

"Media Guide to NWS Products and Services", National Weather Service Forecast Office, Monterey, CA, 1995.

"New Wind Chill Temperature Index", Office of Climate, Water and Weather Services, Washington, DC, 2001.

Siple, P. and C. Passel, 1945. Measurements of Dry Atmospheric Cooling in Subfreezing Temperatures. *Proc. Amer. Philos. Soc.*

Heat Index

Parameters Used: Outside Air Temperature and Outside Humidity

What is it:
Heat Index uses temperature and relative humidity to determine how hot the air actually “feels.” When humidity is low, the apparent temperature will be lower than the air temperature, since perspiration evaporates rapidly to cool the body. However, when humidity is high (i.e., the air is saturated with water vapor) the apparent temperature “feels” higher than the actual air temperature, because perspiration evaporates more slowly.

Formulas:
Older versions of software and the display console using the following methodology. This formula is based upon the lookup table presented by Steadman (1979). The Davis implementation simply extends the range of use of this table to make it usable at temperatures beyond the scope of the table. Some of this extension is based on the table adapted by the US National Weather Service. The GroWeather and EnviroMonitor systems do not display a value beyond the scope of the Steadman table. All other products that display this value either:

- Set values at temperatures below the scope of the table to the air temperature
- Extend the readings using a best-curve fit above and below the air temperature scope of the table. The low temperature cutoff is when the heat index for the given combination of temperature and humidity is 14°C or 57.2°F or below. This corresponds to a vapor pressure of 16 hPa. Heat Indices are set equal to the air temperature or 57.2°F, whichever is less, below these values. (The 14°C cutoff corresponds to the equivalent dewpoint at average testing laboratory conditions.)

WeatherLink software version 5.2 uses the above methodology with the following exceptions for values below an air temperature of 68°F:

- The values use a variable baseline to which the Heat Index is either above or below the air temperature.
- The values are loosely derived from the methodology outlined by Steadman in his 1998 paper (referenced below). Thus, air temperatures below 50°F follow this 1998 procedure. Air temperatures above 68°F follow his procedure outlined in 1979 (since the US NWS continues to use this). Davis has made a smooth transition between the two methods between 50°F and 68°F.

The formula Davis uses is also used by the US National Weather Service. Heat Index can also be used to determine indoor comfort levels.

The following table is used for the software. The console table only differs in that whole degrees are used for memory space conservation. Blank spaces indicate where the value is undetermined. Filler numbers have been substituted in some cases to indicate that the Heat Index is very high at these values.

Note: Heat Index has also been referred to as "Temperature-Humidity Index" and "Thermal Index" in some Davis products.

Heat Index Console Table

Air Temp (ºF)	Relative Humidity %									
	0	10	20	30	40	50	60	70	80	90	100
57	57	57	57	57	57	57	57	57	57	57	57
58	57	57	57	57	57	57	57	57	57	57	58
59	57	57	57	57	57	57	57	57	57	58	59
60	57	57	57	57	57	57	57	58	59	59	60
61	57	57	57	57	57	57	58	59	60	60	61
62	57	57	57	57	58	58	59	60	61	62	62
63	57	57	57	58	59	60	60	61	62	63	64
64	57	57	58	59	60	61	61	62	63	64	65
65	58	58	59	60	61	62	63	63	64	65	66
66	59	60	60	61	62	63	64	65	66	66	67
67	60	61	62	62	63	64	65	66	67	68	68
68	61	63	63	64	66	66	68	68	70	70	70
69	63	64	65	65	67	67	69	69	71	71	72
70	65	65	66	66	68	68	70	70	72	72	74
71	66	66	67	67	69	69	71	71	73	73	75
72	67	67	68	69	70	71	72	72	74	74	76
73	68	68	69	71	71	73	73	74	75	75	77
74	69	69	70	72	72	74	74	76	76	76	78
75	70	71	71	73	73	75	75	77	77	78	79
76	71	72	73	74	74	76	76	78	79	80	80
77	72	73	75	75	75	77	77	79	81	81	82
78	74	74	76	76	77	78	79	80	82	83	84
79	75	75	77	77	79	79	81	81	83	85	87
80	76	76	78	78	80	80	82	83	85	87	90
81	77	77	79	79	81	81	83	85	87	89	93
82	78	78	80	80	82	83	84	87	89	92	96
83	79	79	81	81	83	85	85	89	91	95	99
84	79	80	81	82	84	86	87	91	94	98	103
85	80	81	81	83	85	87	89	93	97	101	108
86	81	82	82	84	86	88	91	95	99	104	113
87	82	83	83	85	87	90	93	97	102	109	120
88	83	84	84	86	88	92	95	99	105	114	131
89	84	84	85	87	90	94	97	102	109	120	144
90	84	85	86	89	92	95	99	105	113	128	146
91	84	86	87	91	93	96	101	108	118	136	
92	85	87	88	92	94	98	104	112	124	144	
93	86	88	89	93	96	100	107	116	130	143	
94	87	89	90	94	98	102	110	120	137		
95	88	90	91	95	99	104	113	124	142		
96	89	91	93	97	101	107	117	128			
97	90	92	95	99	103	110	121	132			
98	90	93	96	100	105	113	125	137			
99	90	94	97	101	107	116	129	140			
100	91	95	98	103	110	119	133	145			
101	92	96	99	105	112	122	137				
102	93	97	100	106	114	125	142				
103	94	98	102	107	117	128	148				
104	95	99	104	109	120	132	153				
105	95	100	105	111	123	136					
106	95	101	106	113	126	139					
107	96	102	107	115	130	143					
108	97	103	108	117	133	146					
109	98	104	110	119	137						
110	99	105	112	122	142						
111	100	106	113	125	147						
112	100	107	115	128	153						
113	100	108	117	131	158						
114	101	109	119	134							
115	102	110	121	136							
116	103	111	123	140							

Air Temp (ºF)	Relative Humidity %									
	0	10	20	30	40	50	60	70	80	90	100
117	104	112	125	143							
118	105	113	127	146							
119	106	114	129	150							
120	107	116	131	154							
121	108	117	132								
122	108	118	134								
123	108	120	136								
124	110	122	138								
125	111	123	139								
126	112	125	140								
127	113	126	142								
128	115	128	144								
129	116	129	145								
130	117	131	147								
131	118	133									
132	118	134									
133	119	136									
134	119	137									
135	120	139									
136	121	141									
137	122	143									
138	123	146									
139	124	148									
140	125	151									

Heat Index Software Table

Air	Relative Humidity %																				
Temp (°F)	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100
-57	-57.0	-57.0	-57.0	-57.0	-57.0	-57.0	-57.0	-57.0	-57.0	-57.0	-57.0	-57.0	-57.0	-57.0	-57.0	-57.0	-57.0	-57.0	-57.0	-57.0	-57.0
-56	-56.1	-56.0	-56.0	-56.0	-56.0	-56.0	-56.0	-56.0	-56.0	-56.0	-56.0	-56.0	-56.0	-56.0	-56.0	-56.0	-56.0	-56.0	-56.0	-56.0	-56.0
-55	-55.1	-55.1	-55.0	-55.0	-55.0	-55.0	-55.0	-55.0	-55.0	-55.0	-55.0	-55.0	-55.0	-55.0	-55.0	-55.0	-55.0	-55.0	-55.0	-55.0	-55.0
-54	-54.1	-54.1	-54.1	-54.0	-54.0	-54.0	-54.0	-54.0	-54.0	-54.0	-54.0	-54.0	-54.0	-54.0	-54.0	-54.0	-54.0	-54.0	-54.0	-54.0	-54.0
-53	-53.1	-53.1	-53.1	-53.0	-53.0	-53.0	-53.0	-53.0	-53.0	-53.0	-53.0	-53.0	-53.0	-53.0	-53.0	-53.0	-53.0	-53.0	-53.0	-53.0	-53.0
-52	-52.1	-52.1	-52.1	-52.1	-52.0	-52.0	-52.0	-52.0	-52.0	-52.0	-52.0	-52.0	-52.0	-52.0	-52.0	-52.0	-52.0	-52.0	-52.0	-52.0	-52.0
-51	-51.1	-51.1	-51.1	-51.1	-51.1	-51.0	-51.0	-51.0	-51.0	-51.0	-51.0	-51.0	-51.0	-51.0	-51.0	-51.0	-51.0	-51.0	-51.0	-51.0	-51.0
-50	-50.1	-50.1	-50.1	-50.1	-50.1	-50.0	-50.0	-50.0	-50.0	-50.0	-50.0	-50.0	-50.0	-50.0	-50.0	-50.0	-50.0	-50.0	-50.0	-50.0	-50.0
-49	-49.1	-49.1	-49.1	-49.1	-49.1	-49.1	-49.0	-49.0	-49.0	-49.0	-49.0	-49.0	-49.0	-49.0	-49.0	-49.0	-49.0	-49.0	-49.0	-49.0	-49.0
-48	-48.1	-48.1	-48.1	-48.1	-48.1	-48.1	-48.0	-48.0	-48.0	-48.0	-48.0	-48.0	-48.0	-48.0	-48.0	-48.0	-48.0	-48.0	-48.0	-48.0	-48.0
-47	-47.1	-47.1	-47.1	-47.1	-47.1	-47.1	-47.1	-47.0	-47.0	-47.0	-47.0	-47.0	-47.0	-47.0	-47.0	-47.0	-47.0	-47.0	-47.0	-47.0	-47.0
-46	-46.1	-46.1	-46.1	-46.1	-46.1	-46.1	-46.1	-46.1	-46.0	-46.0	-46.0	-46.0	-46.0	-46.0	-46.0	-46.0	-46.0	-46.0	-46.0	-46.0	-46.0
-45	-45.1	-45.1	-45.1	-45.1	-45.1	-45.1	-45.1	-45.1	-45.0	-45.0	-45.0	-45.0	-45.0	-45.0	-45.0	-45.0	-45.0	-45.0	-45.0	-45.0	-45.0
-44	-44.1	-44.1	-44.1	-44.1	-44.1	-44.1	-44.1	-44.1	-44.1	-44.0	-44.0	-44.0	-44.0	-44.0	-44.0	-44.0	-44.0	-44.0	-44.0	-44.0	-44.0
-43	-43.1	-43.1	-43.1	-43.1	-43.1	-43.1	-43.1	-43.1	-43.1	-43.0	-43.0	-43.0	-43.0	-43.0	-43.0	-43.0	-43.0	-43.0	-43.0	-43.0	-43.0
-42	-42.1	-42.1	-42.1	-42.1	-42.1	-42.1	-42.1	-42.1	-42.1	-42.0	-42.0	-42.0	-42.0	-42.0	-42.0	-42.0	-42.0	-42.0	-42.0	-42.0	-42.0
-41	-41.1	-41.1	-41.1	-41.1	-41.1	-41.1	-41.1	-41.1	-41.1	-41.1	-41.0	-41.0	-41.0	-41.0	-41.0	-41.0	-41.0	-41.0	-41.0	-41.0	-41.0
-40	-40.1	-40.1	-40.1	-40.1	-40.1	-40.1	-40.1	-40.1	-40.1	-40.1	-40.0	-40.0	-40.0	-40.0	-40.0	-40.0	-40.0	-40.0	-40.0	-40.0	-40.0
-39	-39.1	-39.1	-39.1	-39.1	-39.1	-39.1	-39.1	-39.1	-39.1	-39.1	-39.1	-39.0	-39.0	-39.0	-39.0	-39.0	-39.0	-39.0	-39.0	-39.0	-39.0
-38	-38.1	-38.1	-38.1	-38.1	-38.1	-38.1	-38.1	-38.1	-38.1	-38.1	-38.1	-38.0	-38.0	-38.0	-38.0	-38.0	-38.0	-38.0	-38.0	-38.0	-38.0
-37	-37.1	-37.1	-37.1	-37.1	-37.1	-37.1	-37.1	-37.1	-37.1	-37.1	-37.1	-37.0	-37.0	-37.0	-37.0	-37.0	-37.0	-37.0	-37.0	-37.0	-37.0
-36	-36.1	-36.1	-36.1	-36.1	-36.1	-36.1	-36.1	-36.1	-36.1	-36.1	-36.1	-36.1	-36.0	-36.0	-36.0	-36.0	-36.0	-36.0	-36.0	-36.0	-36.0
-35	-35.1	-35.1	-35.1	-35.1	-35.1	-35.1	-35.1	-35.1	-35.1	-35.1	-35.1	-35.1	-35.0	-35.0	-35.0	-35.0	-35.0	-35.0	-35.0	-35.0	-35.0
-34	-34.1	-34.1	-34.1	-34.1	-34.1	-34.1	-34.1	-34.1	-34.1	-34.1	-34.1	-34.1	-34.1	-34.0	-34.0	-34.0	-34.0	-34.0	-34.0	-34.0	-34.0
-33	-33.1	-33.1	-33.1	-33.1	-33.1	-33.1	-33.1	-33.1	-33.1	-33.1	-33.1	-33.1	-33.1	-33.0	-33.0	-33.0	-33.0	-33.0	-33.0	-33.0	-33.0
-32	-32.1	-32.1	-32.1	-32.1	-32.1	-32.1	-32.1	-32.1	-32.1	-32.1	-32.1	-32.1	-32.1	-32.0	-32.0	-32.0	-32.0	-32.0	-32.0	-32.0	-32.0
-31	-31.1	-31.1	-31.1	-31.1	-31.1	-31.1	-31.1	-31.1	-31.1	-31.1	-31.1	-31.1	-31.1	-31.0	-31.0	-31.0	-31.0	-31.0	-31.0	-31.0	-31.0
-30	-30.1	-30.1	-30.1	-30.1	-30.1	-30.1	-30.1	-30.1	-30.1	-30.1	-30.1	-30.1	-30.1	-30.1	-30.0	-30.0	-30.0	-30.0	-30.0	-30.0	-30.0
-29	-29.2	-29.1	-29.1	-29.1	-29.1	-29.1	-29.1	-29.1	-29.1	-29.1	-29.1	-29.1	-29.1	-29.1	-29.0	-29.0	-29.0	-29.0	-29.0	-29.0	-29.0
-28	-28.2	-28.2	-28.1	-28.1	-28.1	-28.1	-28.1	-28.1	-28.1	-28.1	-28.1	-28.1	-28.1	-28.1	-28.0	-28.0	-28.0	-28.0	-28.0	-28.0	-28.0
-27	-27.2	-27.2	-27.1	-27.1	-27.1	-27.1	-27.1	-27.1	-27.1	-27.1	-27.1	-27.1	-27.1	-27.1	-27.0	-27.0	-27.0	-27.0	-27.0	-27.0	-27.0
-26	-26.2	-26.2	-26.2	-26.1	-26.1	-26.1	-26.1	-26.1	-26.1	-26.1	-26.1	-26.1	-26.1	-26.1	-26.1	-26.0	-26.0	-26.0	-26.0	-26.0	-26.0
-25	-25.2	-25.2	-25.2	-25.2	-25.1	-25.1	-25.1	-25.1	-25.1	-25.1	-25.1	-25.1	-25.1	-25.1	-25.1	-25.0	-25.0	-25.0	-25.0	-25.0	-25.0
-24	-24.2	-24.2	-24.2	-24.2	-24.2	-24.1	-24.1	-24.1	-24.1	-24.1	-24.1	-24.1	-24.1	-24.1	-24.1	-24.0	-24.0	-24.0	-24.0	-24.0	-24.0
-23	-23.2	-23.2	-23.2	-23.2	-23.2	-23.1	-23.1	-23.1	-23.1	-23.1	-23.1	-23.1	-23.1	-23.1	-23.1	-23.0	-23.0	-23.0	-23.0	-23.0	-23.0
-22	-22.2	-22.2	-22.2	-22.2	-22.2	-22.2	-22.1	-22.1	-22.1	-22.1	-22.1	-22.1	-22.1	-22.1	-22.1	-22.1	-22.0	-22.0	-22.0	-22.0	-22.0
-21	-21.2	-21.2	-21.2	-21.2	-21.2	-21.2	-21.1	-21.1	-21.1	-21.1	-21.1	-21.1	-21.1	-21.1	-21.1	-21.1	-21.0	-21.0	-21.0	-21.0	-21.0
-20	-20.2	-20.2	-20.2	-20.2	-20.2	-20.2	-20.2	-20.1	-20.1	-20.1	-20.1	-20.1	-20.1	-20.1	-20.1	-20.1	-20.0	-20.0	-20.0	-20.0	-20.0
-19	-19.2	-19.2	-19.2	-19.2	-19.2	-19.2	-19.2	-19.1	-19.1	-19.1	-19.1	-19.1	-19.1	-19.1	-19.1	-19.1	-19.0	-19.0	-19.0	-19.0	-19.0
-18	-18.2	-18.2	-18.2	-18.2	-18.2	-18.2	-18.2	-18.2	-18.1	-18.1	-18.1	-18.1	-18.1	-18.1	-18.1	-18.1	-18.0	-18.0	-18.0	-18.0	-18.0
-17	-17.2	-17.2	-17.2	-17.2	-17.2	-17.2	-17.2	-17.2	-17.1	-17.1	-17.1	-17.1	-17.1	-17.1	-17.1	-17.1	-17.0	-17.0	-17.0	-17.0	-17.0
-16	-16.3	-16.2	-16.2	-16.2	-16.2	-16.2	-16.2	-16.2	-16.2	-16.1	-16.1	-16.1	-16.1	-16.1	-16.1	-16.1	-16.1	-16.0	-16.0	-16.0	-16.0
-15	-15.3	-15.3	-15.2	-15.2	-15.2	-15.2	-15.2	-15.2	-15.2	-15.1	-15.1	-15.1	-15.1	-15.1	-15.1	-15.1	-15.1	-15.0	-15.0	-15.0	-15.0
-14	-14.3	-14.3	-14.3	-14.2	-14.2	-14.2	-14.2	-14.2	-14.2	-14.2	-14.1	-14.1	-14.1	-14.1	-14.1	-14.1	-14.1	-14.0	-14.0	-14.0	-14.0
-13	-13.3	-13.3	-13.3	-13.2	-13.2	-13.2	-13.2	-13.2	-13.2	-13.2	-13.1	-13.1	-13.1	-13.1	-13.1	-13.1	-13.1	-13.0	-13.0	-13.0	-13.0
-12	-12.3	-12.3	-12.3	-12.3	-12.2	-12.2	-12.2	-12.2	-12.2	-12.2	-12.2	-12.1	-12.1	-12.1	-12.1	-12.1	-12.1	-12.0	-12.0	-12.0	-12.0
-11	-11.3	-11.3	-11.3	-11.3	-11.3	-11.2	-11.2	-11.2	-11.2	-11.2	-11.2	-11.1	-11.1	-11.1	-11.1	-11.1	-11.1	-11.0	-11.0	-11.0	-11.0
-10	-10.3	-10.3	-10.3	-10.3	-10.3	-10.2	-10.2	-10.2	-10.2	-10.2	-10.2	-10.1	-10.1	-10.1	-10.1	-10.1	-10.1	-10.0	-10.0	-10.0	-10.0
-9	-9.3	-9.3	-9.3	-9.3	-9.3	-9.3	-9.2	-9.2	-9.2	-9.2	-9.2	-9.2	-9.1	-9.1	-9.1	-9.1	-9.1	-9.1	-9.0	-9.0	-9.0
-8	-8.4	-8.3	-8.3	-8.3	-8.3	-8.3	-8.3	-8.2	-8.2	-8.2	-8.2	-8.2	-8.1	-8.1	-8.1	-8.1	-8.1	-8.1	-8.0	-8.0	-8.0
-7	-7.4	-7.4	-7.3	-7.3	-7.3	-7.3	-7.3	-7.2	-7.2	-7.2	-7.2	-7.2	-7.1	-7.1	-7.1	-7.1	-7.1	-7.1	-7.0	-7.0	-7.0
-6	-6.4	-6.4	-6.4	-6.3	-6.3	-6.3	-6.3	-6.3	-6.2	-6.2	-6.2	-6.2	-6.2	-6.1	-6.1	-6.1	-6.1	-6.1	-6.0	-6.0	-6.0
-5	-5.4	-5.4	-5.4	-5.3	-5.3	-5.3	-5.3	-5.3	-5.2	-5.2	-5.2	-5.2	-5.2	-5.1	-5.1	-5.1	-5.1	-5.1	-5.0	-5.0	-5.0
-4	-4.4	-4.4	-4.4	-4.4	-4.3	-4.3	-4.3	-4.3	-4.3	-4.2	-4.2	-4.2	-4.2	-4.1	-4.1	-4.1	-4.1	-4.1	-4.0	-4.0	-4.0
-3	-3.4	-3.4	-3.4	-3.4	-3.4	-3.3	-3.3	-3.3	-3.3	-3.2	-3.2	-3.2	-3.2	-3.2	-3.1	-3.1	-3.1	-3.1	-3.0	-3.0	-3.0
-2	-2.5	-2.4	-2.4	-2.4	-2.4	-2.3	-2.3	-2.3	-2.3	-2.3	-2.2	-2.2	-2.2	-2.2	-2.1	-2.1	-2.1	-2.1	-2.0	-2.0	-2.0
-1	-1.5	-1.5	-1.4	-1.4	-1.4	-1.4	-1.3	-1.3	-1.3	-1.3	-1.2	-1.2	-1.2	-1.2	-1.1	-1.1	-1.1	-1.1	-1.0	-1.0	-1.0
0	-0.5	-0.5	-0.4	-0.4	-0.4	-0.4	-0.3	-0.3	-0.3	-0.3	-0.2	-0.2	-0.2	-0.2	-0.1	-0.1	-0.1	-0.1	0.0	0.0	0.0
1	0.5	0.5	0.5	0.6	0.6	0.6	0.6	0.7	0.7	0.7	0.7	0.8	0.8	0.8	0.8	0.9	0.9	0.9	0.9	1.0	1.0
2	1.5	1.5	1.5	1.5	1.6	1.6	1.6	1.7	1.7	1.7	1.7	1.8	1.8	1.8	1.8	1.9	1.9	1.9	1.9	2.0	2.0
3	2.4	2.5	2.5	2.5	2.6	2.6	2.6	2.6	2.7	2.7	2.7	2.7	2.8	2.8	2.8	2.9	2.9	2.9	2.9	3.0	3.0
4	3.4	3.4	3.5	3.5	3.5	3.6	3.6	3.6	3.7	3.7	3.7	3.7	3.8	3.8	3.8	3.9	3.9	3.9	3.9	4.0	4.0
5	4.4	4.4	4.5	4.5	4.5	4.5	4.6	4.6	4.6	4.7	4.7	4.7	4.8	4.8	4.8	4.8	4.9	4.9	4.9	5.0	5.0
6	5.4	5.4	5.4	5.5	5.5	5.5	5.6	5.6	5.6	5.7	5.7	5.7	5.7	5.8	5.8	5.8	5.9	5.9	5.9	6.0	6.0
7	6.3	6.4	6.4	6.4	6.5	6.5	6.5	6.6	6.6	6.6	6.7	6.7	6.7	6.8	6.8	6.8	6.9	6.9	6.9	7.0	7.0
8	7.3	7.3	7.4	7.4	7.5	7.5	7.5	7.6	7.6	7.6	7.7	7.7	7.7	7.8	7.8	7.8	7.9	7.9	7.9	8.0	8.0
9	8.3	8.3	8.4	8.4	8.4	8.5	8.5	8.5	8.6	8.6	8.6	8.7	8.7	8.8	8.8	8.8	8.9	8.9	8.9	9.0	9.0
10	9.3	9.3	9.3	9.4	9.4	9.4	9.5	9.5	9.6	9.6	9.6	9.7	9.7	9.7	9.8	9.8	9.9	9.9	9.9	10.0	10.0
11	10.2	10.3	10.3	10.3	10.4	10.4	10.5	10.5	10.5	10.6	10.6	10.7	10.7	10.7	10.8	10.8	10.8	10.9	10.9	11.0	11.0
12	11.2	11.2	11.3	11.3	11.4	11.4	11.4	11.5	11.5	11.6	11.6	11.6	11.7	11.7	11.8	11.8	11.8	11.9	11.9	12.0	12.0
13	12.2	12.2	12.2	12.3	12.3	12.4	12.4	12.5	12.5	12.5	12.6	12.6	12.7	12.7	12.7	12.8	12.8	12.9	12.9	13.0	13.0
14	13.1	13.2	13.2	13.3	13.3	13.3	13.4	13.4	13.5	13.5	13.6	13.6	13.7	13.7	13.7	13.8	13.8	13.9	13.9	14.0	14.0
15	14.1	14.1	14.2	14.2	14.3	14.3	14.4	14.4	14.5	14.5	14.5	14.6	14.6	14.7	14.7	14.8	14.8	14.9	14.9	15.0	15.0
16	15.1	15.1	15.1	15.2	15.2	15.3	15.3	15.4	15.4	15.5	15.5	15.6	15.6	15.7	15.7	15.8	15.8	15.9	15.9	16.0	16.0
17	16.0	16.1	16.1	16.2	16.2	16.3	16.3	16.4	16.4	16.5	16.5	16.6	16.6	16.7	16.7	16.8	16.8	16.9	16.9	17.0	17.0
18	17.0	17.0	17.1	17.1	17.2	17.2	17.3	17.3	17.4	17.4	17.5	17.5	17.6	17.6	17.7	17.7	17.8	17.8	17.9	17.9	18.0
19	17.9	18.0	18.0	18.1	18.1	18.2	18.3	18.3	18.4	18.4	18.5	18.5	18.6	18.6	18.7	18.7	18.8	18.8	18.9	18.9	19.0
20	18.9	18.9	19.0	19.1	19.1	19.2	19.2	19.3	19.3	19.4	19.4	19.5	19.6	19.6	19.7	19.7	19.8	19.8	19.9	19.9	20.0
21	19.8	19.9	20.0	20.0	20.1	20.1	20.2	20.2	20.3	20.4	20.4	20.5	20.5	20.6	20.7	20.7	20.8	20.8	20.9	20.9	21.0
22	20.8	20.9	20.9	21.0	21.0	21.1	21.2	21.2	21.3	21.3	21.4	21.5	21.5	21.6	21.6	21.7	21.8	21.8	21.9	21.9	22.0
23	21.7	21.8	21.9	21.9	22.0	22.1	22.1	22.2	22.2	22.3	22.4	22.4	22.5	22.6	22.6	22.7	22.7	22.8	22.9	22.9	23.0
24	22.7	22.8	22.8	22.9	23.0	23.0	23.1	23.1	23.2	23.3	23.3	23.4	23.5	23.5	23.6	23.7	23.7	23.8	23.9	23.9	24.0
25	23.6	23.7	23.8	23.8	23.9	24.0	24.0	24.1	24.2	24.3	24.3	24.4	24.5	24.5	24.6	24.7	24.7	24.8	24.9	24.9	25.0
26	24.6	24.7	24.7	24.8	24.9	24.9	25.0	25.1	25.1	25.2	25.3	25.4	25.4	25.5	25.6	25.6	25.7	25.8	25.9	25.9	26.0
27	25.5	25.6	25.7	25.7	25.8	25.9	26.0	26.0	26.1	26.2	26.3	26.3	26.4	26.5	26.6	26.6	26.7	26.8	26.9	26.9	27.0
28	26.5	26.5	26.6	26.7	26.8	26.8	26.9	27.0	27.1	27.2	27.2	27.3	27.4	27.5	27.5	27.6	27.7	27.8	27.8	27.9	28.0
29	27.4	27.5	27.6	27.6	27.7	27.8	27.9	28.0	28.0	28.1	28.2	28.3	28.4	28.4	28.5	28.6	28.7	28.8	28.8	28.9	29.0
30	28.3	28.4	28.5	28.6	28.7	28.8	28.8	28.9	29.0	29.1	29.2	29.3	29.3	29.4	29.5	29.6	29.7	29.8	29.8	29.9	30.0

Heat Index Software Table

Air Temp (°F)	Relative Humidity % 0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100
31	29.3	29.4	29.5	29.5	29.6	29.7	29.8	29.9	30.0	30.1	30.1	30.2	30.3	30.4	30.5	30.6	30.7	30.8	30.8	30.9	31.0
32	30.2	30.3	30.4	30.5	30.6	30.7	30.8	30.9	31.0	31.0	31.1	31.2	31.3	31.4	31.5	31.6	31.7	31.8	31.9	31.9	32.0
33	31.2	31.2	31.3	31.4	31.5	31.6	31.7	31.8	31.9	32.0	32.1	32.2	32.3	32.4	32.5	32.6	32.7	32.8	32.8	32.9	33.0
34	32.1	32.2	32.3	32.4	32.5	32.6	32.7	32.8	32.9	33.0	33.1	33.2	33.3	33.4	33.5	33.5	33.6	33.7	33.8	33.9	34.0
35	33.0	33.1	33.2	33.3	33.4	33.5	33.7	33.8	33.9	34.0	34.1	34.2	34.3	34.4	34.5	34.6	34.7	34.8	34.9	35.0	35.1
36	34.0	34.1	34.2	34.3	34.4	34.5	34.6	34.7	34.8	34.9	35.0	35.1	35.2	35.3	35.4	35.6	35.7	35.8	35.9	36.0	36.1
37	34.9	35.0	35.1	35.2	35.3	35.4	35.6	35.7	35.8	35.9	36.0	36.1	36.2	36.3	36.4	36.6	36.7	36.8	36.9	37.0	37.1
38	35.8	35.9	36.1	36.2	36.3	36.4	36.5	36.6	36.8	36.9	37.0	37.1	37.2	37.3	37.4	37.6	37.7	37.8	37.9	38.0	38.1
39	36.8	36.9	37.0	37.1	37.2	37.4	37.5	37.6	37.7	37.8	38.0	38.1	38.2	38.3	38.4	38.6	38.7	38.8	38.9	39.0	39.2
40	37.7	37.8	37.9	38.0	38.2	38.3	38.4	38.5	38.7	38.8	38.9	39.0	39.2	39.3	39.4	39.5	39.7	39.8	39.9	40.1	40.2
41	38.6	38.7	38.9	39.0	39.1	39.3	39.4	39.5	39.6	39.8	39.9	40.0	40.2	40.3	40.4	40.6	40.7	40.8	40.9	41.1	41.2
42	39.5	39.7	39.8	39.9	40.1	40.2	40.3	40.5	40.6	40.8	40.9	41.0	41.2	41.3	41.4	41.6	41.7	41.8	42.0	42.1	42.2
43	40.5	40.6	40.7	40.9	41.0	41.2	41.3	41.4	41.6	41.7	41.9	42.0	42.2	42.3	42.4	42.6	42.7	42.9	43.0	43.1	43.3
44	41.4	41.6	41.7	41.9	42.0	42.1	42.3	42.4	42.6	42.7	42.9	43.0	43.2	43.3	43.5	43.6	43.8	43.9	44.1	44.2	44.4
45	42.3	42.5	42.6	42.8	42.9	43.1	43.3	43.4	43.6	43.7	43.9	44.0	44.2	44.3	44.5	44.6	44.8	44.9	45.1	45.2	45.4
46	43.3	43.4	43.6	43.7	43.9	44.1	44.2	44.4	44.5	44.7	44.9	45.0	45.2	45.3	45.5	45.6	45.8	46.0	46.1	46.3	46.4
47	44.2	44.3	44.5	44.7	44.8	45.0	45.2	45.3	45.5	45.7	45.8	46.0	46.2	46.3	46.5	46.7	46.8	47.0	47.2	47.3	47.5
48	45.1	45.3	45.4	45.6	45.8	46.0	46.1	46.3	46.5	46.7	46.8	47.0	47.2	47.3	47.5	47.7	47.9	48.0	48.2	48.4	48.6
49	46.0	46.2	46.4	46.6	46.8	46.9	47.1	47.3	47.5	47.7	47.8	48.0	48.2	48.4	48.6	48.7	48.9	49.1	49.3	49.5	49.6
50	47.0	47.2	47.3	47.5	47.7	47.9	48.1	48.3	48.5	48.7	48.8	49.0	49.2	49.4	49.6	49.8	50.0	50.1	50.3	50.5	50.7
51	47.6	47.8	48.0	48.2	48.4	48.6	48.9	49.1	49.3	49.5	49.7	49.9	50.1	50.3	50.5	50.7	50.9	51.0	51.2	51.4	51.6
52	48.3	48.5	48.7	48.9	49.1	49.3	49.6	49.9	50.1	50.3	50.5	50.8	51.0	51.2	51.4	51.6	51.8	52.0	52.2	52.3	52.5
53	49.0	49.2	49.4	49.6	49.9	50.1	50.4	50.7	50.9	51.2	51.4	51.6	51.9	52.1	52.3	52.5	52.7	52.9	53.1	53.3	53.4
54	49.7	49.9	50.1	50.4	50.6	50.9	51.2	51.5	51.8	52.0	52.3	52.6	52.8	53.0	53.3	53.5	53.7	53.9	54.1	54.2	54.4
55	50.4	50.6	50.9	51.1	51.4	51.6	52.1	52.4	52.7	52.9	53.2	53.5	53.7	54.0	54.2	54.5	54.7	54.9	55.1	55.2	55.4
56	51.2	51.3	51.6	51.9	52.2	52.4	52.9	53.2	53.5	53.8	54.1	54.4	54.7	55.0	55.2	55.4	55.7	55.9	56.1	56.2	56.4
57	51.9	52.1	52.4	52.7	53.0	53.2	53.8	54.1	54.5	54.8	55.1	55.4	55.7	56.0	56.2	56.5	56.7	56.9	57.1	57.2	57.4
58	52.7	52.9	53.2	53.5	53.8	54.1	54.7	55.0	55.4	55.7	56.0	56.4	56.7	57.0	57.2	57.5	57.8	57.9	58.1	58.3	58.4
59	53.4	53.6	54.0	54.3	54.6	54.9	55.6	55.9	56.3	56.7	57.0	57.4	57.7	58.0	58.3	58.5	58.8	59.0	59.2	59.4	59.5
60	54.2	54.4	54.8	55.1	55.5	55.8	56.5	56.9	57.3	57.7	58.0	58.4	58.7	59.1	59.4	59.6	59.9	60.1	60.3	60.4	60.6
61	55.1	55.3	55.7	56.0	56.3	56.7	57.4	57.8	58.3	58.7	59.0	59.4	59.8	60.2	60.4	60.7	61.0	61.2	61.4	61.5	61.7
62	55.9	56.1	56.5	56.9	57.2	57.6	58.4	58.8	59.3	59.7	60.1	60.5	60.8	61.3	61.5	61.8	62.2	62.3	62.5	62.7	62.8
63	56.7	56.9	57.4	57.7	58.1	58.5	59.3	59.8	60.3	60.7	61.1	61.6	61.9	62.4	62.7	62.9	63.3	63.5	63.7	63.8	64.0
64	57.6	57.8	58.3	58.6	59.0	59.4	60.3	60.8	61.3	61.8	62.2	62.7	63.1	63.5	63.8	64.1	64.5	64.6	64.8	65.0	65.1
65	58.5	58.7	59.2	59.6	60.0	60.4	61.3	61.8	62.4	62.8	63.3	63.8	64.2	64.7	65.0	65.3	65.7	65.8	66.0	66.2	66.3
66	59.4	59.6	60.1	60.5	60.9	61.3	62.4	62.9	63.4	63.9	64.4	64.9	65.3	65.8	66.2	66.5	66.9	67.0	67.3	67.4	67.5
67	60.3	60.5	61.1	61.5	61.9	62.3	63.4	63.9	64.5	65.1	65.6	66.1	66.5	67.0	67.4	67.7	68.1	68.3	68.5	68.6	68.8
68	61.2	61.5	62.0	62.6	63.1	63.8	64.4	65.0	65.6	66.2	66.7	67.2	67.7	68.2	68.6	68.9	69.3	69.5	69.7	69.9	70.0
69	62.4	62.9	63.3	63.8	64.3	64.8	65.4	66.0	66.6	67.1	67.6	68.0	68.4	68.9	69.4	70.0	70.5	70.8	71.0	71.3	71.9
70	64.0	64.1	64.5	65.0	65.5	65.9	66.4	66.9	67.3	67.8	68.3	68.7	69.2	69.7	70.1	70.6	71.1	71.5	72.0	72.5	73.5
71	65.4	65.5	65.9	66.4	66.8	67.3	67.7	68.2	68.6	69.1	69.6	70.0	70.5	70.9	71.4	71.8	72.3	72.8	73.2	73.7	74.7
72	66.7	66.8	67.2	67.6	68.1	68.6	69.1	69.6	70.1	70.6	71.1	71.5	71.9	72.3	72.7	73.0	73.4	73.8	74.2	74.8	75.6
73	68.0	68.1	68.6	69.2	69.7	70.2	70.7	71.2	71.7	72.1	72.5	73.0	73.4	73.7	74.1	74.5	74.8	75.1	75.5	75.8	76.6
74	69.2	69.5	69.8	70.3	71.0	71.7	72.3	72.7	73.1	73.4	73.7	74.2	74.7	75.2	75.6	75.9	76.0	76.2	76.4	77.0	77.6
75	70.4	71.2	71.7	72.1	72.5	72.9	73.3	73.8	74.2	74.7	75.1	75.5	75.9	76.3	76.7	77.1	77.5	78.0	78.4	78.7	78.8
76	71.5	72.5	73.1	73.6	74.1	74.3	74.5	74.8	75.1	75.6	76.0	76.3	76.7	77.2	77.8	78.4	78.9	79.2	79.5	80.0	80.3
77	72.6	73.7	74.6	75.2	75.5	75.7	75.8	76.0	76.2	76.5	76.8	77.3	77.8	78.3	78.9	79.5	80.0	80.6	81.0	81.5	82.2
78	73.6	73.8	74.6	75.4	75.9	76.2	76.4	76.7	77.1	77.6	78.0	78.5	78.9	79.4	80.0	80.6	81.4	82.1	82.8	83.4	84.4
79	74.6	74.7	75.1	75.6	76.1	76.7	77.2	77.8	78.2	78.7	79.2	79.6	80.1	80.7	81.3	82.0	82.8	83.7	84.7	85.8	86.8
80	75.6	75.7	76.1	76.5	77.0	77.5	78.0	78.5	79.0	79.6	80.1	80.7	81.3	82.0	82.7	83.6	84.5	85.6	86.8	88.1	89.6
81	76.5	76.6	77.0	77.5	77.9	78.4	79.0	79.5	80.0	80.6	81.2	81.9	82.7	83.5	84.4	85.4	86.5	87.8	89.2	90.7	92.5
82	77.4	77.5	77.9	78.4	78.9	79.5	80.1	80.7	81.3	81.9	82.6	83.4	84.2	85.2	86.3	87.5	88.9	90.4	92.1	93.9	95.7
83	78.3	78.5	79.1	79.6	80.0	80.4	81.0	81.8	82.7	83.5	84.2	84.9	85.7	86.9	88.4	90.1	91.7	93.1	94.8	97.3	99.2
84	79.1	79.9	80.6	80.8	81.0	81.5	82.3	83.3	84.3	85.1	85.8	86.6	87.7	89.2	90.9	92.7	94.5	96.1	98.0	100.5	103.1
85	80.0	80.9	81.6	81.7	81.8	82.4	83.2	84.2	85.1	86.0	86.8	87.9	89.4	91.1	92.9	94.6	96.4	98.4	100.9	104.1	107.6
86	80.8	81.8	82.5	82.6	82.8	83.4	84.3	85.3	86.2	87.1	88.2	89.7	91.5	93.4	95.3	97.0	98.8	101.2	104.5	108.6	113.2
87	81.6	82.6	83.3	83.5	83.7	84.3	85.2	86.2	87.4	88.6	90.1	91.8	93.6	95.6	97.5	99.6	102.1	105.4	109.8	114.9	120.5
88	82.4	83.3	83.7	84.0	84.4	84.9	85.7	86.8	88.1	89.7	91.4	93.1	94.9	96.8	99.0	101.4	104.4	108.5	114.2	121.9	130.4
89	83.1	83.6	83.7	84.4	85.2	86.0	87.0	88.3	90.0	91.9	93.7	95.4	97.3	99.6	102.3	105.5	109.2	113.8	120.9	132.0	144.2
90	83.9	84.2	85.5	86.2	86.6	87.4	89.0	89.9	91.2	93.3	95.1	97.4	99.8	102.8	105.8	109.4	113.3	120.3	127.1	142.9	163.4
91	84.7	85.1	86.4	87.2	87.6	88.6	90.2	91.2	92.9	95.1	97.1	99.7	102.3	105.6	109.0	113.4	118.2	126.5	135.1	156.6	190.2
92	85.4	86.0	87.3	88.2	88.6	89.8	91.4	92.6	94.5	96.9	99.1	102.1	104.9	108.6	112.3	117.8	123.6	133.7	144.3	173.2	227.3
93	86.2	86.9	88.2	89.2	89.7	91.0	92.7	94.0	96.3	98.8	101.2	104.6	107.7	111.7	115.7	122.7	129.7	141.7	155.1	193.3	277.7
94	86.9	87.7	89.1	90.2	90.7	92.3	94.0	95.4	98.1	100.8	103.4	107.2	110.7	114.9	119.4	128.0	136.6	150.8	167.6	217.4	345.5
95	87.6	88.6	90.0	91.3	91.8	93.6	95.3	97.0	100.0	102.9	105.7	110.0	113.8	118.4	123.4	134.0	144.4	161.1	182.2	246.0	435.4
96	88.4	89.5	90.9	92.3	93.0	95.0	96.6	98.6	102.0	105.1	108.1	112.9	117.1	122.1	127.5	140.5	153.1	172.7	199.0	279.9	552.9
97	89.1	90.4	91.8	93.3	94.1	96.3	98.0	100.3	104.0	107.3	110.6	116.0	120.6	125.9	131.9	147.7	162.8	185.6	218.5	319.6	704.8
98	89.8	91.2	92.7	94.4	95.3	97.8	99.5	102.1	106.1	109.6	113.2	119.2	124.3	130.0	136.6	155.6	173.7	200.0	241.0	365.8	898.6
99	90.6	92.1	93.7	95.5	96.5	99.2	101.0	103.9	108.3	112.0	115.9	122.6	128.2	134.3	141.6	164.3	185.9	216.0	266.9	419.2	---
100	91.3	93.0	94.6	96.6	97.8	100.7	102.6	105.9	110.6	114.6	118.8	126.2	132.3	138.9	146.8	173.8	199.3	233.8	296.5	480.6	---
101	92.1	93.9	95.5	97.6	99.1	102.2	104.2	108.0	113.0	117.2	121.7	130.0	136.6	143.7	152.4	184.2	214.2	253.3	330.5	550.7	---
102	92.8	94.8	96.4	98.8	100.4	103.7	105.9	110.2	115.5	119.9	124.8	134.0	141.2	148.8	158.3	195.6	230.7	274.8	369.1	630.3	---
103	93.5	95.6	97.4	99.9	101.8	105.3	107.7	112.6	118.0	122.7	128.1	138.1	146.1	154.2	164.6	208.0	248.8	298.4	413.1	720.2	---
104	94.3	96.5	98.3	101.0	103.2	107.0	109.5	115.0	120.7	125.7	131.4	142.5	151.2	159.9	171.3	221.5	268.6	324.1	462.9	821.3	---
105	95.0	97.4	99.3	102.2	104.6	108.6	111.4	117.6	123.5	128.7	134.9	147.1	156.6	165.9	178.4	236.1	290.2	352.2	519.2	934.4	---
106	95.8	98.3	100.3	103.4	106.0	110.3	113.4	120.3	126.4	131.9	138.6	152.0	162.3	172.3	186.0	251.9	313.8	382.6	582.6	---	---
107	96.5	99.2	101.3	104.6	107.5	112.1	115.6	123.1	129.4	135.2	142.4	157.1	168.4	179.1	194.0	269.1	339.4	415.5	653.8	---	---
108	97.3	100.1	102.3	105.8	109.0	113.9	117.8	126.1	132.5	138.7	146.4	162.5	174.8	186.3	202.6	287.5	367.2	451.1	733.6	---	---
109	98.1	101.1	103.3	107.0	110.6	115.8	120.1	129.3	135.7	142.3	150.6	168.2	181.6	193.9	211.7	307.5	397.1	489.4	822.7	---	---
110	98.8	102.0	104.3	108.3	112.2	117.7	122.5	132.6	139.1	146.0	155.0	174.3	188.8	202.0	221.4	328.9	429.4	530.5	922.0	---	---
111	99.6	102.9	105.4	109.6	113.8	119.7	125.0	136.1	142.6	149.9	159.5	180.6	196.4	210.5	231.8	351.8	464.1	574.5	---	---	---
112	100.4	103.8	106.5	110.9	115.4	121.7	127.7	139.7	146.3	154.0	164.3	187.3	204.4	219.6	242.8	376.4	501.3	621.6	---	---	---
113	101.2	104.8	107.6	112.2	117.1	123.8	130.5	143.6	150.1	158.2	169.3	194.3	213.0	229.3	254.6	402.7	541.1	671.8	---	---	---
114	102.0	105.7	108.7	113.6	118.8	125.9	133.4	147.6	154.0	162.6	174.5	201.8	222.1	239.5	267.1	430.8	583.6	725.2	---	---	---
115	102.8	106.7	109.9	115.0	120.6	128.1	136.5	151.7	158.2	167.2	179.9	209.7	231.7	250.4	280.6	460.8	628.8	782.0	---	---	---

Heat Index Software Table

Air	Relative Humidity %																				
Temp (°F)	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100
116	103.6	107.6	111.0	116.4	122.4	130.4	139.7	156.1	162.5	172.0	185.6	218.0	241.9	262.0	294.9	492.6	676.9	842.2	---	---	---
117	104.4	108.6	112.2	117.9	124.2	132.7	143.0	160.7	166.9	176.9	191.6	226.7	252.8	274.4	310.3	526.5	727.9	905.8	---	---	---
118	105.3	109.6	113.5	119.4	126.0	135.1	146.6	165.5	171.6	182.1	197.8	236.0	264.3	287.5	326.7	562.4	781.9	973.1	---	---	---
119	106.1	110.6	114.7	120.9	127.9	137.6	150.3	170.5	176.4	187.6	204.3	245.9	276.6	301.5	344.3	600.5	839.1	---	---	---	---
120	106.9	111.6	116.0	122.4	129.9	140.1	154.2	175.7	181.5	193.2	211.1	256.3	289.7	316.4	363.1	640.8	899.4	---	---	---	---
121	107.8	112.6	117.3	124.0	131.9	142.8	158.2	181.1	186.8	199.1	218.3	267.3	303.6	332.2	383.2	683.3	962.9	---	---	---	---
122	108.6	113.6	118.7	125.6	133.9	145.5	162.5	186.7	192.2	205.3	225.8	278.9	318.4	349.2	404.9	728.3	---	---	---	---	---
123	109.5	114.6	120.0	127.3	136.0	148.3	167.0	192.6	198.0	211.7	233.7	291.3	334.1	367.2	428.1	775.6	---	---	---	---	---
124	110.4	115.6	121.4	129.0	138.1	151.2	171.6	198.7	203.9	218.4	241.9	304.3	350.9	386.5	453.0	825.5	---	---	---	---	---
125	111.3	116.6	122.9	130.7	140.3	154.2	176.5	205.1	210.2	225.4	250.5	318.2	368.8	407.1	479.8	877.9	---	---	---	---	---
126	112.1	117.7	124.4	132.5	142.6	157.3	181.6	211.7	216.7	232.7	259.6	332.9	387.9	429.1	508.5	932.9	---	---	---	---	---
127	113.0	118.8	125.9	134.3	144.9	160.5	187.0	218.6	223.4	240.4	269.1	348.5	408.3	452.7	539.5	990.7	---	---	---	---	---
128	113.9	119.8	127.5	136.1	147.3	163.9	192.6	225.7	230.5	248.4	279.1	365.1	430.1	477.8	572.8	---	---	---	---	---	---
129	114.8	120.9	129.1	138.0	149.8	167.3	198.5	233.1	237.9	256.7	289.5	382.7	453.3	504.8	608.7	---	---	---	---	---	---
130	115.8	122.0	130.7	139.9	152.3	170.9	204.6	240.8	245.6	265.4	300.5	401.4	478.2	533.7	647.4	---	---	---	---	---	---
131	116.7	123.1	132.4	141.9	155.0	174.6	211.0	248.7	253.7	274.6	312.1	421.3	504.8	564.6	689.1	---	---	---	---	---	---
132	117.6	124.2	134.1	143.9	157.7	178.4	217.7	257.0	262.1	284.1	324.2	442.5	533.3	597.8	734.1	---	---	---	---	---	---
133	118.5	125.3	135.9	146.0	160.5	182.4	224.6	265.5	270.9	294.1	337.0	465.0	563.8	633.4	782.7	---	---	---	---	---	---
134	119.5	126.5	137.7	148.1	163.5	186.6	231.9	274.3	280.1	304.6	350.4	488.9	596.4	671.7	835.2	---	---	---	---	---	---
135	120.4	127.6	139.6	150.3	166.6	190.9	239.5	283.4	289.7	315.5	364.5	514.4	631.5	712.7	892.0	---	---	---	---	---	---
136	121.4	128.8	141.5	152.5	169.8	195.4	247.4	292.8	299.7	327.0	379.3	541.6	669.0	756.9	953.4	---	---	---	---	---	---
137	122.4	129.9	143.5	154.7	173.1	200.0	255.6	302.5	310.2	339.0	394.9	570.6	709.4	804.3	---	---	---	---	---	---	---
138	123.3	131.1	145.5	157.0	176.6	204.9	264.2	312.6	321.2	351.6	411.3	601.6	752.7	855.4	---	---	---	---	---	---	---
139	124.3	132.3	147.5	159.4	180.2	210.0	273.1	323.0	332.8	364.7	428.6	634.6	799.2	910.4	---	---	---	---	---	---	---
140	125.3	133.5	149.7	161.8	184.1	215.3	282.4	333.7	344.8	378.6	446.8	669.8	849.2	969.6	---	---	---	---	---	---	---
141	126.3	134.7	151.8	164.3	188.1	220.9	292.0	344.7	357.4	393.0	466.0	707.5	903.0	---	---	---	---	---	---	---	---
142	127.3	135.9	154.1	166.8	192.3	226.6	302.1	356.1	370.6	408.2	486.2	747.7	960.9	---	---	---	---	---	---	---	---
143	128.3	137.2	156.3	169.4	196.7	232.7	312.5	367.8	384.5	424.2	507.6	790.7	---	---	---	---	---	---	---	---	---
144	129.3	138.4	158.7	172.0	201.3	239.1	323.4	379.9	399.0	440.9	530.0	836.7	---	---	---	---	---	---	---	---	---
145	130.3	139.7	161.1	174.7	206.2	245.7	334.6	392.3	414.2	458.5	553.8	886.0	---	---	---	---	---	---	---	---	---
146	131.4	141.0	163.5	177.4	211.4	252.8	346.3	405.1	430.1	476.9	578.8	938.7	---	---	---	---	---	---	---	---	---
147	132.4	142.3	166.1	180.2	216.8	260.1	358.5	418.2	446.9	496.3	605.3	995.2	---	---	---	---	---	---	---	---	---
148	133.4	143.6	168.6	183.1	222.6	267.9	371.1	431.8	464.4	516.6	633.2	---	---	---	---	---	---	---	---	---	---
149	134.4	144.9	171.3	186.0	228.6	276.0	384.2	445.7	482.8	538.0	662.7	---	---	---	---	---	---	---	---	---	---
150	135.5	146.3	174.0	189.0	235.0	284.7	397.7	460.0	502.1	560.5	693.9	---	---	---	---	---	---	---	---	---	---
151	136.6	147.6	176.8	192.1	241.8	293.8	411.8	474.7	522.4	584.1	726.8	---	---	---	---	---	---	---	---	---	---
152	137.6	149.0	179.6	195.2	248.9	303.4	426.3	489.8	543.7	609.0	761.7	---	---	---	---	---	---	---	---	---	---
153	138.7	150.4	182.5	198.4	256.4	313.7	441.4	505.3	566.1	635.1	798.6	---	---	---	---	---	---	---	---	---	---
154	139.8	151.8	185.5	201.6	264.4	324.5	457.0	521.2	589.6	662.6	837.6	---	---	---	---	---	---	---	---	---	---
155	140.9	153.2	188.6	205.0	272.8	336.1	473.1	537.5	614.3	691.6	878.9	---	---	---	---	---	---	---	---	---	---
156	142.0	154.6	191.7	208.4	281.7	348.4	489.8	554.2	640.3	722.1	922.7	---	---	---	---	---	---	---	---	---	---
157	143.0	156.1	194.9	211.8	291.1	361.5	507.1	571.4	667.7	754.3	969.1	---	---	---	---	---	---	---	---	---	---
158	144.2	157.5	198.2	215.3	301.0	375.6	524.9	589.0	696.4	788.1	---	---	---	---	---	---	---	---	---	---	---
159	145.2	159.0	201.5	218.9	311.5	390.7	543.4	607.0	726.7	823.8	---	---	---	---	---	---	---	---	---	---	---
160	146.4	160.5	204.9	222.6	322.6	406.9	562.4	625.5	758.5	861.5	---	---	---	---	---	---	---	---	---	---	---
161	147.5	162.0	208.5	226.4	334.3	424.4	582.1	644.4	792.1	901.2	---	---	---	---	---	---	---	---	---	---	---
162	148.6	163.5	212.0	230.2	346.7	443.4	602.4	663.7	827.4	943.0	---	---	---	---	---	---	---	---	---	---	---
163	149.7	165.0	215.7	234.1	359.8	463.9	623.4	683.6	864.6	987.2	---	---	---	---	---	---	---	---	---	---	---
164	150.8	166.6	219.4	238.0	373.6	486.2	645.1	703.9	903.9	---	---	---	---	---	---	---	---	---	---	---	---
165	151.8	168.2	222.6	242.1	378.0	494.1	667.4	732.3	945.2	---	---	---	---	---	---	---	---	---	---	---	---
166	152.9	169.7	225.8	246.2	382.4	502.2	690.4	762.1	988.8	---	---	---	---	---	---	---	---	---	---	---	---
167	153.9	171.3	229.1	250.4	386.9	510.5	714.2	793.3	---	---	---	---	---	---	---	---	---	---	---	---	---
168	155.0	173.0	232.4	254.7	391.5	519.1	738.7	826.1	---	---	---	---	---	---	---	---	---	---	---	---	---
169	156.0	174.6	235.7	259.1	396.2	527.9	763.9	860.5	---	---	---	---	---	---	---	---	---	---	---	---	---
170	157.1	176.3	239.1	263.5	401.0	537.0	789.9	896.6	---	---	---	---	---	---	---	---	---	---	---	---	---
171	158.1	177.9	242.6	268.1	405.9	546.3	816.7	934.5	---	---	---	---	---	---	---	---	---	---	---	---	---
172	159.2	179.6	246.1	272.7	410.9	555.9	844.2	974.3	---	---	---	---	---	---	---	---	---	---	---	---	---
173	160.3	181.3	249.6	277.4	415.9	565.8	872.6	---	---	---	---	---	---	---	---	---	---	---	---	---	---
174	161.3	183.0	253.2	282.2	421.1	576.0	901.8	---	---	---	---	---	---	---	---	---	---	---	---	---	---
175	162.4	184.8	256.8	287.0	426.4	586.5	931.8	---	---	---	---	---	---	---	---	---	---	---	---	---	---
176	163.4	186.5	260.5	292.0	431.8	597.3	962.7	---	---	---	---	---	---	---	---	---	---	---	---	---	---
177	164.5	188.3	264.3	297.1	437.4	608.4	994.4	---	---	---	---	---	---	---	---	---	---	---	---	---	---
178	165.6	190.1	268.1	302.2	443.0	619.9	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
179	166.6	191.9	271.9	307.4	448.8	631.6	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
180	167.7	193.7	275.8	312.8	454.6	643.8	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
181	168.7	195.6	279.7	318.2	460.6	656.3	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
182	169.8	197.5	283.7	323.7	466.7	669.2	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
183	170.9	199.4	287.8	329.3	473.0	682.5	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
184	171.9	201.3	291.8	335.0	479.4	696.2	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
185	173.0	203.2	296.0	340.8	485.9	710.3	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
186	174.1	205.1	300.2	346.7	492.5	724.9	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
187	175.1	207.1	304.4	352.7	499.3	739.9	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
188	176.2	209.1	308.7	358.8	506.3	755.4	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
189	177.2	211.1	313.0	365.0	513.3	771.3	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
190	178.3	213.1	317.4	371.3	520.6	787.8	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
191	179.4	215.1	321.8	377.7	528.0	804.7	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
192	180.4	217.2	326.3	384.3	535.5	822.2	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
193	181.5	219.3	330.8	390.9	543.2	840.3	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
194	182.5	221.4	335.4	397.6	551.1	858.9	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
195	183.6	223.5	340.0	404.4	559.1	878.1	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
196	184.6	225.6	344.6	411.4	567.3	897.9	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
197	185.7	227.8	349.3	418.4	575.7	918.4	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
198	186.7	230.0	354.1	425.6	584.3	939.5	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
199	187.8	232.2	358.9	432.8	593.0	961.2	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
200	188.8	234.4	363.8	440.2	602.0	983.7	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---

Heat Index Software Table

Air	Relative Humidity %																				
Temp (°F)	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100
201	189.9	236.7	368.7	447.7	611.1	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
202	190.9	238.9	373.6	455.3	620.4	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
203	191.9	241.2	378.6	463.0	630.0	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
204	193.0	243.5	383.6	470.9	639.7	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
205	194.0	245.9	388.7	478.8	649.7	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
206	195.0	248.2	393.8	486.9	659.9	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
207	196.1	250.6	399.0	495.1	670.3	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
208	197.1	253.0	404.2	503.4	680.9	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
209	198.1	255.4	409.5	511.8	691.8	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
210	199.1	257.8	414.8	520.4	702.9	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
211	200.2	260.3	420.2	529.0	714.3	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
212	201.2	262.8	425.6	537.8	725.9	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
213	202.2	265.3	431.0	546.8	737.7	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
214	203.2	267.8	436.5	555.8	749.9	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
215	204.2	270.4	442.0	565.0	762.3	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
216	205.2	273.0	447.6	574.3	775.0	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
217	206.2	275.6	453.2	583.7	787.9	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
218	207.2	278.2	458.9	593.3	801.2	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
219	208.2	280.8	464.6	603.0	814.8	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
220	209.2	283.5	470.4	612.8	828.6	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
221	209.9	286.2	476.2	622.8	842.8	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
222	211.2	288.9	482.0	632.9	857.3	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
223	212.2	291.6	487.9	643.1	872.2	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
224	213.2	294.4	493.8	653.5	887.4	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
225	214.2	297.2	499.8	664.0	902.9	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
226	215.1	300.0	505.8	674.6	918.8	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
227	216.1	302.8	511.8	685.4	935.0	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
228	217.1	305.7	517.9	696.3	951.6	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
229	218.0	308.6	524.1	707.4	968.6	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
230	219.0	311.5	530.2	718.6	986.0	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
231	220.0	314.4	536.5	729.9	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
232	220.9	317.4	542.7	741.4	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
233	221.9	320.3	549.0	753.0	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
234	222.8	323.4	555.4	764.8	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
235	223.8	326.4	561.7	776.7	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
236	224.7	329.4	568.1	788.8	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
237	225.6	332.5	574.6	801.0	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
238	226.6	335.6	581.1	813.4	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
239	227.5	338.8	587.6	825.9	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
240	228.4	341.9	594.2	838.5	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
241	229.3	345.1	600.8	851.4	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
242	230.2	348.3	607.5	864.3	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
243	231.2	351.5	614.2	877.5	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
244	232.1	354.8	620.9	890.8	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
245	233.0	358.1	627.7	904.2	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
246	233.9	361.4	634.5	917.8	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
247	234.8	364.8	641.3	931.6	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
248	235.6	368.1	648.2	945.5	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
249	236.5	371.5	655.1	959.6	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
250	237.4	374.9	662.1	973.8	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---

REFERENCES

Steadman, R.G., 1979: The Assessment of Sultriness, Part I: A Temperature-Humidity Index Based on Human Physiology and Clothing Science. *Journal of Applied Meteorology, July 1979*

"Media Guide to NWS Products and Services", National Weather Service Forecast Office, Monterey, CA, 1995.

Quayle, R.G. and Steadman, R.G., 1998: The Steadman Wind Chill: An Improvement over Present Scales. *Weather and Forecasting, December 1998*

Dewpoint

Parameters Used: Outside Air Temperature and Outside Humidity

What is it:
Dewpoint is the temperature to which air must be cooled for saturation (100% relative humidity) to occur, providing there is no change in water content. The dewpoint is an important measurement used to predict the formation of dew, frost, and fog. If dewpoint and temperature are close together in the late afternoon when the air begins to turn colder, fog is likely during the night. Dewpoint is also a good indicator of the air's actual water vapor content, unlike relative humidity, which is air temperature dependent. High dewpoint indicates high vapor content; low dewpoint indicates low vapor content. In addition a high dewpoint indicates a better chance of rain and severe thunderstorms. Dewpoint can be used to predict the minimum overnight temperature. Provided no new fronts are expected overnight and the afternoon Relative Humidity >=50%, the afternoon's dewpoint gives an idea of what minimum temperature to expect overnight. Since condensation occurs when the air temperature reaches the dewpoint, and condensation releases heat into the air, reaching the dewpoint halts the cooling process.

Formula:
The following method is used to calculate dewpoint:

$v = RH*0.01*6.112 * \exp [(17.62*T)/(T + 243.12)]$,

this equation will provide the vapor pressure value (in pressure units) where T is the air temperature in C and RH is the relative humidity.

Now dewpoint, Td, can be found:

Numerator = 243.12*(ln v) – 440.1

Denominator = 19.43 – ln v

Td = Numerator/Denominator

This equation is an approximation of the Goff & Gratch equation, which is extremely complex. This equation is one recommended by the World Meteorological Organization for saturation of air with respect to water.

REFERENCES

"Guide to Meteorological Instruments and Methods of Observation". World Meteorological Organization, Geneva, Switzerland, 6th Ed. 1996.

"Smithsonian Meteorological Tables". Smithsonian Institution Press, Washington, DC, 4th Ed. 1968.

THSW Index

Parameters Used: Temperature, Humidity, Solar Radiation, Wind Speed, Latitude & Longitude, Time and Date

What is it:
Like Heat Index, the THSW Index uses humidity and temperature to calculate an apparent temperature. In addition, THSW incorporates the heating effects of solar radiation and the cooling effects of wind (like wind chill) on our perception of temperature.

Formula:
The formula was developed by Steadman (1979). The following describes the series of formulas used to determine the THSW or Temperature-Humidity-Sun-Wind Index. Thus, this index indicates the level of thermal comfort including the effects of all these values.

This Index is calculated by adding a series of successive terms. Each term represents one of the three parameters: (Humidity, Sun & Wind). The humidity term serves as the base from which increments for sun and wind effects are added.

The Vantage Pro calculation is an improvement over the THSW Index in the Health EnviroMonitor because the Health system:

- only calculates THSW Index when air temperature is at or above 68°F.
- assumes the sky is clear.
- assumes the elevation is sea level.

Humidity

The first term is humidity. This term is determined in the same manner as the Heat Index. This term serves as a base number to which increments of wind and sun are added to come up with the final THSW Index temperature.

Note: Heat Index has also been referred to as "Temperature-Humidity Index" and "Thermal Index" in some Davis products

Wind

The second term is wind. This term is determined in part by a lookup table (for temperatures above 50°F) and in part by the wind chill calculation.

- At 0 mph, set this term equal to zero.
- For temperatures at or above 70°F and wind speeds above 40 mph, set the wind speed equal to 40 mph and use the table.
- For temperatures at or above 130°F, set this term equal to zero.
- For temperatures below 50°F:
  - For the display console: use the wind chill calculation as the base temperature.
  - For the WeatherLink software (version 5.2 and higher): use the new heat index formula (as described in the heat index section) as the base temperature and calculate the wind chill increment using the difference between the air temperature and wind chill (which is always a negative number).

The resulting value is the wind term, which will be added to the humidity term and subsequently the sun term as indicated below.
Note 1: older console versions of product that use the old wind chill formula (see wind chill section) have a different table for temperatures between 50°F and 70°F.
Note 2: The WeatherLink software (version 5.2) does not include the sun term in its calculation. It shows the result as the “THW Index” or Temperature-Humidity-Wind Index. This value indicates the “apparent” temperature in the shade due to these factors.

Increment (°F) for Wind in THSW Index									
Temp (°F)	Wind Speed (mph)								
	0	5	10	15	20	25	30	35	40
50	0	-2	-4	-5	-6	-7	-8	-9	-9
55	0	-1	-3	-5	-6	-7	-8	-9	-9
60	0	-1	-3	-5	-6	-7	-8	-9	-9
65	0	0	-3	-5	-6	-7	-8	-9	-9
70	0	0	-2	-4	-5	-6	-7	-8	-9
75	0	0	-2	-3	-4	-5	-6	-7	-7
80	0	0	-1	-2	-3	-5	-5	-6	-6
85	0	0	-1	-2	-3	-3	-4	-4	-4
90	0	0	0	-1	-2	-2	-2	-2	-2
95	0	0	0	0	0	0	1	1	1
100	0	0	0	0	1	2	3	3	3
105	0	0	0	1	2	3	4	5	5
110	0	0	0	2	3	4	5	5	6
115	0	0	0	1	2	3	4	6	6
120	0	0	0	1	1	2	3	4	4
125	0	0	0	0	0	1	1	1	1
130	0	0	0	0	0	0	0	0	0

Increment (°F) for Wind in THSW Index															
Temp (°F)	Wind Speed (mph)														
	40	50	60	70	80	90	100	110	120	130	140	150	160	170	180
50	-9	-10	-11	-12	-12	-13	-13	-14	-14	-15	-15	-15	-16	-16	-16
55	-9	-10	-10	-11	-11	-12	-12	-13	-13	-13	-13	-14	-14	-14	-14
60	-9	-10	-10	-10	-11	-11	-11	-11	-12	-12	-12	-12	-12	-12	-12
65	-9	-10	-10	-10	-10	-10	-10	-10	-10	-10	-10	-10	-11	-11	-11
70	-9	-9	-9	-9	-9	-9	-9	-9	-9	-9	-9	-9	-9	-9	-9

Sun

The third term is sun. This term, Qg, is actually a combination of four terms (direct incoming solar, indirect incoming solar, terrestrial, and sky radiation). The term depends upon wind speed to determine how strong an effect it is (discussed later).

It is assumed that a flat, fixed position sensor is being used as in the Vantage Pro Plus system.

$Qg = Q1 + Q2 + Q3 - Q4$

Direct Incoming Solar Radiation Term ($Q1$)

First, calculate what the solar radiation reading would be if the sensor were tilted normal to the sun. The following parameters are calculated in the same manner as for the ET formula (see ET section).

- Sky cover, c
- Solar Zenith Angle, θ

Solar radiation normal to the sun, $Q_n = (5E\text{-}06\theta^3 - 0.0002\theta^2 + 0.0029\theta + 1) * Q$,

Where Q is the measured solar radiation value and θ is the solar zenith angle in degrees (as determined above)
Otherwise, if the c is greater than 60%, $Q_n = Q$.

Next, direct incoming solar, Q_d, is determined from Q_n,

$Q_d = 0.9 * (1 - c^2) * Q_n$, where c is the cloud cover fraction calculated as before,

Finally, $Q1 = 0.56 * F * Q_d$

Where F is the projected area body factor.
If $70° >= \theta >= 2°$, $F = 0.386 - 0.0032*(90 - \theta)$, ($\theta$ is in degrees in the formula),
If $\theta < 2°$, $F = 0.110$
If $\theta > 70°$, $F = 0.325$

Indirect Incoming Solar Radiation Term ($Q2$)

$Q_i = 0.1 * (1 - c^2) * Q_n$, where Q_n is the normal solar radiation & c is the cloud cover fraction (as determined in $Q1$ above)

$Q2 = 0.224 * Q_i$

Terrestrial Radiation ($Q3$)

$Q3 = 0.028 * Q$, where Q is the directly measured solar radiation and is used in this case.

Sky Radiation ($Q4$)

$Q4 = 150\,[1 - c^2\,(0.50 - 0.0043\phi)] * [1 - 0.62 * \exp(-0.108Z) - 0.16 * (vp\text{^}0.5)]$,

Where c is the cloud cover fraction calculated as before, ϕ is the station's latitude in degrees, Z is the station's elevation in **kilometers**, and vp is the vapor pressure (in kPa),

$vp = RH*0.01*0.6112 * \exp[(17.62*T)/(T + 243.12)]$, where RH is the outdoor relative humidity expressed as a percent & T the air temperature in **°C**.

From the resulting Q_g, if the wind speed is < 7 mph, then the sun term in THSWI (in ° F) is $0.101 * Q_g$,

Otherwise, the sun term is $(1.10Q_g)/(8 + 0.45v)$, where v is the wind speed in mph.

REFERENCES

Steadman, R.G., 1979: The Assessment of Sultriness, Part II: Effects of Wind, Extra Radiation and Barometric Pressure on Apparent Temperature. *Journal of Applied Meteorology, July 1979*.

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Quayle, R.G. and Steadman, R.G., 1998: The Steadman Wind Chill: An Improvement over Present Scales. *Weather and Forecasting, December 1998*

Barometric Pressure

What is it:
The weight of the air that makes up our atmosphere exerts a pressure on the surface of the earth. This pressure is known as atmospheric pressure. Generally, the more air above an area, the higher the atmospheric pressure, this, in turn, means that atmospheric pressure changes with altitude. For example, atmospheric pressure is greater at sea-level than on a mountaintop. To compensate for this difference and facilitate comparison between locations with different altitudes, atmospheric pressure is generally adjusted to the equivalent sea-level pressure. This adjusted pressure is known as barometric pressure. In reality, the Vantage Pro measures atmospheric pressure. When entering the location's altitude in Setup Mode, the Vantage Pro calculates the necessary correction factor to consistently translate atmospheric pressure into barometric pressure.

Barometric pressure also changes with local weather conditions, making barometric pressure an extremely important and useful weather forecasting tool. High pressure zones are generally associated with fair weather while low pressure zones are generally associated with poor weather. For forecasting purposes, however, the absolute barometric pressure value is generally less important than the change in barometric pressure. In general, rising pressure indicates improving weather conditions while falling pressure indicates deteriorating weather conditions.

Parameters Used: Outside Air Temperature, Outside Humidity, Elevation, Atmospheric Pressure

Formula:
Simply,

$P_{SL} = P_S * (R)$,

where P_{SL} is sea level pressure, P_S is the unadjusted reading sensed by the Davis barometer, and R is the reduction ratio, which is determined as follows:

First, Tv (virtual temperature in the "fictitious column of air" extending down to sea-level) can be determined as follows. The result is in degrees Rankine, which is similar to Kelvin except it uses a Fahrenheit scale divisions rather than Celsius scale divisions:

$Tv = T + 460 + L + C$,

where T is the average between the current outdoor temperature and the temperature 12 hours ago (in Fahrenheit) in whole degrees. L is the typical lapse rate, or decrease in temperature with height (of the "fictitious column of air"), as calculated by:

$L = 11\ Z/8000$,

where L is a constant value with units in °F. Z is elevation, which must be entered in feet.

The current dewpoint value and the station elevation are necessary to compute C. C is the correction for the humidity in the "fictitious column of air". It is determined from a lookup table (provided in the attached table). The table consists of dewpoints in °F every 4°F and elevations in feet every 1500 feet. Linear interpolation is performed to obtain the correct reduced pressure value. For dewpoints below –76°F, C = 0; for dewpoints above 92°F, a dewpoint of 92°F is assumed.

Now, Tv can be determined. From this, the following can be computed:

Exponent = $[Z/(122.8943111*Tv)]$

Once this exponent is computed, R can be computed from the following:

R = 10^[Exponent].

Thus, $P_{SL} = P_S$ * (R) can be calculated. Pressure can be in any units (R is dimensionless) and still yield the correct value.

This procedure is designed to produce the correct reduced sea-level pressure as displayed. This requires the user to know their elevation to at least ±10 feet to be accurate to every .01" Hg or ±3 feet to be accurate to every 0.1 mb/hPa.

This is a simplified version of the official U.S. version in place now. The accepted method is to use lookup tables of ratio reduction values keyed to station temperature. These are based on station climatology. These values are unavailable for every possible location where a Davis user may have a station, thus this approach is not suitable.

It should be noted that if a sensor's pressure readings require adjustment, the user can adjust either the uncorrected or the final reading to match the user's reference, as appropriate. If the user chooses to measure uncorrected atmospheric pressure or use another reduction method, they should set their elevation to zero. Subsequently, output data using the VantageLink can be read by or exported to another application and converted as desired.

The calibration of the sensor is a separate one time function performed on the unit during the manufacturing process. It is a completely independent operation from the calculation the Vantage Pro console makes to display a reading corrected to sea-level. It is described in a separate section. The calibration is done to ensure the sensor reads uncorrected or raw atmospheric pressure (not barometric pressure) properly. Any properly functioning unit will read the uncorrected atmospheric pressure within specifications. However, limits in the displayable range of the bar value may prevent the user from setting an incorrect elevation for their location. That is, a user at sea-level, may see a dashed reading if they set their unit to 5000' elevation or vice-versa. So, the best way to tell if a unit is functioning properly, is:

- use a reference that has been adjusted to indicate sea-level pressure and setting the Vantage Pro console to the proper elevation or
- use a reference that is reading the raw, uncorrected atmospheric pressure and set the Vantage Pro console elevation to zero

and verify that these readings are comparable.

REFERENCE

"Smithsonian Meteorological Tables". Smithsonian Institution Press, Washington, DC, 4th Ed. 1968.

"Federal Standard Algorithms for Automated Weather Observing Systems used for Aviation Purposes". Office of the Federal Coordinator for Meteorological Services and Supporting Research, Washington, DC, 1988

Rain Total

Unlike previous Davis systems, the Vantage Pro comes with only one type of rain collector. It is equipped with a 0.01" rain collector. All Vantage Pros physically measure in increments of 0.01 in. The system has a prevision for other types should they be added in the future.

The Vantage Pro is pre-configured for this type of rain collector. In the series of "Setup Screens", there is one for "Rain Collector". Simply press the DONE key to move to the next screen. By default, it should be set to ".01" Rain Collector". If it isn't, use the "+" and "-" arrow keys to select this type.

The rain display's units may be changed from inches to millimeters by pressing 2ND, then the UNITS key while in "Current Screen" mode with one of the rain fields selected. If millimeters is displayed, the console converts from inches to mm. If display millimeters is displayed, the counter will occasionally skip a reading due to rounding.

Rain Rate

Parameters Used: Rain Total (actually, rain rate is a measured variable in the sense that it is measured by the ISS and transmitted to the display console, whereas all other calculated variables are determined by the console from data received from the ISS.)

Formula:

Under normal conditions (see packet sequencing below) rain rate data is sent with a nominal interval of 10 to 12 seconds. Every time a rain tip or click occurs, a new rain rate value is computed (from the timer values) and the rate timers are reset to zero.

Rain rate is calculated based on the time between successive tips of the rain collector. The rain rate value is the highest rate since the last transmitted rain rate data packet. (Under most conditions, however, a rain tip will not occur every 10 to 12 seconds.)

If there have been no rain tips since the last rain rate data transmission, then the rain rate based on the time since that last tip is indicated. This results in slowly decaying rate values as a rain storm ends, instead of showing a rain rate which abruptly drops to zero. This results in a more realistic representation of the actual rain event.

If this time exceeds roughly 15 minutes, than the rain rate value is reset to zero. This period of time was chosen because 15 minutes is defined by the U.S. National Weather Service as intervening time upon which one rain "event" is considered separate from another rain "event". This is also the shortest period of time that the Umbrella will be seen on the display console after the onset of rain.

REFERENCES

"Surface Weather Observations and Reports ". Office of the Federal Coordinator for Meteorological Services and Supporting Research, Washington, DC, 1998

UV Index

INTRODUCTION

Ultraviolet (UV) radiation can cause health damage in many ways --
- to the skin: burning, premature aging, and possible skin cancer
- to the eyes: possible cataracts and other disorders
- to the body's immune system.

This Note discusses the interpretation of the Health EnviroMonitor® and Vantage Pro system's UV readings in terms of possible skin damage. One should, however, be aware of the other hazards and minimize exposure to UV.

The UV SPECTRUM

UV radiation is divided into three spectral regions: UV-A, wavelengths of 400 to 320 nanometers (nm); UV-B, 320 to 280 nm; and UV-C, 280 to 100 nm.

The earth's atmosphere absorbs wavelengths shorter than 290 nm (UV-C). UV-B rays pose the greatest risk of skin cancer. Some UV-A radiation is needed by the human body for the synthesis of vitamin D, but excessive amounts cause aging, wrinkling, and loss of elasticity of the skin, and they contribute to skin cancer and cataracts.

The Erythemal Action Spectrum (EAS) was defined by McKinlay and Diffey (1987) and has been accepted by the Commission Internationale de l'Eclairage (CIE) as the standard representation of the average skin response to UV-B and UV-A. The skin is 100 times more sensitive to radiation at 298 nm than to that at 319 nm.

UV MEASUREMENTS

The Health EnviroMonitor and Vantage Pro system displays two types of UV measurement: **Intensity**, the strength of UV radiation at the moment of measurement, and **Dose**, the total UV energy measured over a period of time.

INTENSITY

The UV intensity at a given instant is usually defined in one of three ways:
- The scientific measure of UV irradiance is usually given in units of Watts per square meter.
- The UV Index has been defined to give a more-easily-remembered set of units, ranging from 1 to 15.
- The intensity may also be defined as a Dose-rate, MEDs per hour.

The Health EnviroMonitor and Vantage Pro calculate and display the Index and Dose-rate.

UV Index. The Index was first defined by Environment Canada and has since been adopted by the World Meteorological Organization. In the U.S. the Environmental Protection Agency (EPA) has categorized the Index values as follows:

0 to 2, Minimal
3 to 4, Low
5 to 6, Moderate
7 to 9, High
10 and higher, Very High.

The Index is equal to the EAS-weighted irradiance (in Watts/m²) x 40. An Index of 10 is equivalent to an EAS-weighted irradiance of 0.25 W/m². The relationship between Index value and estimated time for sunburn is discussed below.

The Index value published by the U.S. National Weather Service is a forecast of the next day's noontime UV intensity (see Long, et al). The Index value displayed by the Health EnviroMonitor and Vantage Pro is the result of a real-time measurement.

Dose-rate. The Dose-rate is expressed in MEDs per hour, where a MED is the Minimum Erythemal Dose, the amount of sun exposure which causes barely perceptible skin sunburn redness (erythema). The MED and its scale factor are discussed below under DOSE.

For a MED scale factor of 1.0 (the base, or default, value) a Dose-rate of 4.3 MEDs per hour is equivalent to an Index of 10. Stated another way, the base MED rate is 3/7 of the Index value.

DOSE

As mentioned above, the MED, or Minimum Erythemal Dose, is the integral, or summation, of UV intensity over a period of time; it is the amount of EAS-weighted energy which causes barely perceptible redness to appear within 24 hours in previously-unexposed skin. The Health EnviroMonitor and Vantage Pro calculate the dose by performing a real-time integration of EAS-weighted intensity.

The base MED is equal to 21 mJ/cm^2 of EAS-weighted UV energy.

It's obvious that not all skin types have the same sensitivity to sunlight. The following sections discuss the interpretation of dose information for various skin types.

SKIN TYPES

The EPA has defined four skin phototypes to help individuals interpret UV data for their own sensitivities; these definitions are shown in Table 1a. Within each skin type a range of sensitivities are found; some

Table 1a. Description of Four Skin Phototypes (Source: EPA -017)

SKIN PHOTOTYPE		SKIN COLOR IN UNEXPOSED AREA	TANNING HISTORY
1	Never Tans, Always Burns	Pale or milky white; alabaster	Develops red sunburn; painful swelling; skin peels.
2	Sometimes Tans, appears; Usually Burns	Very light brown; sometimes freckles	Usually burns; pinkish or red coloring can gradually develop light brown tan.
3	Usually Tans, Sometimes Burns	Light tan, brown, or olive; distinctly pigmented	Rarely burns; shows moderately rapid tanning response.
4	Always Tans, Rarely Burns	Brown, dark brown, or black	Rarely burns; shows very rapid tanning response.

Table 1b. Description of Six Skin Types (Source: Environment Canada)

SKIN TYPE	CHARACTERISTICS	TANNING HISTORY
I	Blond hair, blue or green eyes, very light skin.	Always burns easily, never tans
II	Light to medium hair, eyes, and skin.	Always burns easily, tans minimally.
III	Medium hair, dark eyes, medium skin.	Burns moderately, tans gradually.
IV	Dark hair and eyes, light brown skin.	Burns minimally, always tans well.
V	Dark hair and eyes, very dark skin.	Rarely burns, tans profusely.
VI	Dark hair and eyes, very dark skin.	Never burns, deeply pigmented.

people will experience sunburn more quickly than others of the same phototype. Environment Canada has defined six skin types, as defined in Table 1b.

DOSE TO BURN

It must be remembered that reflected UV can play a large role in sun-burning, and the UV sensor may not be in a position to measure all the reflected radiation to which an individual -- one sitting beside a swimming pool, for example -- might be exposed. That person, then, could be receiving a larger dose than the weather station's measurement would indicate.

Table 2a. Suggested MED Scale Factor Ranges (four skin types)

SKIN PHOTOTYPE (EPA)		SCALE FACTORS
1	Never Tans, Always Burns	1.0 to 1.4
2	Sometimes Tans, Usually Burns	0.7 to 1.0
3	Usually Tans, Sometimes Burns	0.5 to 0.7
4	Always Tans, Rarely Burns	0.3 to 0.5

Table 2b. Description of Six Skin Types (Source: Environment Canada)

SKIN TYPE (Environment Canada)		SCALE FACTOR
I	Always burns easily, never tans	1.4
II	Always burns easily, tans minimally	1.0
III	Burns moderately, tans gradually	0.7
IV	Burns minimally, always tans well	0.6
V	Rarely burns, tans profusely.	0.5
VI	Never burns, deeply pigmented.	0.4

TIME TO BURN

To estimate the length of exposure time that will cause sunburn one can divide the Dose to Burn by the current Dose Rate. For example: 0.8 MEDs ÷ 3.2 MEDs/hour = 0.25 hour = 15 minutes.

The above Time to Burn equation must be used with caution. The Dose Rate can be expected to change during the dose period, so the Time to Burn will change. If, for example, the dose period is begun before solar noon the Dose Rate will probably increase during the period, so the Time to Burn will be shortened.

Similarly, if the initial Dose Rate is observed during a period of cloudiness or overcast skies, the subsequent Dose Rates and Time to Burn will be quite different if the sky clears.

REFERENCES

Environmental Protection Agency, 1994: Experimental UV Index. EPA 430-F-94-017, -018, and –019.

Long, C. S., et al: Ultraviolet Index Forecasts Issued by the National Weather Service*. Bulletin of the American Meteorological Society, April 1996.*

McKinlay, A. F., and B. L. Diffey, 1987: A reference spectrum for ultraviolet-induced erythema in human skin. *Human Exposure to Ultraviolet Radiation: Risks and Regulations.* W. F. Passchier and B. F. Bosnajakovic, eds., Elsevier, 83-87.

Moon Phase

Parameters Used: Latitude, Longitude, Time and Date, Time Zone, Daylight Savings Time Setting

Sufficient accuracy is obtained from the following formula for i, the phase angle:

$$i = 180° - D - 6.289° \sin M' + 2.1° \sin M - 1.274° \sin (2D - M') - 0.658° \sin 2D$$

where

- D is the mean elongation of the moon (the maximum angular distance between the earth and the moon)
- M' is the moon's mean anomaly (angular distance, measured from where the moon is closest to the earth in its orbit, if it moved around the earth at a constant angular velocity)
- M is the sun's mean anomaly (angular distance, measured from where the earth is closest to the sun in its orbit, if it moved around the earth at a constant angular velocity)

and the terms in the equation provide increasing amounts of mean accuracy to calculate the phase angle as follows (hr:min):

- D = 20:57
- $6.289° \sin M'$ = 8:35
- $2.1° \sin M$ = 4:26
- $1.274° \sin (2D - M')$ = 1:56
- $0.658° \sin 2D$ = 0:38

Note: these equations assume that the sun and moon both revolve around the earth, for simplicity. However, when addressing the positions in orbit, it is actually the earth revolving around the sun, so this should be understood when trying to understand the physical meaning described in the definitions.

The equations for D, M' and M are as follows:

$D = 297.8501921 + 12.19074911 * days$
$M' = 134.9633964 + 13.06499295 * days$
$M = 357.52911 + 0.985600281 * days$,

Where *days* (in days and fractions of days) is the number of days since Jan 1st, 2000 at 12:00 UTC

Local time needs to be converted to UTC in order to be used in the formulas:

UTC = Local Time - Time Zone Offset (including adding one hour for daylight savings if and when in use)

The phase angle is modified so that it can be used to determine whether the moon is waxing (illuminated portion increasing in size) or waning (decreasing in size):

If $i >= 180°$, then $k = 1 - (k / 2)$

Now, the phase angle can be used to determine which phase the moon is in:

$i = (i * 8) + 0.5$

The result is interpreted as follows:
0 = New Moon, 1 = Waxing Crescent, 2 = First Quarter, 3 = Waxing Gibbous, 4 = Full Moon,
5 = Waning Gibbous, 6 = Last Quarter, 7 = Waning Crescent

Bulletin Graphic

k is the fraction of the moon's disk that is illuminated. It is used to draw the moon phase icon in the Bulletin.

k = (1 + cos i)/ 2

k is a number between zero and one that indicates how much of the moon's disk should be drawn as lit. It indicates the "terminator's" (boundary between light and dark face) position on the observed face of the moon.

k can also be interpreted as listed below
0.00 = New Moon
0.25 = First Quarter
0.50 = Full Moon
0.75 = Last Quarter

REFERENCE

Meeus, Jean: "Astronomical Algorithms". Willman-Bell, Richmond, VA, 2nd Ed. 1998.

Description of ET, Reference ET, and the Crop Coefficient

Evapotranspiration (ET) is the amount of water that moves from the ground (and plants on the ground) to the atmosphere through both evaporation and transpiration. It is primarily important to people who are monitoring plant growth and associated water usage.

Measuring actual ET for a given location requires the measurement of weather variables at different heights at the same location and is beyond the capabilities of the current Davis weather stations. Instead, a single set of weather data measurements (described in detail below) are used to calculate a Reference ET (ET_o). ET_o is the amount of ET that is expected at a location with specified reference conditions under the actual weather conditions. The two most common reference conditions used for agricultural purposes are the grass reference – well watered grass that completely shades the ground, is uniformly clipped to a few inches in height – and the alfalfa reference – similar to the grass reference with alfalfa instead of grass, and a different height. The Davis ET calculations all calculate ET_o for a grass reference.

To determine actual ET from a reference ET_o, multiply the ET_o by a crop coefficient (K_c). The crop coefficient accounts for the type of plant, the maturity of the plant, and may include local factors such as soil type. Davis Instruments does not supply crop coefficients. It is up to the individual user to determine what K_c is appropriate. See below for a list of some sources. It is very important, when selecting K_c to make sure that the coefficient is for use with a grass reference. Do not use coefficients that were derived from alfalfa referenced ET_o.

The different Davis ET_o calculations

There are three ways that ET is calculated by Davis weather stations. They differ in how the weather data values are gathered and in how Net Radiation is calculated. The three methods are: GroWeather calculated on the console, GroWeather calculated on a PC, and Vantage Pro (calculated on the console). In all methods, hourly ET values are calculated from hourly averages of weather variables. The differences arise from differences in the computational abilities of the GroWeather station, Vantage Pro station and a PC.

Data Sampling and variables required for Calculation

The GroWeather console calculated ET_o samples Temperature, Humidity, Wind Speed, Solar Radiation over a one hour period. This sampling is independent of sampling undertaken for the creation of archived data records. At the end of the hour, the arithmetic mean is calculated for each value by dividing the sum of the sampled data values by the number of samples taken. The number of samples is tracked for each sensor independently in case some sensors are not connected for some part of the period. In addition, the raw Barometer value (i.e. not corrected for altitude) at the end of the hour is read.

The temperature is calculated in tenths of a degree F, the humidity is calculated in tenths of a percent, wind speed is calculated in miles per hour, solar radiation is calculated in watts per square meter, and atmospheric pressure is read in thousandths of an inch of mercury. All arithmetic is in integers. Values that use fractions are represented by multiplying by an appropriate value. The formulas given below that use functions more complicated than addition, subtraction, multiplication, and division are calculated with table lookups with linear interpolation where appropriate.

The GroWeather PC calculated ET_o uses data from the historical archived data to calculate the average temperature, humidity, wind speed, solar radiation; and the final atmospheric pressure. In addition, the software uses the latitude, longitude, and time zone settings set in the Station Configuration dialog.

The Vantage calculated ET_o takes samples of Temperature, Wind Speed, and Solar Radiation over a one hour period and derives an average value in a manner similar to the GroWeather console. Instead of sampling the humidity and deriving an "average humidity" for the hour, each time the temperature is sampled, the value of the saturation vapor pressure and actual water vapor pressure are calculated from the current values of temperature and humidity and sampled. These vapor pressure values (in kPa) are used to compute the average saturation vapor pressure and the average water vapor pressure for the hour. The Vantage has the capability to perform floating point arithmetic.

General ET_o Calculation

For the most part, these equations are applicable to all 3 calculation methods. Where they differ they are marked as follows: (GWc) applies to the GroWeather Console calculation, (GWpc) applies to the GroWeather PC calculation, and (VP) applies to the Vantage calculation

Measured Variables

T_F mean air temperature in tenths of a degree Fahrenheit
U_{MPH} mean wind speed in whole miles per hour
R_s mean solar radiation in whole Watts per square meter
H mean humidity in percent (value is between 0 and 100). (GWc and GWpc only)
P_{in} atmospheric air pressure (not corrected for elevation) at the end of the hour; thousandths of inches of mercury.

Calculated Values
(unit conversions)

T_C mean temperature in Celsius

$$T_c = (T_F - 32) * 5/9$$

T_K mean temperature in Kelvin

$$T_K = T_C + 273.16$$

P_{kPa} atmospheric pressure in kPa

$$P_{kPa} = P_{in} * 33.864$$

$U_{m/s}$ mean wind speed in meters per second

$$U_{m/s} = U_{MPH} * 0.44704$$

R_n average net radiation over the hour as described in the next section. Watts per square meter

e_a saturation water vapor pressure in kPa

$$e_a = 0.6108 * e^{\left(\frac{17.27 * T_C}{T_C + 237.3}\right)}$$

e_d actual water vapor present

Δ

$$e_d = e_a * \frac{H}{100}$$

Δ slope of the saturation vapor curve at T_C

$$\Delta = \frac{e_a}{T_K} * \left(\frac{6790.4985}{T_K} - 5.02808\right)$$

γ psychometric constant

$$\gamma = 0.000646 * (1 + 0.000946 * T_C) * P_{kPa}$$

W weighting factor that expresses the relative contribution of the radiation component

$$W = \frac{\Delta}{\Delta + \gamma}$$

F the wind function indicates the amount of energy that the wind contributes towards ET. There are two functions, one for day (solar radiation > 0) and one for night.

$$F_d = 0.030 + 0.0576 * U_{m/s}$$

$$F_n = 0.125 + 0.0439 * U_{m/s}$$

λ latent heat of vaporization. Used to convert net radiation in Watts per square meter into the amount of water evaporated in mm

$$\lambda = 694.5 * (1 - 0.000946 * T_C)$$

ET_o the hourly potential ET in mm

$$ET_o = W * \frac{R_n}{\lambda} + (1 - W) * (e_a - e_d) * F$$

Formulas for Net Radiation

Solar radiation is the primary source of energy that drives evapotranspiration, but what is important is the net radiation, incoming radiation minus outgoing radiation, at all wavelengths.

The Davis solar radiation sensor measures incoming radiation in the visible portion of the spectrum. From this we must subtract out the component that is reflected off the plant leaves. This value is called the albedo (α).

In addition to the radiation in the visible spectrum, we must also take account of the longer wavelength thermal radiation. This is modeled as black-body radiation coming from three sources at the measured air temperature. The first source is the portion of the sky that does not contain clouds, the second source is the portion of the sky containing clouds, and the third source is the ground radiating into the sky. The first two sources are incoming radiation and the third is outgoing radiation. In order to determine the relative contributions of source one and two, we need to calculate the percentage of the sky that is covered by clouds.

The cloud cover fraction is estimated by comparing the actual mean solar radiation received against the amount we would have received if the sky was clear. In order to calculate the clear sky radiation, it is necessary to calculate the height of the sun above the horizon (solar altitude angle). The altitude of the sun depends, in turn, on the latitude, longitude, day of the year, and time of the day.

Net Radiation on the GroWeather Console

ET_o calculated by the GroWeather console assumes a simple relationship between solar radiation and net radiation.:

$$R_n = 0.5625 * R_s$$

The constant 0.5625 was chosen by examining several 15 day sets of ET_o data from CIMIS weather stations in July and May 1994. For each data set, the total ET_o was calculated using several scale factors. It was found that calculated ET_o was equal to the reported ET_o for scale factors between about 0.535 and 0.5875. Any value in this range would have produced a value within 10 percent of the correct value. Later, a whole year's worth of data from a single station was analyzed and this criteria was found to be true only between April and September. From October through March, lower scale factors are required (as low as 0.24 in January) and therefore the ET_o calculated on the GroWeather console is too high.

Net Radiation on the GroWeather calculated on the PC

Here are the equations used in the GroWeatherLink software (version 1.2) to calculate net radiation

Input values

Lat_d Latitude of the station (N is positive) in degrees

Lon_d Longitude of the station (E is positive) in degrees

TZ timezone of the station (difference in time between the local civil time and UTC, PST = -8.0) in hours

DOY Day of the year (between 1 and 365)

D_l serial number of the day (number of days since Jan 1, 1900

$Time_l$ local civil time in minutes after midnight (0 – 1439)

Note that this is the time and date of the middle of the hour.

D_{UTC} the date in Greenwich at the same instant as $Time_l$ in days since Jan 1, 1900

$Time_{UTC}$ the time in Greenwich at the same instant as $Time_l$ in minutes

$$Time_{GMT} = Time_l - (TZ * 60)$$

$$\text{if } Time_{GMT} < 0$$

$$D_{GMT} = D_l - 1$$

$$Time_{GMT} = Time_{GMT} + 1440$$

if $Time_{GMT} \geq 1440$

$$D_{GMT} = D_l + 1$$

$$Time_{GMT} = Time_{GMT} - 1440$$

otherwise

$$D_{GMT} = D_l$$

Astronomical Values

D_{J2000} number of days (with fractions) since J2000.0 (i.e. 1/1/2000 12:00 noon)

$$D_{J2000} = \left(D_{GMT} - D_{12/31/1999}\right) - 1.5 + \frac{Time_{GMT}}{1440}$$

L' mean solar longitude in radians

$$L' = \left(280.46 + 0.98564742 * D_{J2000}\right) * \frac{\pi}{180}$$

M mean solar anomaly in radians

$$M = \left(357.528 + 0.985600273 * D_{J2000}\right) * \frac{\pi}{180}$$

L_{ecl} solar ecliptic longitude in radians

$$L_{ecl} = \begin{pmatrix} L'_{\deg} \\ + (1.915 - 0.00000013142) * \sin(M) \\ + 0.2 * \sin(2 * M) \end{pmatrix} * \frac{\pi}{180}$$

ε obliquity of the ecliptic in radians

$$\varepsilon = \left(23.439 + 0.0000003559 * D_{J2000}\right) * \frac{\pi}{180}$$

δ solar declination in radians

$$\delta = \sin^{-1}\left(\sin\left(L_{ecl}\right) * \sin(\varepsilon)\right)$$

Equation of Time

A_1 angle 1 in radians

$$A_1 = (0.98561 * DOY - 4.02) * \frac{\pi}{180}$$

A_2 angle 2 in radians

$$A_2 = (1.9712 * DOY - 8.04) * \frac{\pi}{180}$$

θ angle Theta in radians

$$\theta = \begin{pmatrix} 9.122 + 0.98561 * DOY \\ + 1.915 * \sin(A_1) + 0.014 * \cos(A_1) \\ + 0.02 * \sin(A_2) \end{pmatrix} * \frac{\pi}{180}$$

Q quadrant of Θ (1 to 5)

Φ Another angle in degrees

$$\phi = \tan^{-1}\left(\frac{\tan(\theta)}{0.91747}\right) * \frac{180}{\pi}$$

Now put Φ in the same quadrant as θ

if $\phi < 0$

$$\phi = \phi + Q * 90$$

otherwise

$$\phi = \phi + (Q - 1) * 90$$

Eqt equation of time (the difference between mean noon and true solar noon) in minutes

$$Eqt = 36.486 + 3.94244 * DOY - 4 * \phi$$

LTO Local Time Offset takes into account the difference between the station's longitude and the standard longitude of the timezone. It also takes care of the fact that we want Noon (instead of Midnight) to be zero. In minutes of time

$$LTO = \left(\frac{Lon_d}{15} - TZ + 12\right) * 60$$

HA hour angle of the sun (noon is zero) in radians

$$HA = \left(\frac{LTO + Eqt + Time_l}{4}\right) * \frac{\pi}{180}$$

h_r solar altitude angle in radians

$$h_r = \sin^{-1}\begin{pmatrix} \sin(Lat) * \sin(\delta) + \\ \cos(Lat) * \cos(\delta) * \cos(HA) \end{pmatrix}$$

h_d solar altitude angle in degrees

$$h_d = h_r * \frac{180}{\pi}$$

Cloud Cover

c cloud cover factor. Fraction of the sky covered by clouds (between 0.0 and 1.0)

if $h_d < 10$

Use the previous value for *c*

Otherwise, use the following equations:

G_{sc} Solar constant (extraterrestrial radiation, normal to the sun at 1 AU) in Watts per square meter

$$G_{sc} = 1367$$

R_a clear sky global radiation in Watts per square meter

$$R_a = \left(0.79 - \frac{3.75}{h_d}\right) * G_{sc} * \sin(h_r)$$

Make sure that R_s is <= R_a then calculate:

$$c = \left(1.333 - 1.333 * \frac{R_s}{R_a}\right)^{0.294}$$

Make sure c is between 0.0 and 1.0.

Albedo

I extraterrestrial radiation

$$I = G_{sc} * \sin(h_r)$$

α albedo (percent of visible light reflected from plant surface

$$if\ \frac{R_s}{I} < 0.375$$

$$\alpha = 0.26$$

otherwise

$$\alpha = 0.00158 * h_d + 0.386 * e^{(-0.0188 * h_d)}$$

$e_{d\text{-}mb}$ water vapor pressure in millibars

$$e_{d,mb} = e_d * 10$$

$\varepsilon_a(0)$ clear sky emissivity

$$\varepsilon_a(0) = 1.08 * \left(1 - e^{-\left(e_{d,mb}^{\left(\frac{T_k}{2016}\right)}\right)}\right)$$

σ Stefan Boltzmann constant that relates blackbody radiation to temperature.

$$\sigma = 5.67 * 10^{-8}\ W\ m^{-2}\ K^{-4}$$

R_c Net radiation in Watts per square meter

$$R_n = 0.89 * \left((1-\alpha) * R_s + (\varepsilon_a(0) * (1-c) + c - 0.98) * \sigma T_k^4\right)$$

Net Radiation on the GroWeather calculated on the Vantage

Here are the equations used in the Vantage to calculate net radiation

Input values

Lat_d Latitude of the station (N is positive) in degrees

Lon_d Longitude of the station (E is positive) in degrees

Z_f station altitude in feet

TZ timezone of the station (difference in time between the local civil time and UTC, PST = -8.0) in hours

D_l serial number of the day (number of days since Jan 1, 1900

$Time_l$ local civil time in minutes after midnight (0 – 1439)

Note that this is the time and date of the middle of the hour.

D_{UTC} the date in Greenwich at the same instant as $Time_l$ in days since Jan 1, 1900

$Time_{UTC}$ the time in Greenwich at the same instant as $Time_l$ in minutes

$$Time_{GMT} = Time_l - (TZ * 60)$$

$$\text{if } Time_{GMT} < 0$$

$$D_{GMT} = D_l - 1$$

$$Time_{GMT} = Time_{GMT} + 1440$$

$$\text{if } Time_{GMT} \geq 1440$$

$$D_{GMT} = D_l + 1$$

$$Time_{GMT} = Time_{GMT} - 1440$$

otherwise

$$D_{GMT} = D_l$$

Astronomical Values

D_{J2000} number of days (with fractions) since J2000.0 (i.e. 1/1/2000 12:00 noon)

$$D_{J2000} = \left(D_{GMT} - D_{1/1/2000}\right) - 0.5 + \tfrac{Time_{GMT}}{1440}$$

L' mean solar longitude in radians

$$L' = \left(280.46646 + 0.98564736 * D_{J2000}\right) * \tfrac{\pi}{180}$$

M mean solar anomaly in radians

$$M = \left(357.52911 + 0.985600281 * D_{J2000}\right) * \tfrac{\pi}{180}$$

C equation of the center is the difference between the mean and true values of longitude and anomaly, in radians

$$C = \begin{pmatrix} \left(1.914602 - 1.3188 * 10^{-7}\ D_{J2000}\right)\sin(M) + \\ \left(0.019993 - 2.765 * 10^{-9}\ D_{J2000}\right)\sin(2M) \end{pmatrix} * \frac{\pi}{180}$$

ϵ obliquity of the ecliptic in radians

$$\varepsilon = 23.43929$$

δ solar declination in radians

$$\delta = \sin^{-1}\left(\sin(L' + C) * \sin(\varepsilon)\right)$$

Equation of Time

e eccentricity of the earth's orbit

$$e = 0.016708634 - 0.0000000011509 * D_{J2000}$$

y intermediate value

$$y = \tan^2\left(\frac{\varepsilon}{2}\right)$$

Eqt_r equation of time (the difference between mean noon and true solar noon) in radians

$$Eqt_r = y\sin(2L) - 2e\sin(M) + 4ey\sin(M)\cos(2L)$$

Eqt_m equation of time in minutes

$$Eqt_m = Eqt_r * 4 * \frac{180}{\pi}$$

r distance between the earth and sun in AU

$$r = \frac{1.000001018 * \left(1 - e^2\right)}{1 + e * \cos(M + C)}$$

LTO Local Time Offset takes into account the difference between the station's longitude and the standard longitude of the timezone. It also takes care of the fact that we want Noon (instead of Midnight) to be zero in minutes of time

$$LTO = \left(\frac{Lon_d}{15} - TZ + 12\right) * 60$$

HA hour angle of the sun (noon is zero) in radians

$$HA = \left(\frac{LTO + Eqt + Time_l}{4}\right) * \frac{\pi}{180}$$

----

h_r solar altitude angle in radians

$$h_r = \frac{12}{\pi} * \left[\sin(Lat_r) * \sin(\delta) * \frac{\pi}{12} + \cos(Lat_r) * \cos(\delta) * \left(\sin\left(HA + \frac{\pi}{24}\right) - \sin\left(HA - \frac{\pi}{24}\right)\right)\right]$$

h_d solar altitude angle in degrees

$$h_d = h_r * \frac{180}{\pi}$$

Cloud Cover

c cloud cover factor. Fraction of the sky covered by clouds (between 0.0 and 1.0)

if h_d < 10

$$c = c_{saved}$$

Otherwise, use the following equations:

G_{sc} Solar constant (extraterrestrial radiation, normal to the sun at 1 AU) in Watts per square meter

$$G_{sc} = 1367$$

z_m station altitude in meters

$$z_m = z_f * 0.3048$$

Ra clear sky global radiation in Watts per square meter

$$R_a = \left(0.75 - \frac{z_m}{32}\right) * \frac{G_{sc}}{r^2} * \sin(h_r)$$

Make sure that R_s is <= R_a then calculate:

$$c = \left(1.333 - 1.333 * \frac{R_s}{R_a}\right)^{0.294}$$

Make sure that c is between 0.0 and 1.0, then calculate

c_{saved} cloud factor to use at night if this is the last hour with h_d > 10

$$c_{saved} = \mathrm{MAX}((c - 0.25), (0.0))$$

Albedo

I extraterrestrial radiation

$$I = \frac{G_{sc}}{r^2} * \sin(h_r)$$

α albedo (percent of visible light reflected from plant surface

$$if\ \frac{R_s}{I} < 0.375$$

$$\alpha = 0.26$$

otherwise

$$\alpha = 0.00158 * h_d + 0.386 * e^{(-0.0188 * h_d)}$$

$e_{d,mb}$ water vapor pressure in millibars

$$e_{d,mb} = e_d * 10$$

$\varepsilon_a(0)$ clear sky emissivity

$$\varepsilon_a(0) = 1.08 * \left(1 - e^{-\left(e_{d,mb}^{\left(\frac{T_k}{2016}\right)}\right)}\right)$$

σ Stefan Boltzmann constant that relates blackbody radiation temperature.

$$\sigma = 5.67 * 10^{-8}\ W\ m^{-2}\ K^{-4}$$

R_c Net radiation in Watts per square meter

$$R_n = 0.89 * \left((1-\alpha) * R_s + 0.98 * (\varepsilon_a(0) * (1-c) + c - 1) * \sigma T_k^4 \right)$$

ACCURACY

These equations were modeled after the ones used by the California Irrigation Management Information System (CIMIS), a program run by the California Department of Water Resources. Therefore, the accuracy of the Davis ET_o calculations are made against the ET_o calculations made by CIMIS. Some of the differences between Davis and CIMIS ET_o calculated values are due to differences in resolution, rather than accuracy.

There are two major factors that cause differences between Davis and CIMIS ET_o calculations: differences in sensor measurements, and differences in net radiation values.

On the GroWeather, all wind averages are in one mile per hour increments, whereas CIMIS data has a higher resolution. The Vantage Pro measures wind speed in one mile per hour increments, but maintains a higher resolution for hourly averages.

As explained above, there are several different ways to calculate a hourly average vapor pressure and saturation vapor pressure values. The CIMIS method is to calculate and sample the vapor pressure value as described for the Vantage Pro. However, the saturation vapor pressure is calculated from the average temperature. This method will produce a saturation vapor pressure that is equal or lower than the average of the sampled saturation pressures.

The net radiation formula given above are all approximations of the formula CIMIS uses. CIMIS either directly measures net radiation, or uses a formula that includes a provision for an empirically derived cloud cover factor. CIMIS determines this factor either from data collected at the site over a four year period, or from other sites in the same region. Twelve factors are determined, one for each month.

REFERENCES

General reference on ET
Jensen, M .E., Burman, R. D., Allen, R. G., Editors (1990) "*Evapotranspiration and irrigation water requirements.*" ASCE Manuals and Reports on Engineering Practice No 70.

Paper describing CIMIS' equations and methodology
Snyder, R. L., Pruitt, W. O. (1992). "Evapotranspiration Data Management in California" *Irrigation & Drainage Session Proceedings/Water Forum '92 EE, HY, IR, WR, div/ASCE*

Paper describing the net radiation equations used by the GroWeather PC calculation
Dong, A, Grattan, S. R., Carroll, J. J., Prashar, C. R. K. (1992). "Estimation of net radiation over well-watered grass." *J. of Irrigation and Drainage Engineering*, Vol. 118, No. 3 ASCE

Web sites with useful information
CIMIS home page
http://wwwdpla.water.ca.gov/cgi-bin/cimis/cimis/hq/main.pl

Provides some guidelines for water requirements for growing landscape plants in California
http://wwwdpla.water.ca.gov/urban/conservation/landscape/wucols/index.html

Sunrise/Sunset

Parameters Used: Latitude, Longitude, Time and Date, Time Zone, Daylight Savings Time Setting

Sunrise and sunset is a matter of finding when, local time, the sun is on the horizon. The following equations describe the position of the sun in the sky:

Solar altitude, α, is the angular distance of the sun above the horizon, given by:

$\sin \alpha = \sin \phi \sin \delta + \cos \phi \cos \delta \cos h$

ϕ is latitude, δ is the declination angle of the sun, h is the hour angle

declination angle is the latitude on the earth at which the sun is directly overhead (south latitudes are indicated as a negative number)

hour angle is the non-negative angular distance east or west from directly overhead

These formulas indicate the true geometric position of the sun. When the sun is on the horizon (as in the case of sunrise and sunset), refraction by the atmosphere will alter the apparent position of the sun. Under average conditions, the sun will appear at the horizon when it is actually 34' (0.567°) below the horizon. Since sunrise and sunset is defined as when the upper half of the sun is visible on the horizon, and the radius of the sun when on the horizon is 16' (0.267°), sunrise and sunset are defined when the geometric position of the sun is 50' (0.833°) below the horizon. This is especially critical in polar regions.

The report also generates twilight times. There are three separate twilight times listed for both morning and evening:

Astronomical Twilight (Astro) is defined as the time at which the center of the sun is 18° below the horizon. At this time, stars and planets of sixth magnitude are visible directly above and generally there is no trace of twilight glow on the horizon. It's the time of complete darkness without an artificial light source.

Nautical Twilight (Naut) is defined as the time at which the center of the sun is 12° below the horizon. Distinguishing the outlines of objects on the ground is impossible past this point toward darkness, thus it marks the point at which navigation is impossible without an artificial light source.

Civil Twilight (Civil) is defined as the time at which the center of the sun is 6° below the horizon. At this time, stars and planets of first magnitude are visible and suspension of outdoor activities is required (on a clear day) without artificial lighting. Civil twilight is roughly 30 minutes long during the equinox.

The procedure to calculate any of these parameters is as follows. Details on the equations used and time convention and unit conversions follow this brief description:

1. First assume that a sunrise event occurred at 6:00 am local time, a sunset event at 6:00 pm local time. The equations used to describe the position of the sun already require a time, so we must make a first "guess" as to when the event will be.
2. Convert this local time to UTC time. The equations used to define the position of the sun (in this case, on the horizon) use UTC time.
3. Calculate the **declination** and subsequently the **hour angle** of the sun using this UTC time and the specified solar altitude of the given event.
4. Convert the resultant **hour angle** (which is in geometric coordinates) to UTC time.
5. Take the resultant UTC time to again *recalculate* the **declination** and subsequently the **hour angle** using this more accurate indication of the position of the sun.
6. Convert the resultant **hour angle** (which is in geometric coordinates) to UTC time.

To calculate the **hour angle** of the sun, *h*, at the given altitude (which is defined by sunrise/sunset or the twilight parameters), so rearranging the equation for the sun's altitude above for the hour angle, we get:

$$\cos h = \frac{\sin \alpha - \sin \phi \sin \delta}{\cos \phi \cos \delta}$$

If the result of this equation is undefined, that is, cos *h* > 1 or *h* < 1, then the event did not occur.

Otherwise, we can solve for $\cos^{-1}(h)$. The value of *h* here is an angle, which must be converted to a 24 hour time base. The procedure is as follows:
Convention: h = 0 = midnight, *h* = 90 = 6:00 am, *h* = 180 = noon, *h* = 270 = 6:00 pm
If h is determined to be a sunrise, then (180 – *h*)/15 is the value in hours (and fractions of hours), otherwise
If *h* is determined to be a sunset, then (180 + *h*)/15 is the value in hours (and fractions of hours)
The result is in **solar time**, which, in this convention, at Noon, the **mean sun** is at its highest point in the sky for the day, which can differ considerably from local time.

The sun's **declination** angle, δ, is determined as follows:

$\delta = \sin^{-1}(\sin T \sin \epsilon)$

$T = L + C$

L = (280.46646 + 0.98564736**days*)

C = ((1.914602-0.00000013188**days*)*sin *M* +
(0.019993-0.000000002765*days)*sin 2*M*)

$\epsilon = 23.43929°$

M = (357.52911 + 0.985600281**days*)

where *days* (including fractional days) is the number of days since Jan 1st, 2000, 12:00 UTC in UTC

T is the true anomaly of the sun (the angular distance between where the earth is closest to the sun is its orbit and the actual position in orbit)

L is the mean longitude of the sun (mean angular distance measured around the earth's orbit from the position at the time of equinox)

C is the center of the sun or the difference between the true, *T*, and mean, *M*, anomalies of the sun (determines the location of the sun resolving the differences between the actual position of the sun and the position the sun would have if the earth's angular motion were uniform)

M is the mean anomaly of the sun (same as true anomaly except it assumes the earth moves around the sun at a constant angular velocity), same as mean anomaly of the earth

ϵ is the obliquity of the earth (the amount the earth is tilted on its axis), which is constant for a century or so (It has an error in the year 2100 of only 0.013° when this constant is used.)

Note: these equations assume that the sun revolves around the earth, for simplicity. However, when addressing the positions in orbit, it is actually the earth revolving around the sun, so this should be understood when trying to understand the physical meaning described in the definitions.

Time Conversions

First, convert local mean solar time to local actual solar time. (Note: When calculating sunrise and sunset, the 6:00 am or 6:00 pm local time is considered actual solar time for simplicity. In the second iteration, when higher precision is needed, the result, local mean solar time, is corrected to actual solar time):

Actual Solar Time = Local Mean Solar Time – E

$E = y \sin 2L - 2e \sin M + 4ey \sin M \cos 2L$

where e is eccentricity of the earth's orbit (how much of an elliptical shape it has) as described below, and M is the sun's mean anomaly and L is the sun's mean longitude as described earlier

$e = 0.016708634 - 0.0000000011509 * days$

$y = \tan^2 (\epsilon / 2)$

where ϵ is obliquity as described earlier

The equation of time must be taken into account in order to determine the exact local time (as opposed to the local mean time). This specifies the difference between apparent time and mean time. Stated another way, it is the difference between the true position of the sun and the mean position of the sun. The mean sun assumes that its motion across the sky is uniform.

Then to convert to actual local solar time to local civil time (local civil time is refers to the time convention used by the public at large within a given time zone), take into account how far west or east of the "standard meridian" for their particular time zone. Fractions of minutes must be incorporated to avoid rounding errors. The **standard meridian** is determined as follows:

Standard Meridian = |(UTC Offset)| * 15

UTC Offset should include whether or not Daylight Savings Time is currently in use and be the absolute value or always positive value of the offset in this case.
Then, determine the offset from the standard meridian in hours:

Local Offset = (Standard Meridian - Longitude) / 15

Summarized, the formula for determining sunrise and sunset in local civil time:

Local Civil Time = Mean Solar Time – E + Local Offset

The Davis software further converts the results into UTC so a standard time base is used and thus, it is much easier to use any combination of Time Zone and latitude/longitude coordinates. Some may prefer to have the sunrise/sunset times in UTC. Others, for example, may want to determine what time it is in San Francisco when the sunrise in Tokyo occurs. Here is the relationship between UTC and local civil time:

UTC = Local Civil Time – UTC Offset

In general, UTC offsets are negative if the longitude is west, positive if east. The UTC Offset includes any corrections for Daylight Savings Time (if specified) and must be converted into hours and minutes as needed.

To convert between days, hours and minutes the following formulas may be used:

convert hours to days, hours / 24	convert minutes to days, minutes / 1440
convert days to hours, days * 24	convert minutes to hours, minutes / 60
convert days to minutes, days * 1440	convert hours to minutes, hours * 60

Retain fractional values to provide sufficient resolution, (e.g., days to 0.0001 resolution to obtain minutes)

REFERENCES

Meeus, Jean: "Astronomical Algorithms". Willman-Bell, Richmond, VA, 2nd Ed. 1998.

"Smithsonian Meteorological Tables". Smithsonian Institution Press, Washington, DC, 4th Ed. 1968.

WeatherLink Reports

NOAA Monthly Summary

General station information (Station Name, City, State, Units of Measure, etc.) appears at the top of the report. For each day in the report, you can view the following information (and a total for the month):

Day - Each row in the report shows information for a single day. The date for each row appears at the left of the row.
Mean Temperature - The mean temperature for the day. At the bottom of the column, the mean temperature for the month is displayed. The mean temperature is derived using all the Temp Out data values collected throughout the day. If "Calculate using integration method" is checked in the Degree-Day section of the NOAA setup dialog window, then the mean temperature is calculated by adding up all the temperature measurements for that day and then dividing by the number of samples. If "Calculate using integration method" is not checked in the NOAA setup, the mean temperature is the average of the daily high and low temperatures.
High Temperature & Time - The high temperature for the day and the time at which it occurred. At the bottom of the column, the highest temperature recorded during the month and the day on which it occurred is displayed. The time is the archive record time which contained the highest temperature for that day.
Low Temperature & Time - The low temperature for the day and the time at which it occurred. At the bottom of the column, the lowest temperature recorded during the month and the day on which it occurred is displayed. The time is the archive record time which contained the lowest temperature for that day.
Heating Degree-Days - The number of heating degree-days accumulated on each day. At the bottom of the column, the total heating degree-days accumulated during the month is displayed. Heating degree-days can be calculated using either the high/low summary or the integration methods.
Cooling Degree-Days - The number of cooling degree-days accumulated on each day. At the bottom of the column, the total cooling degree-days accumulated during the month is displayed. Cooling degree-days can be calculated using either the high/low summary or the integration methods.
Rain - The rainfall accumulated on each day. At the bottom of the column, the total rainfall accumulated during the month is displayed.
Average Wind Speed - The average wind speed for each day. At the bottom of the column, the accumulated average wind speed during the month is displayed.
High Wind Speed & Time - The high wind speed for each day and the time at which it occurred. At the bottom of the column, the highest wind speed for the month and the day on which it occurred is displayed.
Dominant Wind Direction - The dominant (a.k.a., prevailing) wind direction for the day. At the bottom of the column, the dominant wind direction for the month is displayed. The dominant wind direction is the wind direction that occurred most often throughout the day. In the event of a tie, the direction closest to the north going counter-clockwise around the wind rose is the result.

At the bottom of the report, the following monthly information is summarized:

Max >= 90°F (32°C) - The number of days on which the daily high temperature was 90°F (32°C) or above.
Max <= 32°F (0°C) - The number of days on which the daily high temperature was 32°F (0°C) or below.
Min <= 32°F (0°C) - The number of days on which the daily low temperature was 32°F (0°C) or below.
Min <= 0°F (-18°C) - The number of days on which the daily low temperature was 0°F (-18°C) or below.
Max Rain - The maximum daily rainfall during the month.
Days of Rain - The number of days on which rainfall exceeded 0.01" (0.2 mm), 0.1" (2 mm), or 1" (20 mm) is displayed.

Note: Max/Min thresholds are always in whole degrees. It's therefore possible for the number of days in these last four items to be different, depending on whether you're using US or metric units. For example, if there were a daily high registered between 89.6°F and 89.9°F the maximum would not count as >= 90°F; however, if you were using metric units, the maximum would count as >= 32°C (the equivalent of 90°F).

NOAA Yearly Summary

General station information (Station Name, City, State, Units of Measure, etc.) appears at the top of the report. Below the general information section are separate temperature, rainfall, and wind summary sections.

NOAA Yearly Temperature Summary

For each month in the NOAA Yearly Summary, you may view the temperature information listed below (and total and average for the year). The NOAA Yearly Summary also contains a rainfall and a wind summary section.

Year & Month - Each row in the report shows information for a single month. The month and year appear at the left of the row.
Mean Max - The mean maximum temperature for the month. At the bottom of the column, the mean maximum temperature for the year is displayed.
Mean Min - The mean minimum temperature for the month. At the bottom of the column, the mean minimum temperature for the year is displayed.
Mean - The mean temperature for the month. At the bottom of the column, the mean temperature for the year is displayed.
Departure From Norm - The amount by which the mean temperature departed from normal for the month. At the bottom of the column, the amount by which the mean temperature departed from normal for the year is displayed.
Heating Degree-Days - The number of heating degree-days accumulated during each month. At the bottom of the column, the total heating degree-days accumulated during the year is displayed. Heating degree-days can be calculated using either the high/low summary or the integration methods.
Cooling Degree-Days - The number of cooling degree-days accumulated during each month. At the bottom of the column, the total cooling degree-days accumulated during the year is displayed. Cooling degree-days can be calculated using either the high/low summary or the integration methods.
High Temperature & Date - The highest temperature for the month and the date on which it occurred. At the bottom of the column, the highest temperature recorded during the year and the month in which it occurred is displayed.
Low Temperature & Date - The lowest temperature for the month and the date on which it occurred. At the bottom of the column, the lowest temperature recorded during the year and the month in which it occurred is displayed.
Max >= 90°F (32°C) - The number of days on which the high temperature was 90°F (32°C) or above during the month. At the bottom of the column, the total number of days on which the high temperature was 90°F (32°C) or above during the year is displayed.
Max <= 32ºF (0°C) - The number of days on which the high temperature was 32°F (0°C) or below during the month. At the bottom of the column, the total number of days on which the high temperature was 32°F (0°C) or below during the year is displayed.
Min <= 32°F (0°C) - The number of days on which the low temperature was 32°F (0°C) or below during the month. At the bottom of the column, the total number of days on which the low temperature was 32°F (0°C) or below during the year is displayed.
Min <= 0°F (-18°C) - The number of days on which the low temperature was 0°F (-18°C) or below during the month. At the bottom of the column, the total number of days on which the low temperature was 0°F (-18°C) or below during the year is displayed.

Note: Thresholds are always in whole degrees. It’s therefore possible for the number of days in these last four items to be different, depending on whether you’re using US or metric units. For example, if there were a daily high registered between 89.6 and 89.9°F the maximum would not count as >= 90°F; however, if you were using metric units, the maximum would count as >= 32°C (the equivalent of 90°F).

NOAA Yearly Rainfall Summary

For each month in the NOAA Yearly Summary, you can view the rainfall information listed below (and total and average for the year). The NOAA Yearly Summary also contains a Temperature and a Wind summary section.
Year & Month - Each row in the report shows information for a single month. The month and year appear at the left of the row.
Total - The total rainfall for the month. At the bottom of the column, the total rainfall for the year is displayed.
Departure From Norm - The amount by which the total rainfall departed from normal for the month. At the bottom of the column, the amount by which the total rainfall departed from normal for the year is displayed.
Maximum Observation Day & Date - The highest daily rainfall total during the month and the date on which it occurred. At the bottom of the column, the highest daily rainfall total during the year and the month during which it occurred are displayed.
Days of Rain Over .01 in (0.2 mm) - The number of days on which total rainfall exceeded 0.01" (0.2 mm) during the month. At the bottom of the column, the number of days on which rainfall exceeded 0.01" (0.2 mm) during the year is displayed.
Days of Rain Over .1 in (2 mm) - The number of days on which total rainfall exceeded 0.1" (2 mm) during the month. At the bottom of the column, the number of days on which rainfall exceeded 0.1" (2 mm) during the year is displayed.
Days of Rain Over 1.0 in (20 mm) - The number of days on which total rainfall exceeded 1" (20 mm) during the month. At the bottom of the column, the number of days on which rainfall exceeded 1" (20 mm) during the year is displayed.

NOAA Yearly Wind Summary

For each month in the NOAA Yearly Summary, you may view the wind information listed below (and an average for the year). The NOAA Yearly Summary also contains a temperature and a rainfall summary section.
Year & Month - Each row in the report shows information for a single month. The month and year appear at the left of the row.
Average - The average wind speed for the month. At the bottom of the column, the average wind speed for the year is displayed.
High & Date - The high wind speed for the month and the date on which it occurred. At the bottom of the column, the highest wind speed recorded during the year and the month in which it occurred is displayed.
Dominant Direction - The dominant (a.k.a., prevailing) wind direction for the month. At the bottom of the column, the dominant wind direction during the year is displayed. The dominant wind direction is the wind direction that occurred most often throughout the month. In the event of a tie, the direction closest to the north going counter-clockwise around the wind rose is the result.

Heating & Cooling Degree-Days

Although degree-days are most commonly used in agriculture, they are also useful in building design and construction, and in fuel use evaluation. The construction industry uses heating degree-days to calculate the amount of heat necessary to keep a building, be it a house or a skyscraper, comfortable for occupation. Likewise, cooling degree-days are used to estimate the amount of heat that must be removed (through air-conditioning) to keep a structure comfortable. Just like growing degree-days, heating and cooling degree-days are based on departures from a base temperature. 65ºF is almost always used as this base.

One heating degree–day is the amount of heat required to keep a structure at 65ºF when the outside temperature remains one degree below the 65ºF threshold for 24 hours. One heating degree–day is also the amount of heat required to keep that structure at 65ºF when the temperature remains 24°F below that 65ºF threshold for 1 hour.

Likewise, one cooling degree–day is the amount of cooling required to keep a structure at 65ºF when the outside temperature remains one degree above the 65ºF threshold for 24 hours. One cooling degree–day is also the amount of cooling required to keep that structure at 65ºF when the temperature remains 24°F above that 65ºF threshold for 1 hour.

Depending on the calculation method, both heating and cooling degree-days can accumulate in the same day. Also, note that there are no negative degree-days. If the temperature remains below the threshold, there is no degree-day accumulation.

Heating and Cooling degree-days may be calculated by either the **High/Low method** or the **Integration method**.

Below are some representative heating and cooling degree-day totals from different parts of the United States.

Barrow, Alaska		Key West, Fla.	
Heating degree days	20,370	Heating degree days	68
Cooling degree days	0	Cooling degree days	4,820
Kansas City, Mo.		Hilo, Hawaii	
Heating degree days	5,326	Heating degree days	0
Cooling degree days	1,388	Cooling degree days	3,134
Bismarck, N.D.		Yuma, Ariz.	
Heating degree days	8,932	Heating degree days	983
Cooling degree days	499	Cooling degree days	4,244

Table data source: Williams, Jack. 1995. The USA TODAY Weather Almanac.

Growing Degree Days

Because temperature plays an important part in the rate of development of plants and many diseases and pests (especially insects), a measurement including the accumulation of heat with passing time is necessary to predict maturation. Growing degree-days provide a measure for calculating the effect of temperature on the development of plants and pests. One growing degree-day is the amount of heat that accumulates when the temperature remains one degree above the base developmental threshold for 24 hours. One growing degree–day is also the amount of heat that accumulates when the temperature remains 24° above the base threshold for 1 hour. Note that there are no negative degree-days. If the temperature remains below the threshold, there is no degree-day accumulation.

Unlike strict time predictions of plant or pest development, growing degree-day predictions hold true regardless of location or temperature fluctuations. As long as you know the number of degree-days necessary for plant/pest development, you may use degree-days as an accurate predictor. For example, you may know that it takes, in general, three weeks for a specific pest to develop. What you will find, however, is that the pest may take 4 weeks to develop in cooler weather and only 2 weeks to develop in warmer weather. The time prediction can be off by up to a week by looking at time alone, while the degree–day prediction should result in far greater accuracy.

Degree-Day Calculation Methods

The WeatherLink software uses the outside temperature data in conjunction with the base and upper thresholds entered for each crop/pest to calculate degree-days. You can choose between three possible methods for calculating degree-days: the growing degree-day cutoff method, the high/low method or the integration method.

Growing degree-day cutoff method

If you select the cutoff method, the software uses the highest and lowest temperatures for a given day to calculate the average for that day. Note, however, that if the low temperature is below the base threshold, the software uses the base threshold as the low temperature when calculating the average temperature for the day. In addition, if the high temperature is above the upper threshold, the software uses the upper threshold as the high temperature when calculating the average temperature. For this method to work, you must have entered the upper and lower thresholds.

The difference between the average temperature and the base threshold is assumed to be the number of degree-days accumulated on that day. (For example, if the average of the highest and lowest temperatures was 24° above the base threshold, the software would assume 24 degree-days for the entire day.

Note: Unless 15 hours worth of records exist in the database for that day (from midnight to 3pm, for example), the software will not calculate degree-days for that day.

High / Low method

If you select the high/low method, the software uses the highest temperature and the lowest temperature for a given day to calculate the average temperature for that day. The difference between the average temperature and the base threshold are assumed to be the number of degree-days accumulated on that day. For example, if the average of the highest and lowest temperatures is 24° above the base threshold, the software assumes 24 degree–days for the entire day.

Note: Unless 15 hours worth of records exist in the database for that day (from midnight to 3pm, for example), the software will not calculate degree-days for that day.

Integration method

If you select the integration method, the software calculates degree–days using the average temperature for an interval and the interval time. For example, if the average temperature during a 15 minute interval was 24° above the base threshold, the software would calculate 0.25 degree-days during that interval (24 * 15 minutes in interval/1440 minutes per day). The number of degree-days during each interval are added together to arrive at a degree-day total. This method calculates degree-day totals more accurately than the high/low method.

Temperature-Humidity Hours Report

Certain pests (in particular, some molds) develop most aggressively under specific combinations of temperature and humidity. Each pest can be expected to emerge when a specific number of temperature/humidity hours has accumulated. Temperature/Humidity hours, therefore, can be used to select the optimum time for application of preventative measures. The use of pesticides can be minimized and, when needed, used more efficiently and effectively. For more information, contact your local agricultural agent or university agricultural extension.

The temperature-humidity hours report contains the following information:

Name, Start Date, Thresholds - The report shows the name, start date, and the thresholds you entered.
Days Occurred - The report shows the number of days on which temperature-humidity hours accumulated.
Total for prior 3 days - The report shows the number of temperature-humidity hours accumulating on each of the past 3 days.
Development Total - The report shows the development total you entered.
Hours to Go - The report shows the total temperature-humidity hours left before the development total is reached.
Days to Go - The report shows the expected number of days before the development total is reached. This calculation is based on the average number of temperature-humidity hours during the last three complete days.

Soil Temperature Hours Report

Soil temperature hours can be used to monitor the relative portion of time that soil temperature is above freezing (or some other threshold) in order to select a time to plant. For more information, contact your local agricultural agent or university agricultural extension.

The soil temperature hours report contains the following information:

Total - The total number of soil temperature hours accumulating during the selected period of time.
Start Date, End Date, Threshold - The report shows the start and end dates and the threshold you entered.
Hours for the last 15 days - The report shows the number of soil temperature hours accumulating on each of the past 15 days.

Chilling Requirement Report

Certain fruit trees bear best when temperatures drop below specific levels for specific amounts of time during the dormant season. Chilling requirements provide a measure of this dormancy. For more information, contact your local agricultural agent or university agricultural extension.

The software calculates the number of hours of chilling for the selected period and displays that information at the bottom of the dialog box.

Bright Sunshine Hours Report

This report is only available in version 5.2 of the WeatherLink for Vantage Pro software.

WeatherLink can calculate the total hours of bright sunshine during any given period. To do so, you must enter a solar energy threshold above which is considered "bright sunshine". The default is 100 W/m2. WeatherLink calculates the amount of time the solar energy was above the threshold and reports that amount of time as the hours of daylight.

WeatherLink calculates and displays the hours of daylight accumulated between the start and end dates. The report is opened into Window's Notepad, from which you can print or copy the information. The report shows the total hours of daylight that occurred during the selected period of time, the selected start and end dates for the report and the solar radiation threshold used to determine "daylight", and the hours of daylight which occurred on each of the last 15 days of the report time period.

Leaf Wetness Hours Report

This report is only available in version 5.2 of the WeatherLink for Vantage Pro software.

You may track the number of hours during which temperature fell within a certain range and a leaf wetness threshold was exceeded.

The software calculates leaf wet hours and displays that information. The report is opened into Windows' Notepad from which you may copy or print the report information. The report shows the total leaf wet hours during the selected period, the start and end dates and the temperature and wetness the thresholds you entered, and the total leaf wet hours for each of the past 30 days.

Total ET Report

This report is only available in version 5.2 of the WeatherLink for Vantage Pro software.

You may calculate the total ET (evapotranspiration) which has occurred since a specified start date using a single K factor for the entire period.

Crop-specific K factors allow you to calculate evapotranspiration rates more accurately by allowing you to factor in the different transpiration rates of different crops at different stages in the growth cycle. A K factor of 1.0 is used for well watered grass that completely covers the ground and is uniformly clipped to a few inches in height. If a crop transpires more or less then average then the K factor is adjusted up or down. A K factor of 1.25 is used if the crop transpires 25% more than grass. A K factor of 0.80 is used if the crop transpires 20% less than grass. More information on ET K factors can be found at the following URL:
http://lawr.ucdavis.edu/coopextn/biometeorology/evapotranspiration/CropCoef/crop_coefficients.htm

The software calculates ET for the selected period and displays that information. The report is opened into Windows' Notepad from which you may copy or print the report information. The report shows the total ET since the start date, the start and end dates and the K factor you entered, and the total ET on each of the last 30 days.

Note: Do not use a K factor of 1.00 for alfalfa.

Fuel Demand Report

This report is only available in version 5.2 of the WeatherLink for Vantage Pro software.

The software includes a versatile fuel demand feature which allows you to track fuel demand for a hundreds of customers. The list shows all entered fuel customers. The check box at the bottom of the screen allows you to select the method by which the software calculates heating degree-day totals. By default, the software calculates heating degree-days using the average temperature for an interval and the interval time. For example, if the average temperature during a 15 minute interval was 75°F, the software would calculate 2.5 degree-hours during that interval for a base threshold of 65°F (10° * 15 minutes / 60 minutes). The number of degree-hours during each interval since the start date are added together to arrive at a heating degree-day total for use in estimating fuel usage.

You may select (by checking the check box) to have the software use the high/low method for calculating heating degree-days instead. In this method, the software uses the highest temperature and the lowest temperature to calculate the average temperature for each day. It then calculates heating degree-days by multiplying the number of degrees by which this "average" exceeds the heating degree day threshold by 24 hours.

To view an estimate of the remaining fuel for a customer, open the customer’s record and choose Estimate. The software calculates the heating degree-days since the last reading date (using the heating degree day threshold entered from the software) and calculates fuel usage based on this number of degree days. The estimated fuel used is subtracted from the number of gallons at the last reading to arrive at an estimate of the number of gallons remaining. The estimated gallons left is shown at the bottom of the dialog box.

Fuel Demand K factors allow you to calculate fuel demand more accurately by factoring in the different fuel consumption rate each customer has for a given number of heating degree-days. A K factor of 1.0 is used when degree days equals fuel consumption. If a customer uses more or less fuel then the K factor is adjusted up or down. The Fuel Demand report will also calculate the K factor based on past usage, and also allows you to edit the K factor if you wish.

WeatherLink Data Types

Parameter	Data Type	Size (bytes)	Sample Rate
Inside Temp	Current or Average	2	1 minute
Outside Temp	Current or Average	2	10-12 secs.
Hi Outside Temp	Highest	2	10-12 secs.
Low Outside Temp	Lowest	2	10-12 secs.
Inside Hum	Current	1	1 minute
Outside Hum	Current	1	50-60 secs.
Barometer	Current	2	15 minutes
Wind Speed	Average	2	2.5-3 secs.
Hi Wind Speed	Highest	2	2.5-3 secs.
Direction of Hi Wind		1	2.5-3 secs.
Wind Direction	Dominant (prevailing)	1	2.5-3 secs.
Wind Run	Total	Not stored	Calculated
Wind Chill	Average	Not stored	Calculated
Rain	Total	2	10-12 secs.
Rain Rate	Highest	2	10-12 secs.
Dewpoint	Current	Not stored	Calculated
Heat Index	Current	Not stored	Calculated
THW Index	Current	Not stored	Calculated
Solar Radiation	Average	2	50-60 secs.
Solar Energy	Total	Not stored	Calculated
Hi Solar Rad*	Highest	2	50-60 secs.
UV Radiation	Average	1	50-60 secs.
UV Dose	Total	Not stored	Calculated
Hi UV Index*	Highest	1	50-60 secs.
Heating Degree Days	Total	Not stored	Calculated
Cooling Degree Days	Total	Not stored	Calculated
ET	Total	1	1 hour
Leaf Wetness*	Current	1	62.5-75 secs.
Soil Moisture	Current	1	62.5-75 secs.
Leaf Temperature*	Current	1	62.5-75 secs.
Soil Temperature	Current	1	62.5-75 secs.
ISS Data Packets Received	Total	2	2.5-3 secs.
ISS Reception	Current	Calculated	Calculated
Archive Interval	Not Logged**	1	1 minute

*Available only with Revision B firmware in the display console

**value is stored in the WeatherLink database on the computer

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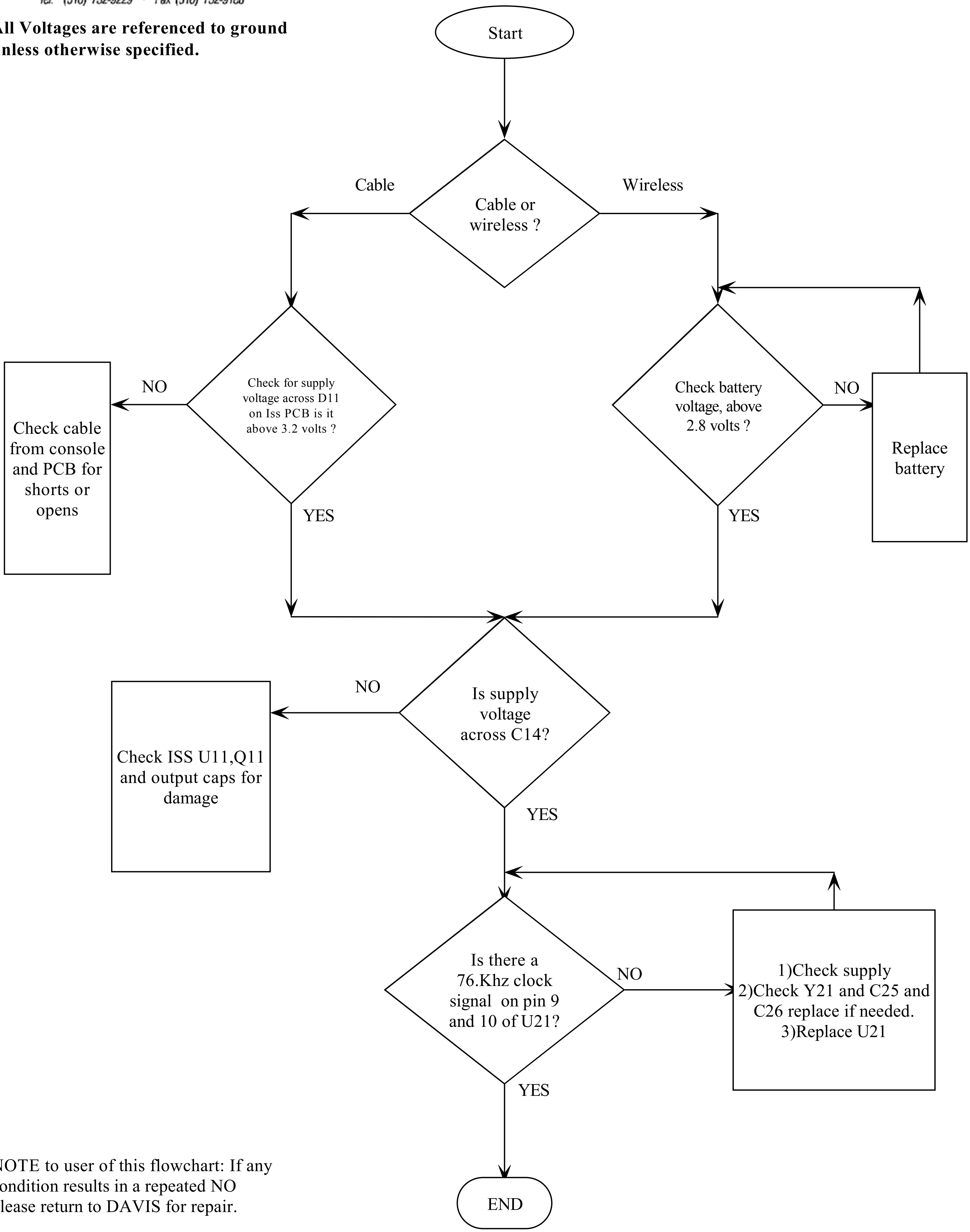
ISS Microprocessor Troubleshooting

Problem: console not recieving data from ISS station

All Voltages are referenced to ground unless otherwise specified.



NOTE to user of this flowchart: If any condition results in a repeated NO please return to DAVIS for repair.

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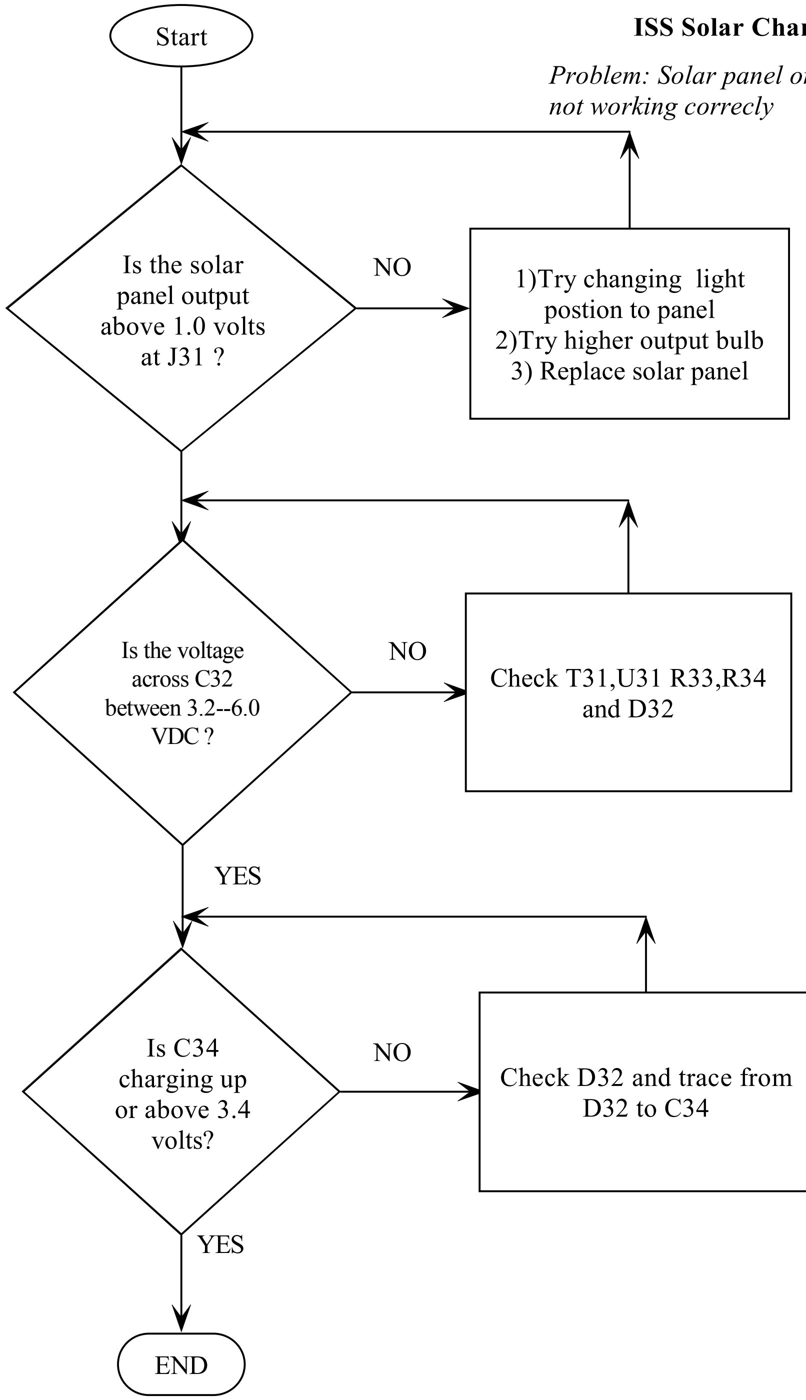
ISS Solar Charger

Problem: Solar panel or Super Cap not working correcly

All Voltages are referenced to ground unless otherwise specified.
Setup condition
1)Solar panel plugged in to J31
2)Sunlight or a 40watt bulb shining directly on solar panel



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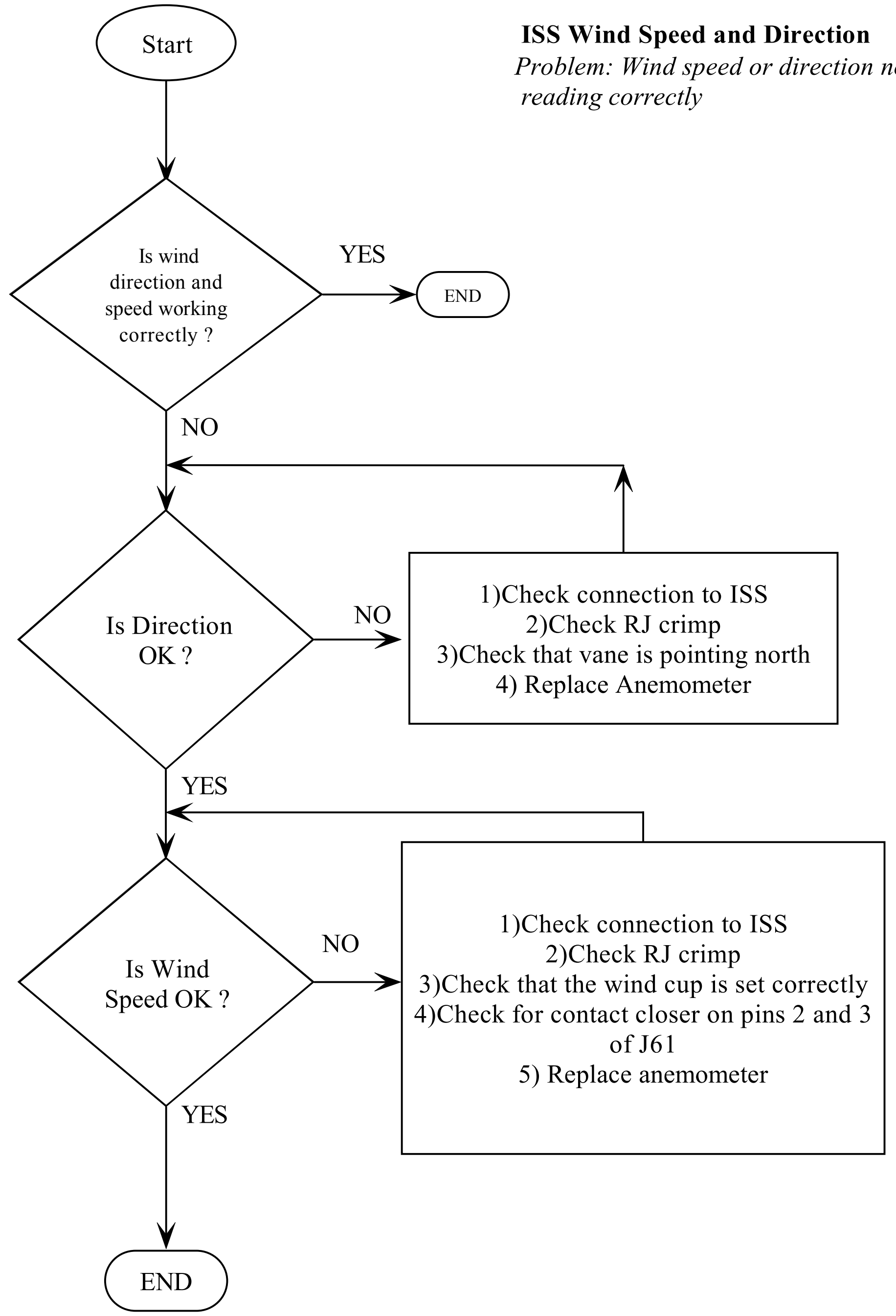
ISS Wind Speed and Direction

Problem: Wind speed or direction not reading correctly

All Voltages are referenced to ground unless otherwise specified.

Setup conditions are Anemometer plugged in and ISS PCB is powered and console recieveing packets (X) of data.



NOTE to user of this flowchart: If any condition results in a repeated NO please return to DAVIS for repair.

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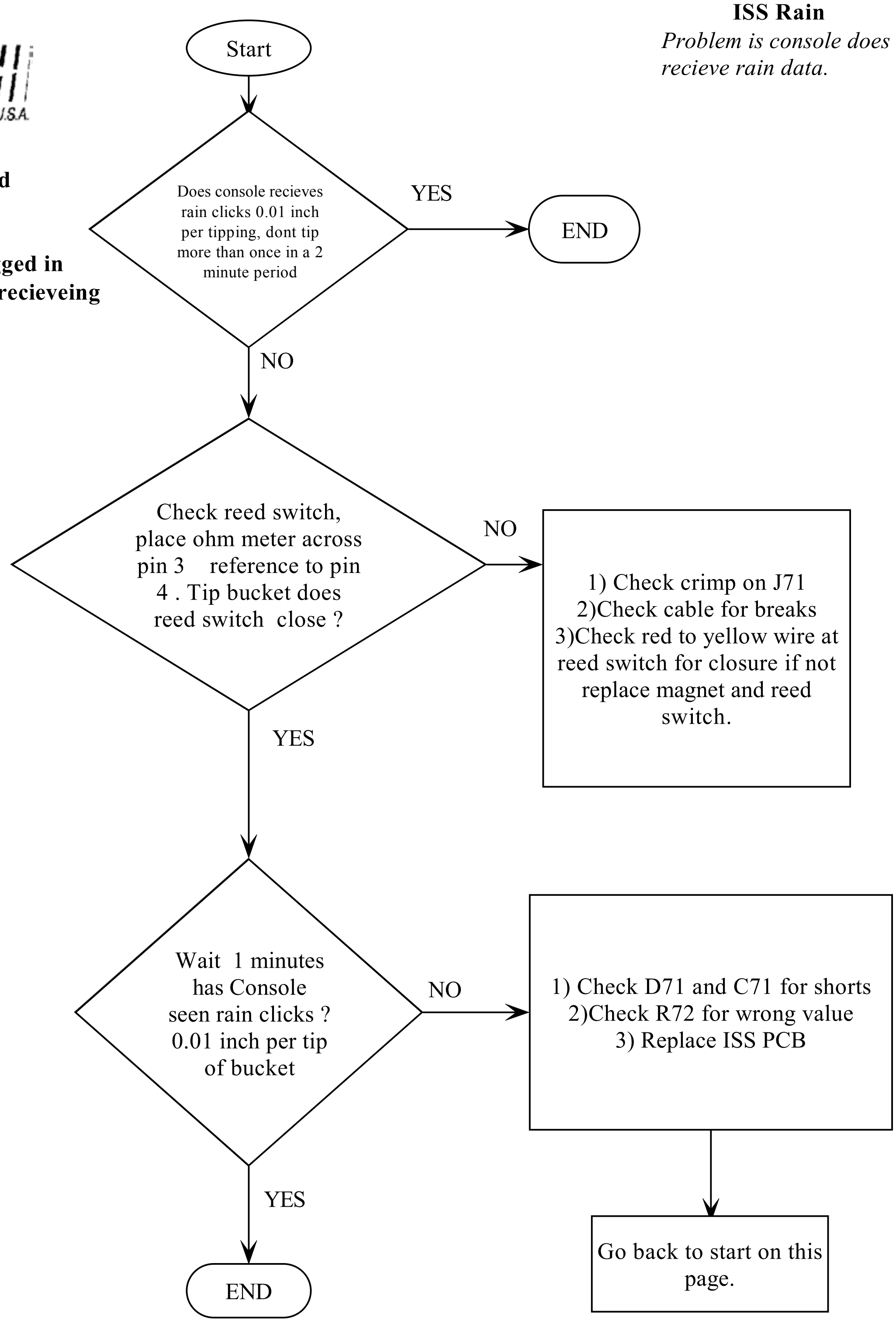
All Voltages are referenced to ground unless otherwise specified.

Setup conditions are rain bucket plugged in and ISS PCB is powered and console recieveing packets (X) of data.

ISS Rain

Problem is console does not recieve rain data.



NOTE to user of this flowchart: If any condition results in a repeated NO please return to DAVIS for repair.

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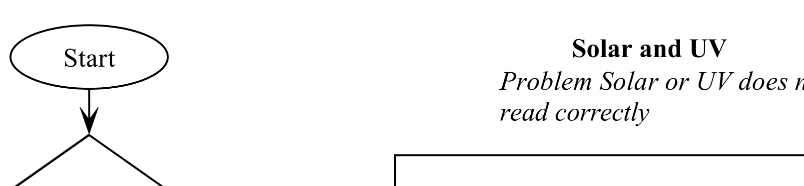
All Voltages are referenced to ground

Solar and UV

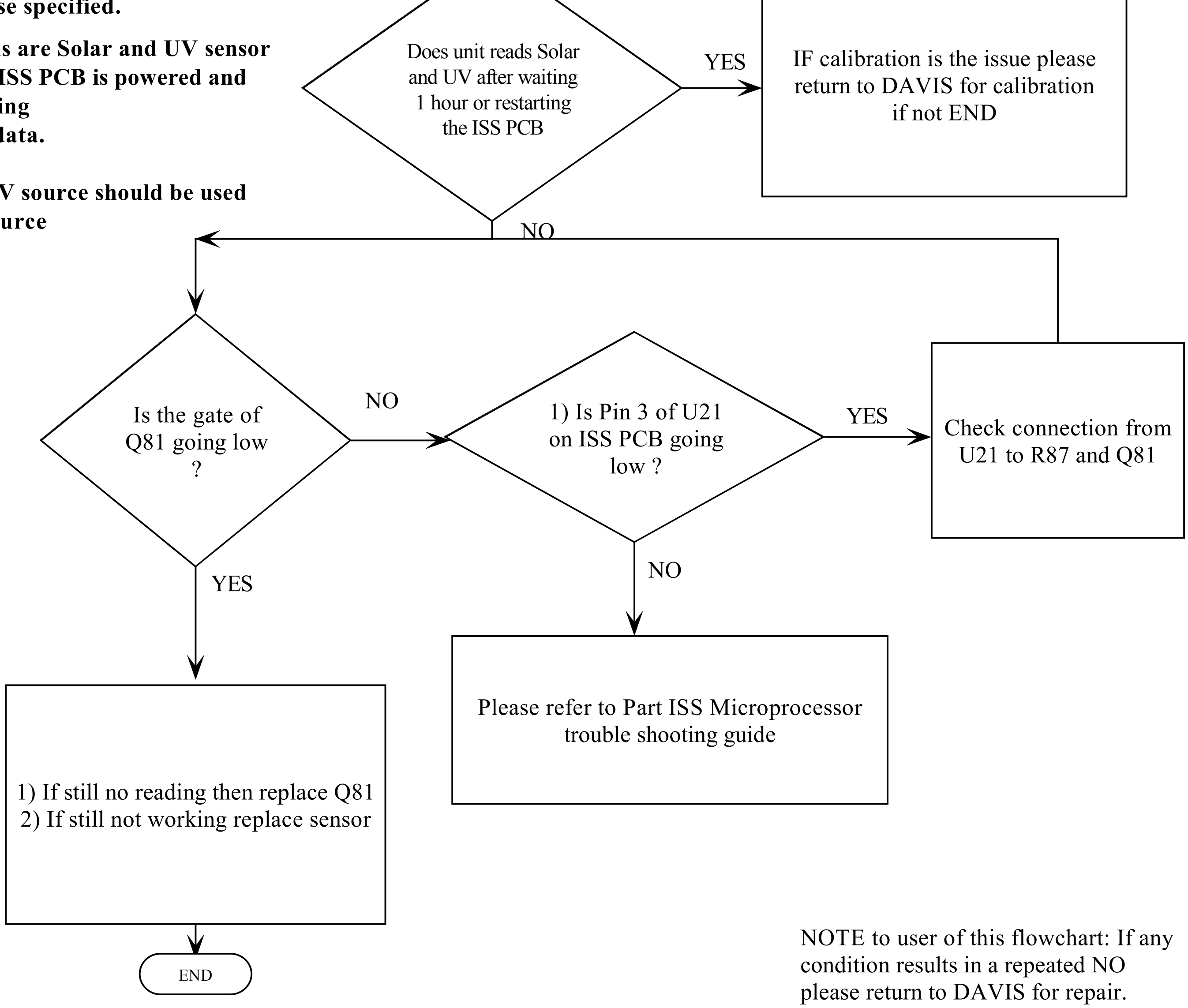
Problem Solar or UV does not read correctly



unless otherwise specified.

Setup conditions are Solar and UV sensor plugged in and ISS PCB is powered and console recieveing packets (X) of data.

The Sun or a UV source should be used to stimulate source



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ISS Outside Temperature

Problem : Outside temperature does not read correctly.

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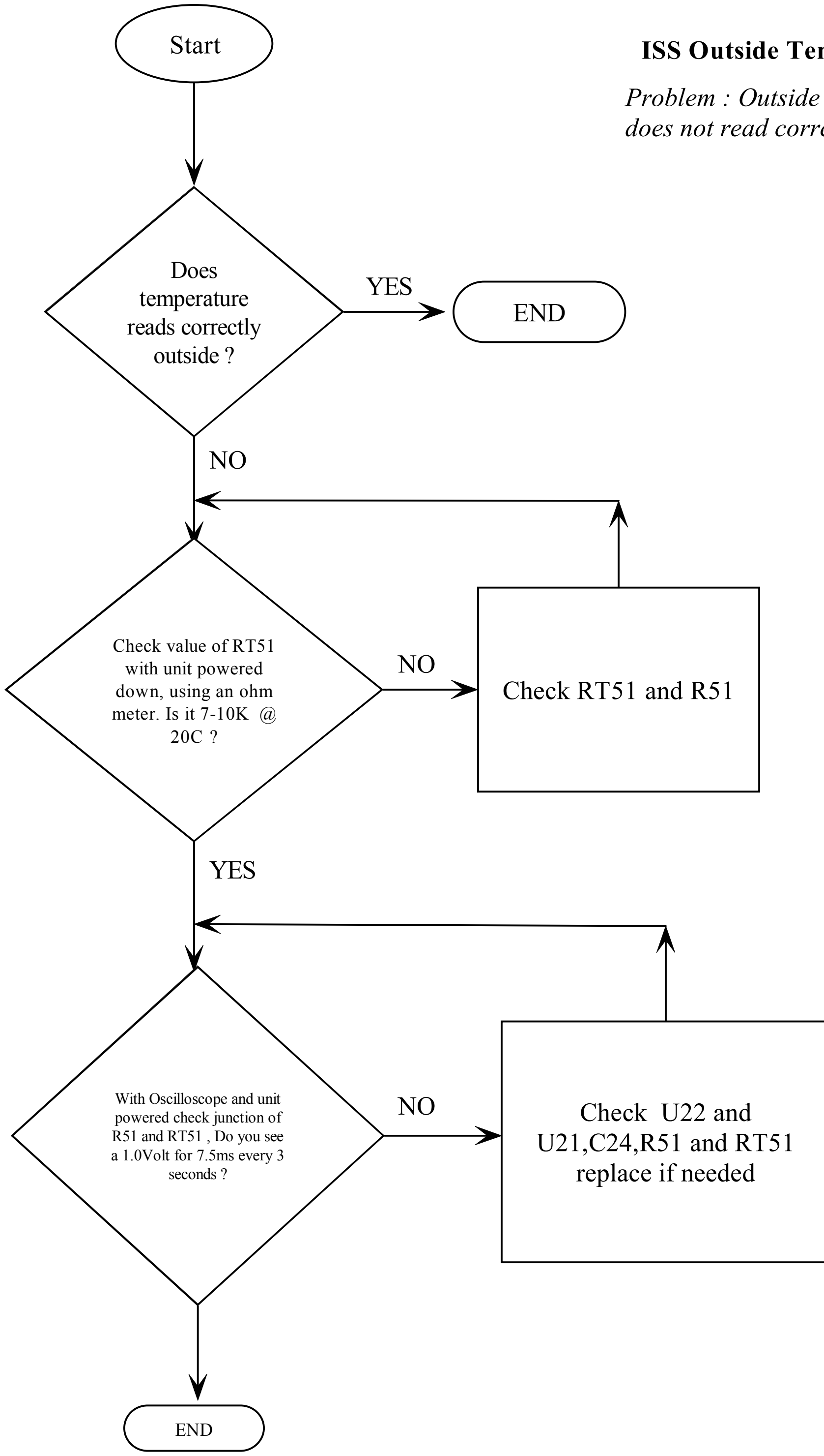

NOTE to user of this flowchart: If any condition results in a repeated NO please return to DAVIS for repair.

ISS Outside Humidity

Problem: Inside humidity reads incorrectly

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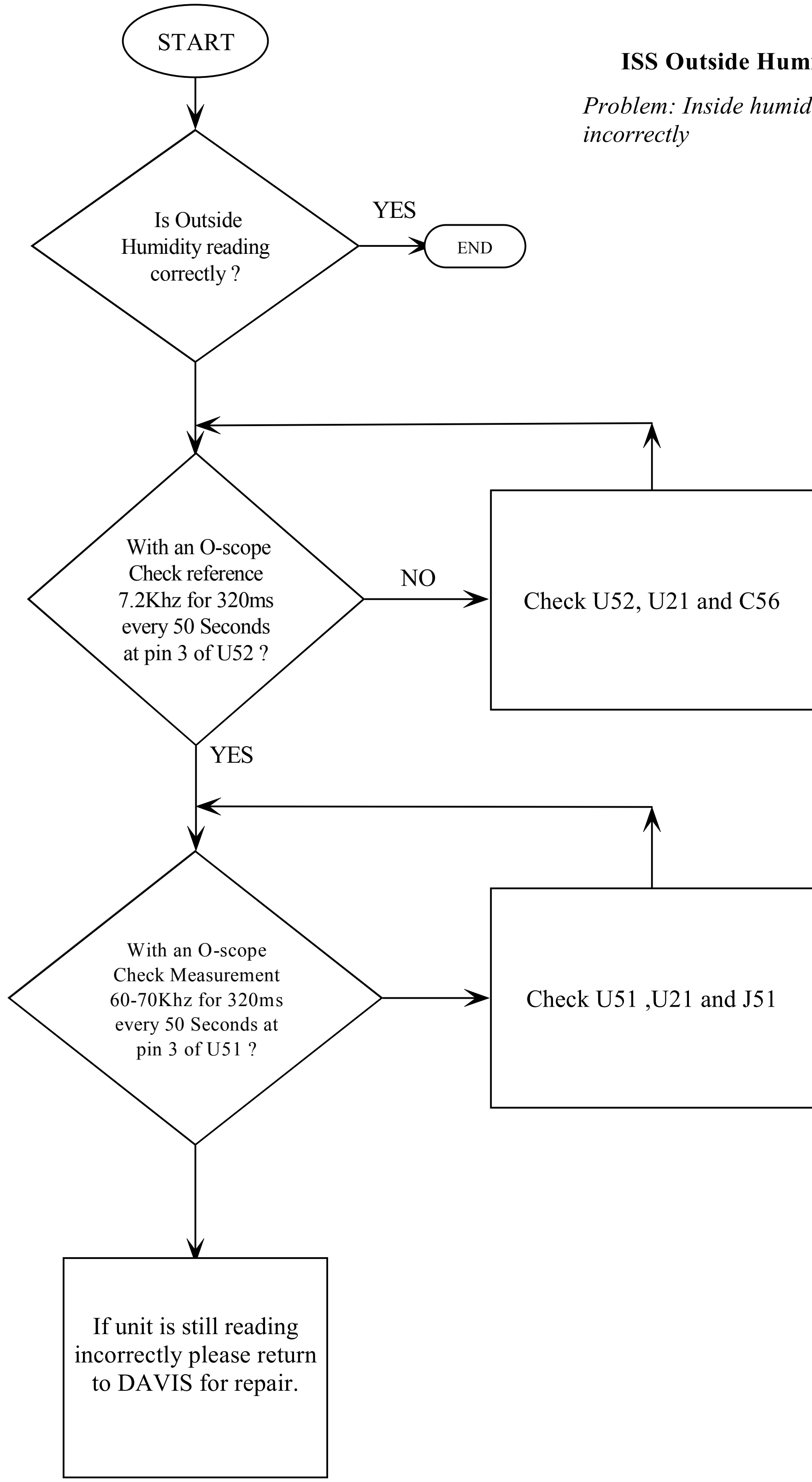
All Voltages are reference to ground unless otherwise specified.

Disclaimer if any components are changed a factory calibration should be done



NOTE to user of this flowchart: If any condition results in a repeated NO please return to DAVIS for repair.

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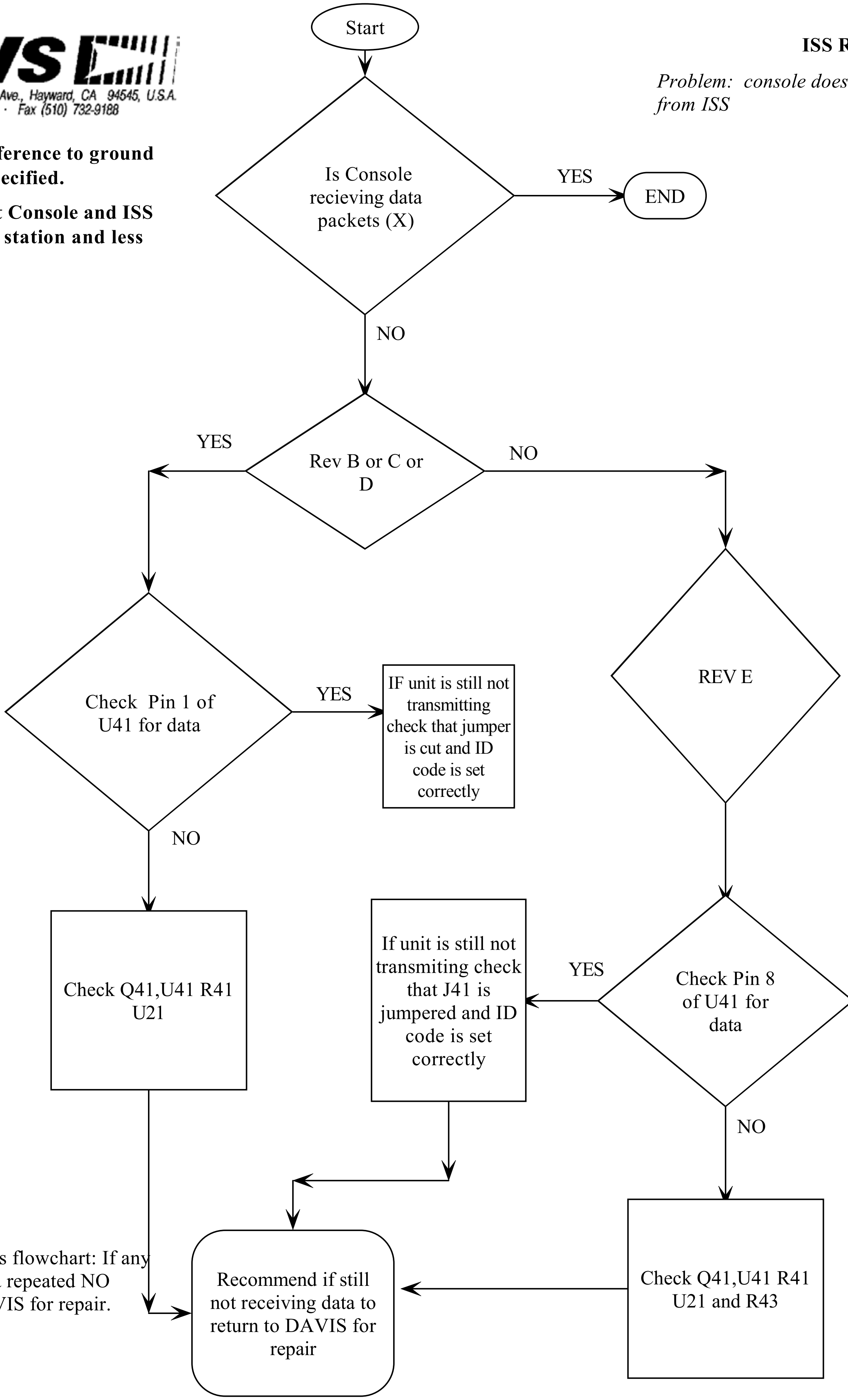
ISS RF

Problem: console does not recieve data from ISS

All Voltages are reference to ground unless otherwise specified.

Conditions are that Console and ISS are set to the same station and less than 50ft away.



NOTE to user of this flowchart: If any condition results in a repeated NO please return to DAVIS for repair.

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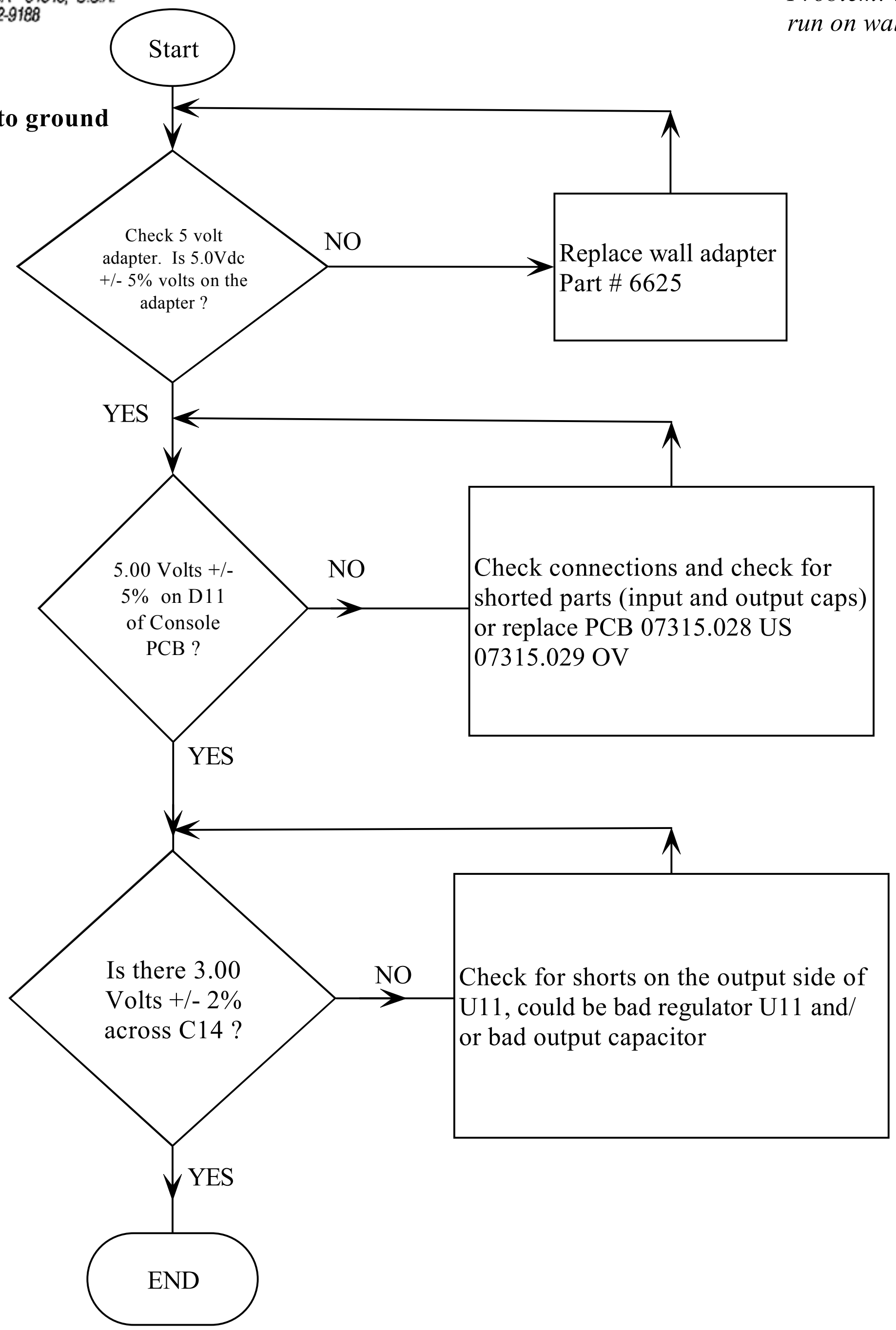
Console Power Via Wall Adapter

Problem: unit does not start up or run on wall adapter power

All Voltages are referenced to ground unless otherwise specified.



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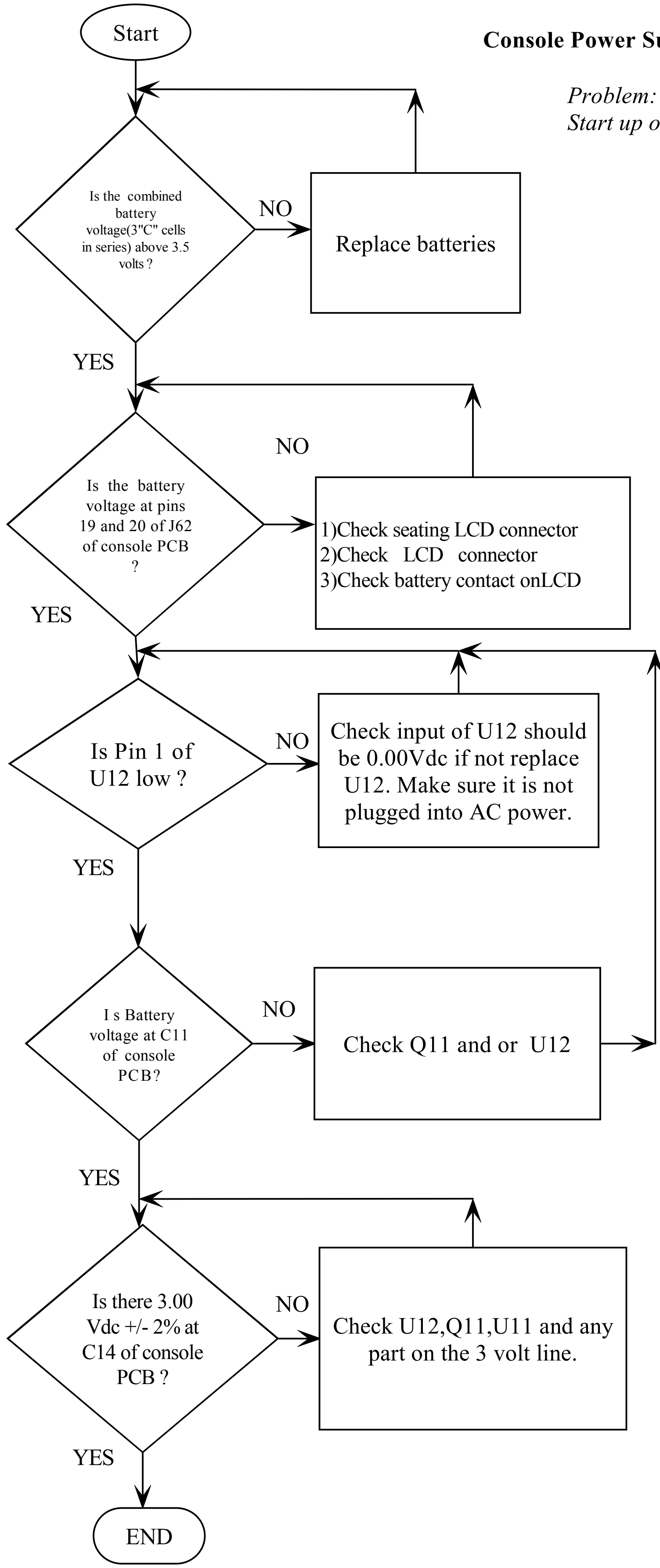
All Voltages are referenced to ground unless otherwise specified.

Console Power Supply Via Batteries

Problem: unit does not Start up or run on batteries



NOTE to user of this flowchart: If any condition results in a repeated NO please return to DAVIS for repair.

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Console Microprocessor U21

Problem: power to unit but still does not start up

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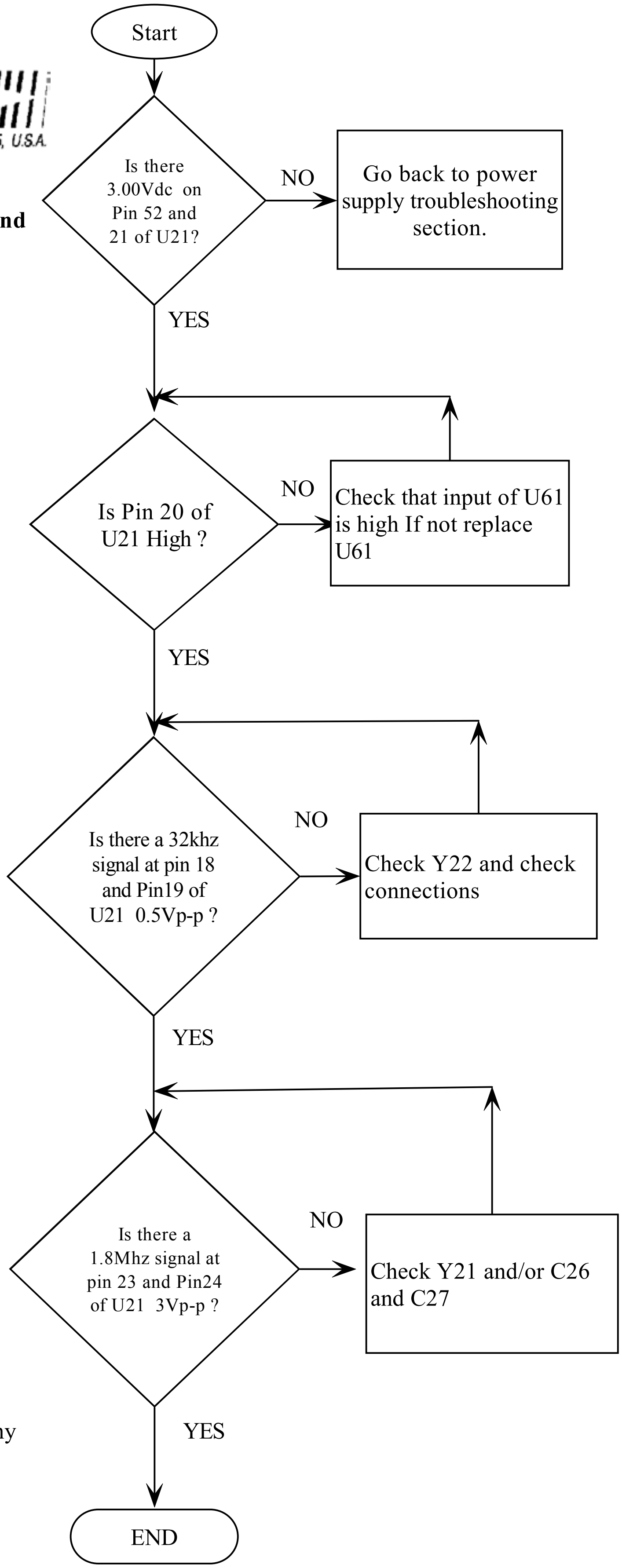
Conditions are unit powered from AC or Battery power.



NOTE to user of this flowchart: If any condition results in a repeated NO please return to DAVIS for repair.

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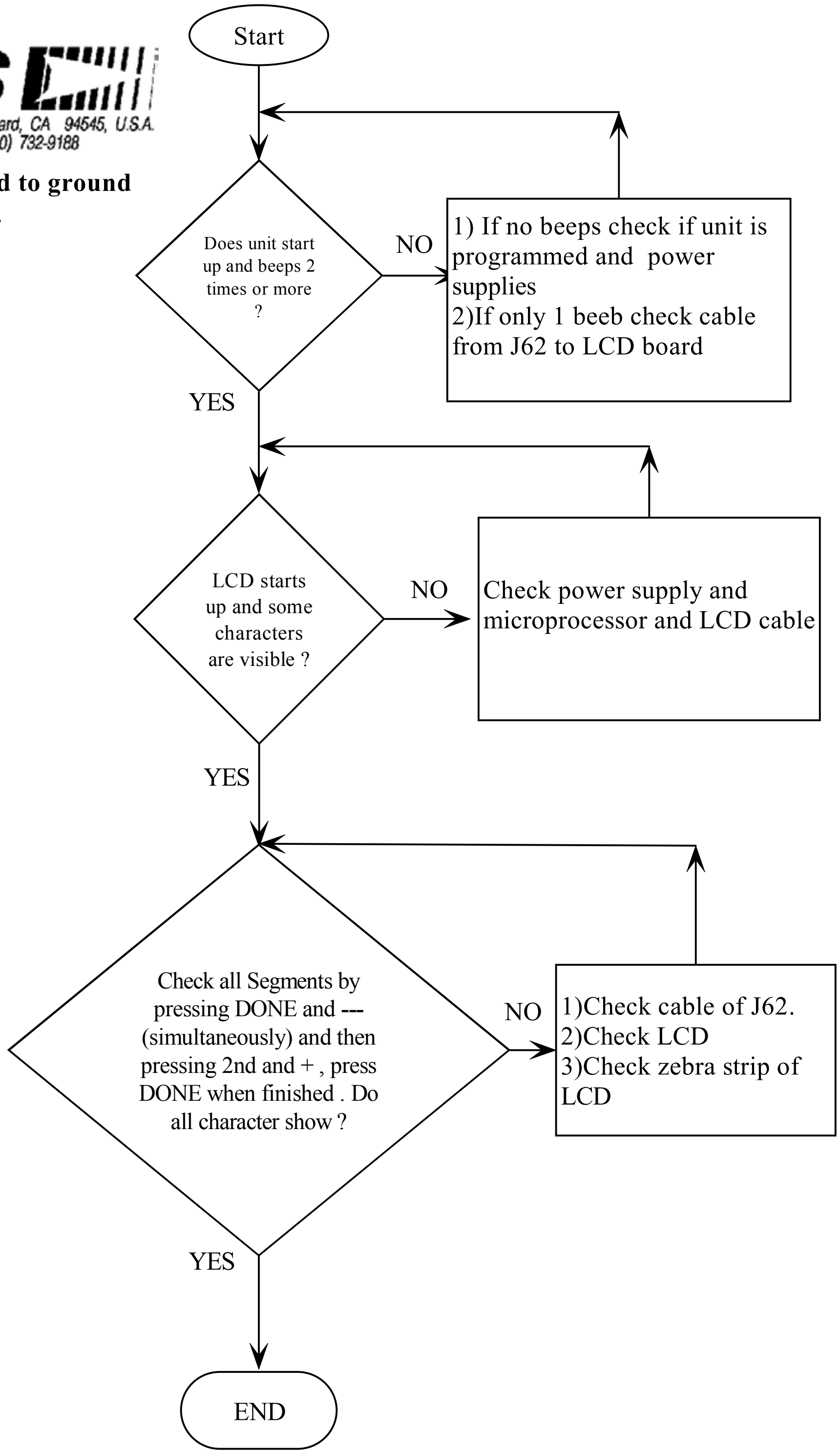
All Voltages are referenced to ground unless otherwise specified.

Console LCD

Problem: unit starts up but display is erratic.



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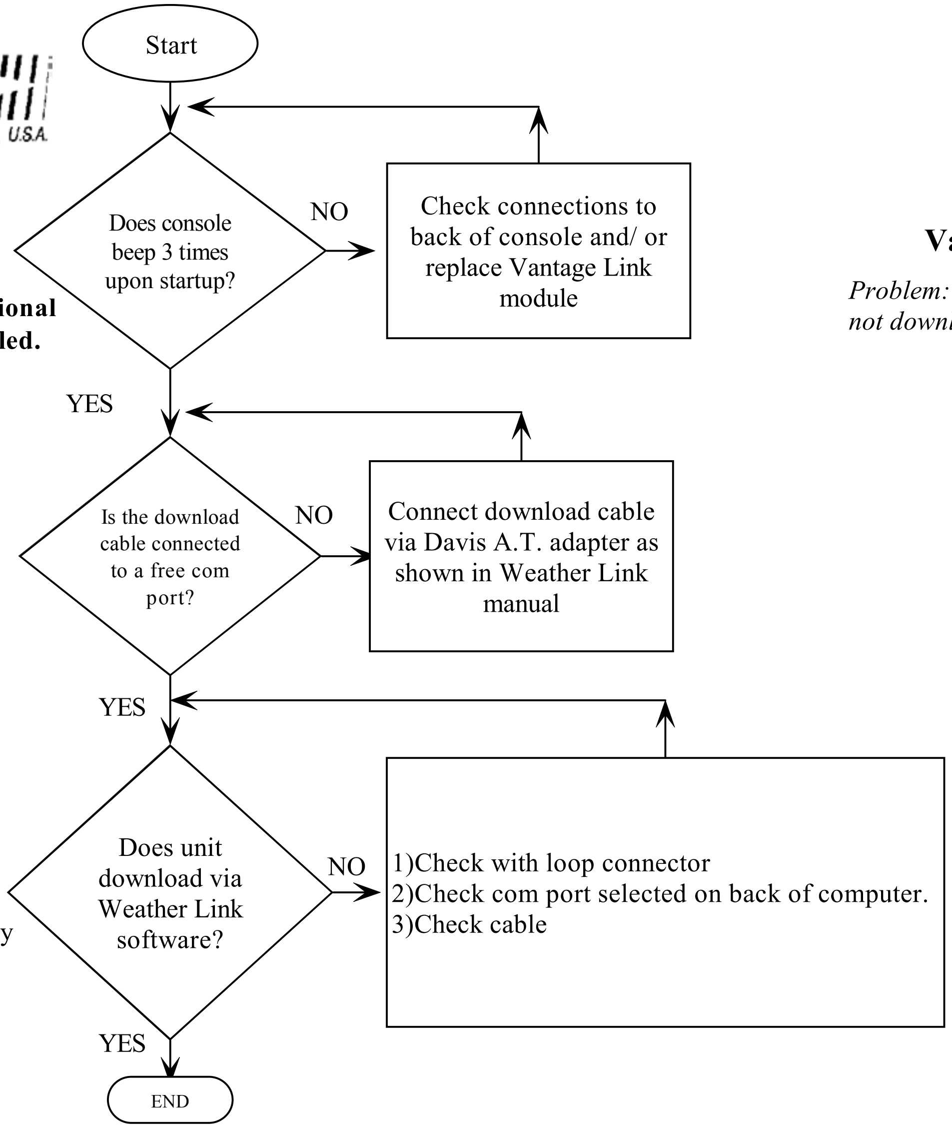
Vantage Link

Problem: Vantage station does not download data to computer

Conditions are the Console is functional and Weather link software is installed.



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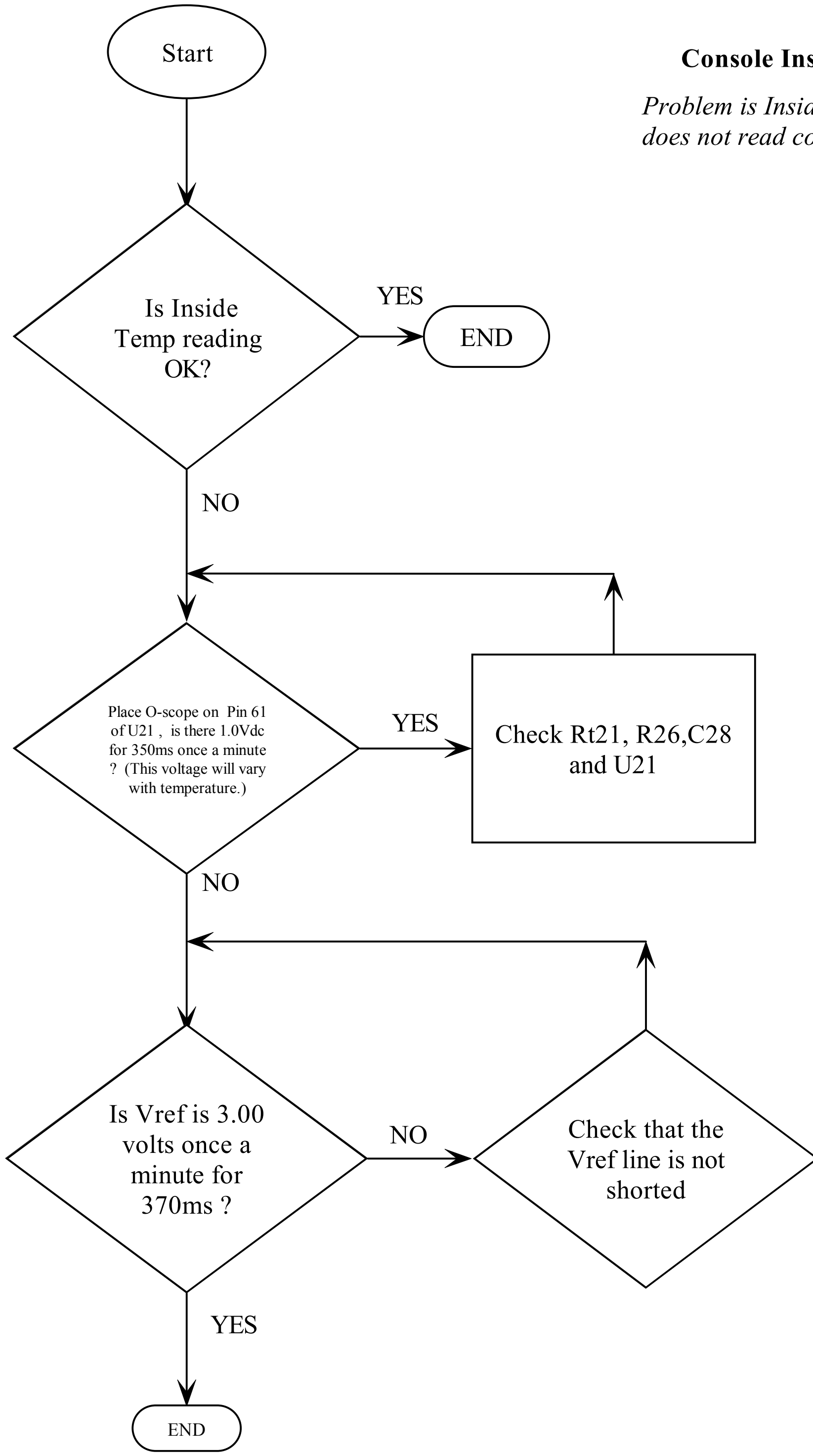
Special note inside temp is taken every 1 minute for 370ms

Clear any offsets that may of been applied to reading ,refer to Vantage Pro Console Mauual (Clearing Variables)

Console Inside Temp

Problem is Inside temperature does not read correctly



NOTE to user of this flowchart: If any condition results in a repeated NO please return to DAVIS for repair.

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Console Bar Circuit

Problem: Barometer reads incorrectly

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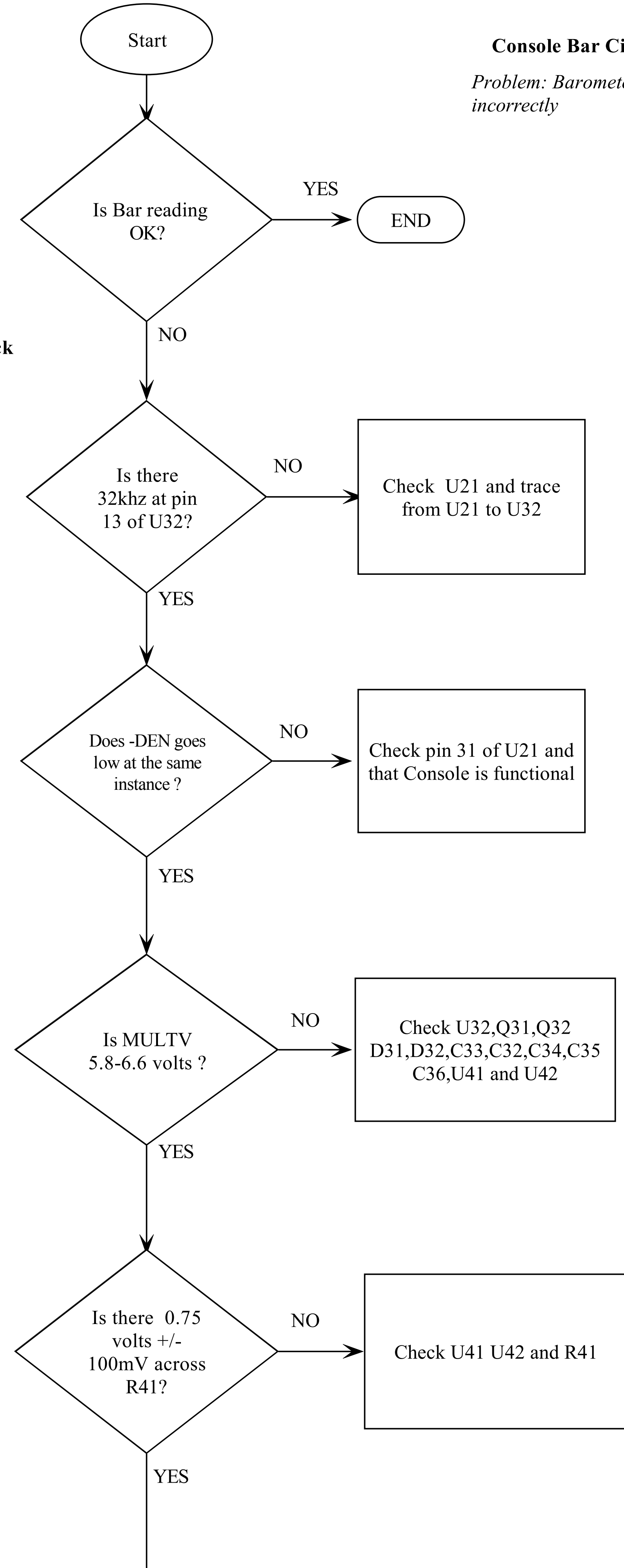
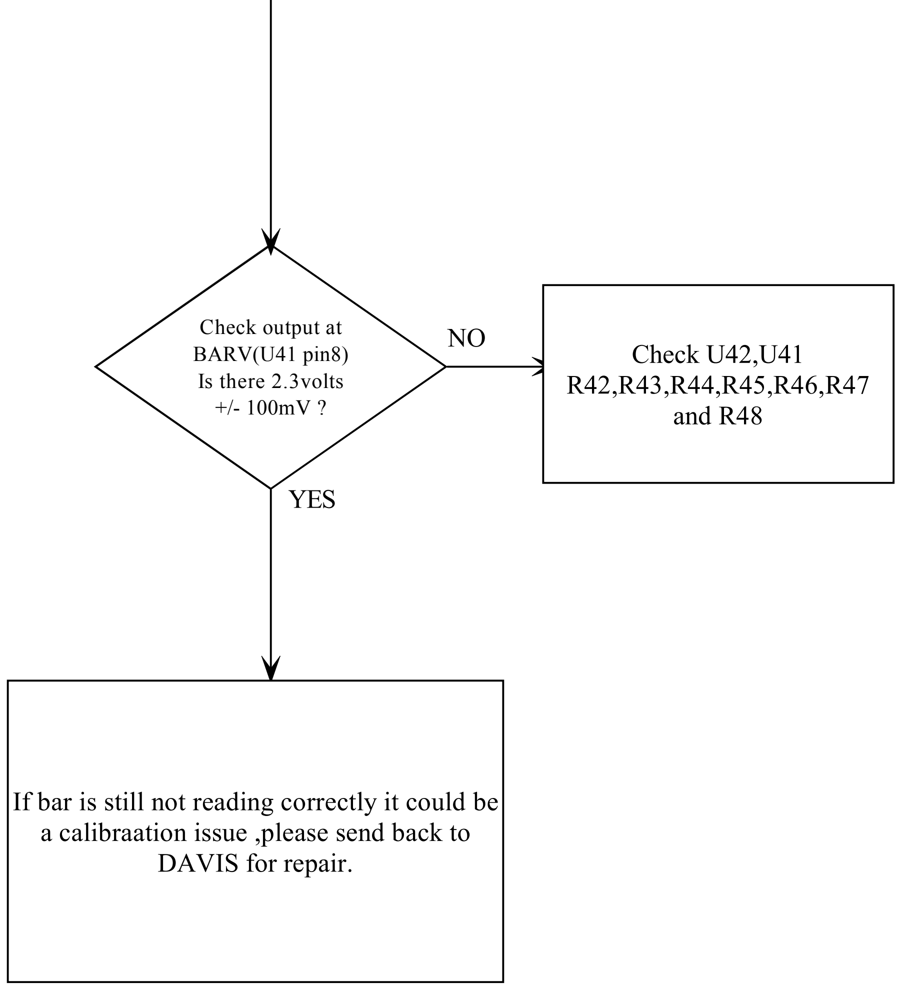
Bar Circuit Warning, although the circuit is analog, the calibration is done electronicly via firmware

1)Special note bar circuit is only on for 2 Seconds every 15 minutes and is schedule to be turned on at xx:59 , xx:14 , xx:29 and xx:44 of clock. To turn on the BAR the clock can be set to these times minus 1 minute to prepare for readings.

2) Bar can also be turned on by pressing the BAR key twice

3)Clear any offsets that may of been applied to reading ,refer to Vantage Pro Console Mauual (Clearing Variables)





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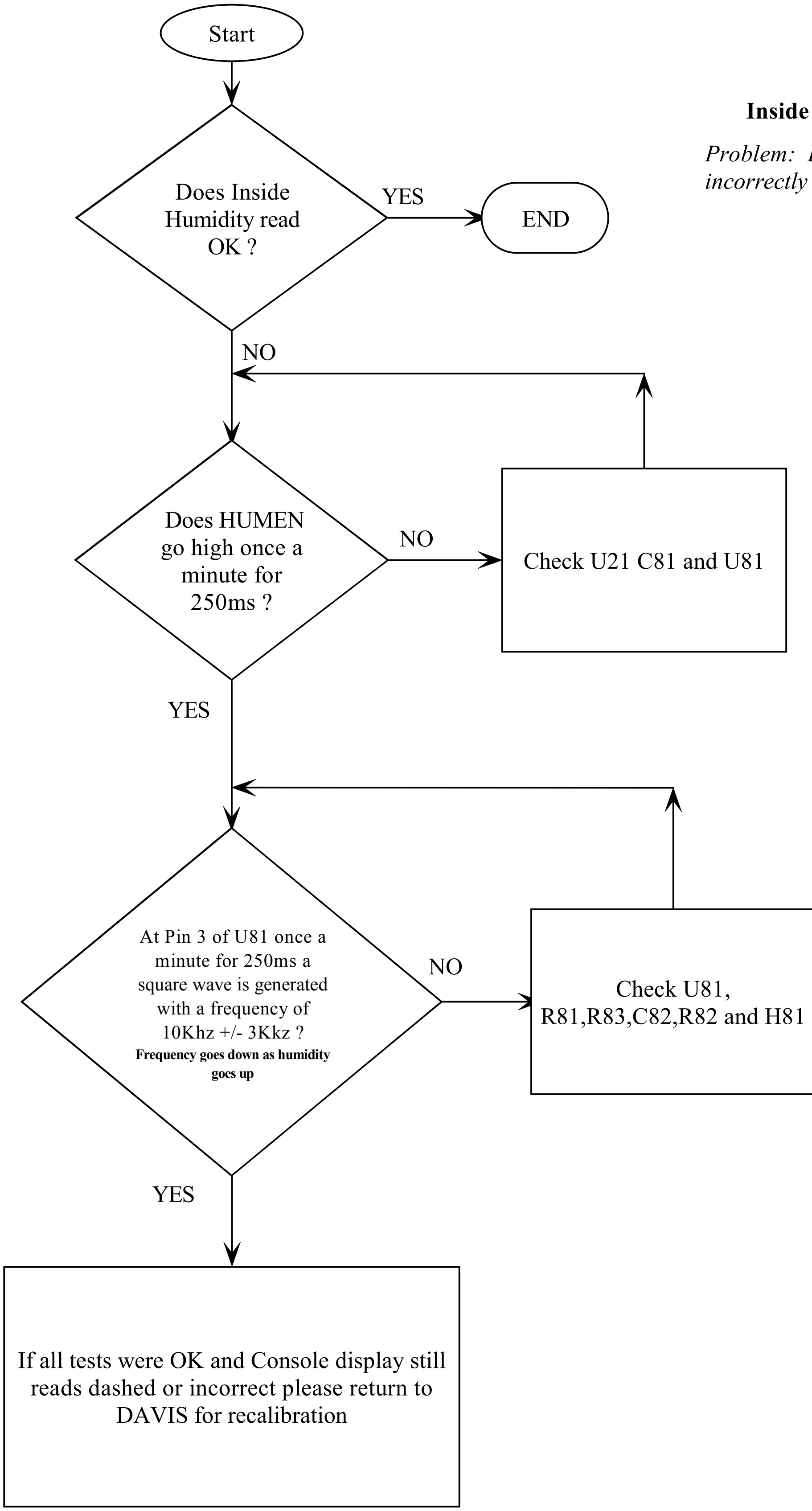
All Voltages are referenced to ground unless otherwise specified.

Special note inside HUM is taken every 1 minute for 250ms

Clear any offsets that may of been applied to reading ,refer to Vantage Pro Console Mauual (Clearing Variables)

Inside Humidity

Problem: Humidity reads incorrectly



NOTE to user of this flowchart: If any condition results in a repeated NO please return to DAVIS for repair.

	Function	Standard	Sensor Required	Update Interval*	USA Units				Metric Units			
					Display Resolution	Typical** Measurement Resolution	Range	Typical** Accuracy (+/-)	Display Resolution	Typical** Measurement Resolution	Range	Typical** Accuracy (+/-)
Barometric Pressure	Corrected Barometric Pressure (Elevation: -999' to +12,500' ; -460 to +3810 m)	X	Included in Console	15 min.	0.01" Hg	0.001" Hg	26" to 32" Hg	0.03" Hg	0.1 hPa, mm Hg	.03 hPa, mm Hg	880 to 1080 hPa, 660 to 810 mm Hg	1.0 hPa, 0.8 mm Hg
	Uncorrected Pressure	X	Included in Console: Set Elevation to Zero				18" to 33.5" Hg				610 to 1130 hPa, 460 to 850 mm Hg	
	Barometric Trend (3 hour)	X	Included in Console		Change >=.06" Hg = Rapidly; >=.02" Hg = Slowly		5 Position Arrow, Rising (Rapidly or Slowly), Steady, Falling (Rapidly or Slowly)		Change >=2 hPa, 1.5 mm Hg = Rapidly; >=.7 hPa, 0.5 mm Hg = Slowly		5 Position Arrow, Rising (Rapidly or Slowly), Steady, Falling (Rapidly or Slowly)	
ET	Evapotranspiration		Solar Radiation, Temperature/Humidity & Anemometer	1 hour	0.01"	0.001"	Daily to 99.99"; Monthly & Yearly to 199.99"	5% or 0.01" (whichever is greater)	0.25 mm	0.025 mm	Daily to 999.9 mm; Monthly & Yearly to 1999.9"	5% or 0.25 mm (whichever is greater)
Humidity & Dew Point	Inside Humidity	X	Included in Console	1 min.	1%	0.1%	10 to 90%	5% RH	1%	0.1%	10 to 90%	5% RH
	Outside Humidity	X	Temperature/Humidity Sensor or Vantage Pro ISS	50 to 60 sec.			0 to 100%	3% RH; 4% above 90%			0 to 100%	3% RH; 4% above 90%
	Dew Point (Overall)	X		10 to 12 sec.	1°F	0.2°F	-105° to +130°F	3°F	1°C	0.1°C	-76° to +54°C	1.5°C
	Frost/Dew Point at High Humidity	X						2°F				1°C
	Extra Humidity			50 to 60 sec.	1%	0.1%	0 to 100%	3% RH; 4% above 90%	1%	0.1%	0 to 100%	3% RH; 4% above 90%
Leaf Wetness	Leaf Wetness		Leaf Wetness Sensor, Wireless Leaf & Soil Moisture/Temperature Station	62.5 to 75 sec.	1	0.01	0 to 15	0.5	1	0.01	0 to 15	0.5
Rainfall	Daily & Storm Rainfall	X	Rain Collector	10 to 12 sec.	.01"	.01"	up to 99.99"	4% or one tip (whichever is greater)	0.25 mm	0.25 mm	up to 999.9 mm	4% or one tip (whichever is greater)
	Monthly & Yearly Rainfall	X					up to 199.99"		0.25 mm to 1999.9 mm; 1 mm above		up to 19,999 mm	
	Rain Rate	X			.01"/hr.	.01"/hr. above 0.04"/hr.	up to 100"/hr.	5% or 0.04" (whichever is greater)		.25 mm/hr. above 1.0 mm/hr.	up to 2540 mm/hr.	5% or 1.0 mm (whichever is greater)
Soil Moisture	Soil Moisture		Soil Moisture Sensor, Wireless Leaf & Soil Moisture/Temperature Station	62.5 to 75 sec.	1 cb	0.2 cb	0 to 200 cb		1 cb	0.2 cb	0 to 200 cb	
Solar Radiation	Solar Radiation		Solar Radiation Sensor	50 to 60 sec.	1 W/m^2	2 W/m^2	0 to 1800 W/m^2	5% of full scale	1 W/m^2	2 W/m^2	0 to 1800 W/m^2	5% of full scale
Temperature	Inside Temperature	X	Included in Console	1 min.	0.1°F	0.2°F	+32° to +140°F	1 ° F	0.1°C	0.1°C	0° to +60°C	0.5°C
	Outside Temperature	X	Temperature Sensor, Temperature Probe, Temperature/Humidity Sensor or Vantage Pro ISS	10 to 12 sec.			-40° to +150°F				-40° to +65°C	
	Extra Temperature		Temperature Sensor, Temperature Probe		1°F				1°C			
	Passive Radiaton Shield Effectiveness	X	Temperature Sensor, Temperature/Humidity Sensor or Vantage Pro ISS		0.1°F			+4° F	0.1°C			+2°C
	Fan Aspirated Radiation Shield Effectiveness		Temperature Sensor, Temperature/Humidity Sensor or Vantage Pro with Fan-Aspirated Radiation Shield ISS				-40° to +131°F	+0.6°F			-40° to +55°C	+0.3°C
Apparent Temperature	Heat Index	X	Temperature/Humidity Sensor or Vantage Pro ISS	10 to 12 sec.	1°F	0.2°F	-40° to +135°F	3°F	1°C	0.1°C	-40° to +57°C	1.5°C
	Temp-Humidity-Sun-Wind Index		Solar Radiation Sensor, Anemometer, Temperature/Humidity Sensor or Vantage Pro Plus ISS				-90° to +148°F	4°F			-68° to +64°C	2°C
Time & Date	Time	X	Included in Console	1 min.	1 min.	1 sec	24 hours	8 sec./mo.	1 min.	1 sec	24 hours	8 sec./mo.
	Date	X			1 day	1 day	month/day	8 sec./mo.	1 day	1 day	day/month	8 sec./mo.
UV Radiation	UV Index		UV Radiation Sensor or Vantage Pro Plus ISS	50 to 60 sec.	0.1 Index	0.02 Index	0 to 16 Index	5% of full scale	0.1 Index	0.02 Index	0 to 16 Index	5% of full scale
	UV Dose				0.1 MEDs to 19.9 MEDs; 1 MED above		0 to 199 MEDs	5%	0.1 MEDs to 19.9 MEDs; 1 MED above		0 to 199 MEDs	5%
Wind	Wind Direction	X	Anemometer	2.5 to 3 sec.	1°	1.4°	0° to 360°	7°	1°	1.4°	0° to 360°	7°
	Compass Rose	X			22.5°	22.5°	16 compass pts	0.3 comp. pt.	22.5°	22.5°	16 compass pts	0.3 comp. pt.
	Wind Speed (Large Cups)	X			1 mph, 1 kt	1.125 mph, 0.979 kts	2 to 150 mph; 2 to 130 kts	2 mph/kts or 5% (whichever is greater)	0.5 m/s 1 kph	0.5062 m/s, 1.811 kph	3 to 241 kph; 1 to 68 m/s	3 kph; 1 m/s or 5% (whichever is greater)
	Wind Speed (Small Cups)						3 to 175 mph; 3 to 150 kts	3 mph/kts or 5% (whichever is greater)			5 to 282 kph; 1.5 to 79 m/s	5 kph; 1.5 m/s or 5% (whichever is greater)
	Wind Chill	X	Anemometer & Temperature Probe, Temperature Sensor or Temperature/Humidity Sensor	1 min.	1°F	0.2°F	-120° to +130°F	2°F	1°C	0.1°C	-84° to +54° C	1°C

*Update Interval (except barometer, inside temperature and inside humidity) is dependent upon ID code used. The shortest time corresponds to ID #1, the longest, ID #8

**Typical means the most often observed value.

Vantage Pro Console Current Draw

Component	Interval (s)	Duration (s)	% of time on	Full (mA)	Avg (mA)
Receiver	2.5	0.04	1.60%	8	0.128
Barometer Circuit	900	2	0.22%	8	0.018
Temp & Hum Circuits	60	0.5	0.83%	5	0.042
Clock (times in ms)	250	0.35	0.14%	4	0.006
In Sleep Mode			100.00%		0.150
LCD			100.00%		0.100
Updating Display	2.5	0.075	3.00%	4	0.120
Updating Status Line	5	0.08	1.60%	4	0.064
Lamps (times in min)	1440	1	0.07%	80	0.056
Total					**0.6826**

Interval is the period of time between component usage

Duration is how long full current draw takes

Full is the amount of full current draw

Avg is the amount of average current draw the component takes over a long time period

Vantage Spare Parts Kit - Major

Item ID	Item Description	
2205.130	Washer, Flat, for U-bolt, 1/4	
2205.140	Washer, Lock, for U-bolt, 1/4	
3300.140	LED, Yellow, LCD Backlight	
7000.011	Piezo, 3v	
7000.865	Screw, #6x1"	
7011.001	3 Volt Lithium Battery	
7011.016	Super Cap	
7120.031	Reed Switch, Anemometer/Rain Collector	
7120.035	Magnet, Rain Collector	
7194.050	Bumpon, Clear	
7330.009	Loopback Test Cable	
7330.021	4 cond. 8 ft Vanatge Datalogger Cable	
7330.126	LCD to PCD Flat Flex Cable	
7330.211	Anemometer Test Cable	
7331.029	Antenna, ISS, Overseas 858MHz version	
7342.014	Splice Shell	
7342.028	Bucket, Rain Collector	
7342.029	Magnet Cap, Rain Collector	
7342.030	Cover, Reed Switch, Rain Collector	
7342.031	Screen, Rain Collector	
7342.102	Closed Plate, Radiation Shield, ISS	
7342.103	Open Plate, radiation Shiled, ISS	
7342.209	Reflector, LCD	
7342.602	Cover, SIM, ISS	
7342.606	Screen, SIM, ISS	
7342.700	Case, Top	
7342.701	Case, Bottom	
7342.702	Battery Door	
7342.703	Kickstand	
7342.704	Backplate, Vantage Console	
7342.705	Plastic Sheet, LCD	
7345.056	Solar Panel Assembly, ISS	
7345.508	Mounting Hardware Kit	
7345.510	Mounting Base, Anemometer	
7350.331	Screw, SIM Board, #4-24x1/2"	
7350.700	Wing Nuts, Radiation Shield	
7350.702	Screw, Radiation Shield, 8-32x4"	
7350.703	Push Nut, Radiation Shield, #8	
7350.704	U-bolt, ISS, 1/4-20x2x3	
7350.775	Washer, Lock, #4, Console Antenna	
7350.777	Screw, 4-40 x 5/16", Console Antenna	
7350.778	Spacer, 1/4", Console Antenna	
7350.779	Screw, Console Case	
7350.780	Screw, Console Board, #4 x 1/4"	
7353.030	Battery Holder Clip	
7353.211	Battery Contact, Negative	
7353.212	Battery Contact, Positive	

7355.022	Sleeve, Weatherlink	
7355.141	Box, Vantage System	
7355.142	Insert, Vantage System	
7356.015	Label, Caution Reed Switch	
7356.304	Label, SIM Cover	
7356.330	Display Console Label, Overseas	
7365.014	LCD Glass	
7365.099	LCD Assembly	
7367.106	Antenna, Vantage Console	
7371.003	Thermistor, Inside Temperature, 10k, 2%	
7371.004	Thermistor, Outside Temperature, 10k, 1%	
7376.004	Crystal, 1.8432 MHz	
7376.005	Crystal, 32.768 kHz	
7381.002	Receptacle, RJ11	
7381.008	Receptacle, RJ12	
7381.029	Zebra Strips, LCD	
7381.037	Adapter, RJ-11 to DB-9	
7381.040	Connector, Male, Datalogger	
7381.302	Connector, Solar Panel SIM	
7381.603	Connector, 1.3mm, Female, Power Jack	
7381.604	Power Plug, ISS, 1.3mm	
7388.006	Aluminum Tube, Anemometer	
7390.050	Vantage Keypad	
7390.150	DIP Switch, SIM, 4	
7395.010	Manual, Coupler Kit	
7395.095	Manual, UV Sensor	
7395.133	Manual, Solar Sensor	
7395.134	Manual, Vantage Console	
7395.135	Quick Reference Guide	
7395.141	Manual, ISS	
7802.010	Drip Ring	
7802.016	Wind Cup Magnet	
7802.082	Nut, Anemometer Arm, Hex 4-40	
7802.083	Nut, for U-bolt, 1/4-20	
7802.084	Screw, Anemometer Arm, #4-40x1-1/8	
7802.085	Washer, Anemometer Arm, Flat #4	
7802.086	Washer, Anemometer Arm, Lock #4	
7802.090	Allen Wrench, 0.05"	
7802.150	Set Screw, Anemometer	
7902.130	Potentiometer, Anemometer	
7904	Wind Vane	
7957.000	Coupler Kit	
7876-040	4-cond Extension Cable, Standard, 40ft	
7903L	Wind Cups, Large	
7903S	Wind Cups, Small	
7395.160	Gettign Started Guide, Vantage WeatherLink	

Vantage Spare Parts Kit - Minor

Item ID	Item Description	
2205.130	Washer, Flat, for U-bolt, 1/4	
2205.140	Washer, Lock, for U-bolt, 1/4	
7011.001	3 Volt Lithium Battery	
7120.035	Magnet, Rain Collector	
7194.050	Bumpon, Clear	
7330.009	Loopback Test Cable	
7330.021	4 cond. 8 ft Vanatge Datalogger Cable	
7330.211	Anemometer Test Cable	
7342.028	Bucket, Rain Collector	
7342.029	Magnet Cap, Rain Collector	
7342.031	Screen, Rain Collector	
7342.602	Cover, SIM, ISS	
7342.606	Screen, SIM, ISS	
7342.700	Case, Top	
7342.701	Case, Bottom	
7342.702	Battery Door	
7342.703	Kickstand	
7342.704	Backplate, Vantage Console	
7345.056	Solar Panel Assembly, ISS	
7345.508	Mounting Hardware Kit	
7345.510	Mounting Base, Anemometer	
7350.700	Wing Nuts, Radiation Shield	
7350.704	U-bolt, ISS, 1/4-20x2x3	
7350.779	Screw, Console Case	
7355.022	Sleeve, Weatherlink	
7355.141	Box, Vantage System	
7355.142	Insert, Vantage System	
7356.304	Label, SIM Cover	
7356.330	Display Console Label, Overseas	
7381.037	Adapter, RJ-11 to DB-9	
7388.006	Aluminum Tube, Anemometer	
7395.010	Manual, Coupler Kit	
7395.095	Manual, UV Sensor	
7395.133	Manual, Solar Sensor	
7395.134	Manual, Vantage Console	
7395.135	Quick Reference Guide	
7395.141	Manual, ISS	
7802.010	Drip Ring	
7802.082	Nut, Anemometer Arm, Hex 4-40	
7802.083	Nut, U-bolt, 1/4-20	
7802.084	Screw, Anemometer Arm, #4-40x1-1/8	
7802.085	Washer, Anemometer Arm, Flat #4	
7802.086	Washer, Anemometer Arm, Lock #4	
7802.090	Allen Wrench, 0.05"	
7904	Wind Vane	
7957.000	Coupler Kit	
7876-040	4-cond Extension Cable, Standard, 40ft	

7903L	Wind Cups, Large	
7903S	Wind Cups, Small	
7395.160	Gettign Started Guide, Vantage WeatherLink	

Vantage Console Tester 10/27/00 B.P.

The Vantage console tester board is used to initial test stuffed console boards (wired and wireless) before the Bar cal station. The tester board contains 8 status LED's and one Start button. An optional PC display running Procomm or Hyperterminal is recommended for diagnostic output and display of error codes. The error codes are also output to the LED's.

The current test takes 75 seconds plus the time to connect the board to the tester.

Use the toggle switch (S81) to select a Cabled or a Wireless board. Put the switch in the down position for wireless boards, and in the up position for wired boards.

A description of the connectors on the board follows.

J41: Input for 10 Mhz oscillator used for time calibration.
J91: SPI serial UART to be plugged into PC for diagnostic output and command input. 19.2K baud 1 start 1 stop and no parity.
J11: Power jack. 5V regulated DC required.

J21: Provides access to tester UART using Vantagelink. Not used in test. SPI serial UART is used for diagnostics since tester UART talks to the unit under test.

J81: Used to test receive circuit of wired boards.
J55: Output to simulate console power adapter.
J82: Plug cable from this plug into console link connector port.
JP41: Used to divide clock cal output from unit under test. Set at third pin down from J41.

Note the tester can run 1 individual test by sending commands through the SPI UART.

Note, you can just clock cal the board by first turning it on (DAC 0 1000) and then giving the CLKCAL command.

A description of each test follows.

1. ***Check for shorts, 3V regulator value and reset chip operation.*** First, the Jack power is ramped up (to DAC 0 1000) and the voltage output of the 3V regulator is noted when reset goes high. Also, the ipwr is checked at each voltage step to make sure no current is

over 20 ma. The 3V regulator is checked to make sure it is within it's +/-2% range. If the reset goes high before the 3V regulator gets to 2.5V and error results. The same procedure is then used on battery power. The peak battery output is DAC 1 750 so if the battery switch over transistor does not turn on, but conducts through the body diode, we will see a sag in the 3V regulator. After the above checks, the jack power is restored and the battery power checked to make sure the battery is switched off. Next, jack power is removed and the battery is ramped down to find where reset returns low. If reset returns low before 2.8v, or if reset returns low below 2.5v an error results.

2. ***Check circuits with load.*** UUTlOAD and LEDload are both switched in and the current checked on both battery and jack power. The UUTload should result in at least a 5.5 ma increase in current of an error results. The LEDload must result in a 70 ma increase. The LEDload tests the high side transistor switch used to supply the back light LED's. The 3V reference is also checked to be within it's +/-2% range for each test.

3. ***Check bar circuit, rfm, VREF, and HUM circuit currents.*** The tester is able to tell the console to shut off and turn on the relevant sub circuits using the "POW X" command where X is a hex number describing what circuits to be on. POW X where X's bits turn on and off the following.

```
bit
---
 0    RFM Chip
 1    RFM Gain
 2    HUME
 3    ~VREF (~DEN)
 4    BAR POWER
```

So to turn everything on you would enter "POW 17" to the console or from the tester SPI port you would forward the command to the console using "FWD POW 17".

The current with none of the above circuits on must be below 4.2 ma. The RFM chip is limited to 3 ma. The HUM circuit to 1 ma. VREF circuits to 1 ma and the bar circuit to 3.5 ma. You can run this command using "TEST U"

4. ***Check sleep mode and serial wakeup.*** The "SLEEP" command is sent to the unit under test and the current measured. The current in sleep mode is not allowed to be over 400 uA, but this number includes tester current load, measurement offset, and needs to be examined. I would like to be able to establish a definite limit here. After the current is measured, a character (13) is sent to the unit and it should return a 'Y' if it wakes up properly.

5. ***Clock calibration.*** A precision 10 Mhz oscillator time reference is input into the tester board. The uut is told to output a square wave based on it's 32 khz crystal. This signal is divided by 2 on the tester board to give a 1/2 hertz signal used to gate the reference oscillator to a 24 bit counter circuit. The tester console then calculates based on this count how many ticks to add or subtract each day to correct the time. There are 4 console ticks to each second so 1 tick is 2.895 ppm. The number of ticks to adjust is later written to the console EEPROM along with it's 1's complement. Right now no count is allowed to be outside of the 50 ppm crystal specification.

6. ***Check inside temperature.*** An "ADREAD" command is sent to the console and the counts are returned to the teseter. This count is used to calculate the console temperature and is compared to the tester temperature. If the reading is more than 2 degrees F different an error results.

7. ***Check bar circuit.*** The current source, voltage doubler output, and bar circuit output voltage are all checked. The current source should be set for 3/4 ma through 1k resister resulting in .75V. The "ADREAD" command is sent to the console to read these voltages. The BARC (3/4 ma) should be .75V or > 250 and < 260 counts. The MULTS signal is 1/3 of the MULTV signal which is the voltage doubler output. This output is typically around 6.5V and should not go below 6.25 volts. The count limit for 6.25 volts is 720. The bar circuit voltage is currently given a large range to account for the variations in circuit, sensor, and pressure that day. Later, we might put a bar circuit on the tester to reduce this range. Min circuit offset should be 17" and max 19" while gain is 7.5 psi or 2.036 * 7.5 = 15.27". Until we have a circuit on the tester figure bar could be from 28" to 31".
if (x < 600 | | x > 975) is the count range used.

8. ***Check humidity.*** The "MEASHUM" command is sent to the console and humidity is measured. The number of counts in 1/2 second is

then sent back to the console. Note, F94 = HICAL + 1000, and HICAL for Phillips sensor is ~6700. So typically 61% change in hum results in a 9K (33%)-7.7k or 1300 hz change in frequency. Not sure what offset range is but uncalibrated signal should be say from 6k to 12k. We count for .5 sec so should see a number from 3000 to 6000.

9. ***Check LCD I/O pins.*** The LCD data line pins PORTA and the LCD control pins PORTC.3...PORTC.7 are all driven both high and low and examined by the tester.

10. ***Check SPI port by reading flash on tester.*** A page of flash was pre-programmed on the tester. The unit under test is told to read this page and send it back to the tester. The tester verifys that the data is correct. Note, the "FLASH" command entered on the tester while connected to a working console will reprogram the flash in case it is corrupted or changed.

11. ***If wired station, Check packet receive circuit.*** Two temperature packets are sent by the tester to the console. The packet ID's are 1 and 2. The console keeps track of transmitter ID's it has seen and this variable is read by the tester to verify that the packets were received and processed.

12. ***Check uP EEPROM.*** The tests are in the code on the console chip. The tester sends the "CHECKEE" command to the unit under test and expects to see 4 ok's returned if the tests are successful. The first test writes 12 unique numbers exercising each address line once and then reads them back - if the numbers do not match a possible short or open failure exists. The second test writes all 0's to every location and then verifys the write. The third test writes all 1's to every location and verifys the write. The EEPROM is left in the all 1's state for later initialization.

13. ***Initialize EEPROM.*** Here the CLRALM and CLRCAL commands are sent to the console. The CLRGRAPH command is not needed because the each EEPROM byte is left at 0xff by the EEPROM test. The time calibration is also written here.

SPI Serial Commands

"WIRED x" where x is 1 for wired or cabled units and 0 for wireless units.

"PAUSE x" where x is either 0 or 1 will cause the tester to pause in between each test. You press a key to move on to the next test.

"VERBOSE x" where x is either 0 or 1 is used to turn on more verbose diagnostic output.

"FWD CMD" where CMD is a command you would normally enter the console.

"UAD X N" reads the A/D channel X on the console N times.

"DAC N X" where N is a number 0 to 3 specifying DAC A through D. X is a decimal number specifying counts.

Example: DAC 0 600 will output 600/1023 * Vref on DAC A.

What is actually sent to the DAC for debugging purposes is sent back, but this isn't really needed anymore.

"ADREAD C N" where C is the channel number 0 through 7 and N is the number times to read the channel. The total number of counts is returned.

Example: ADREAD 0 100 reads channel 0 100 times. If channel 0 = VREF, counts returned equals 1023 * 100.

"UEEWR A X" writes to the console EEPROM where A is a hex address and X is the hex number to write.

"UEERD A N" reads N bytes from the console EEPROM starting at address A and outputs the hex numbers to the screen.

The individual tests can be run by entering "TEST X" where X is a single upper case character indicating the test to be run. The corresponding character for a given test can be found below. Note, you may need to use the DAC command to power the unit up before some of these tests can be run.

Error Codes

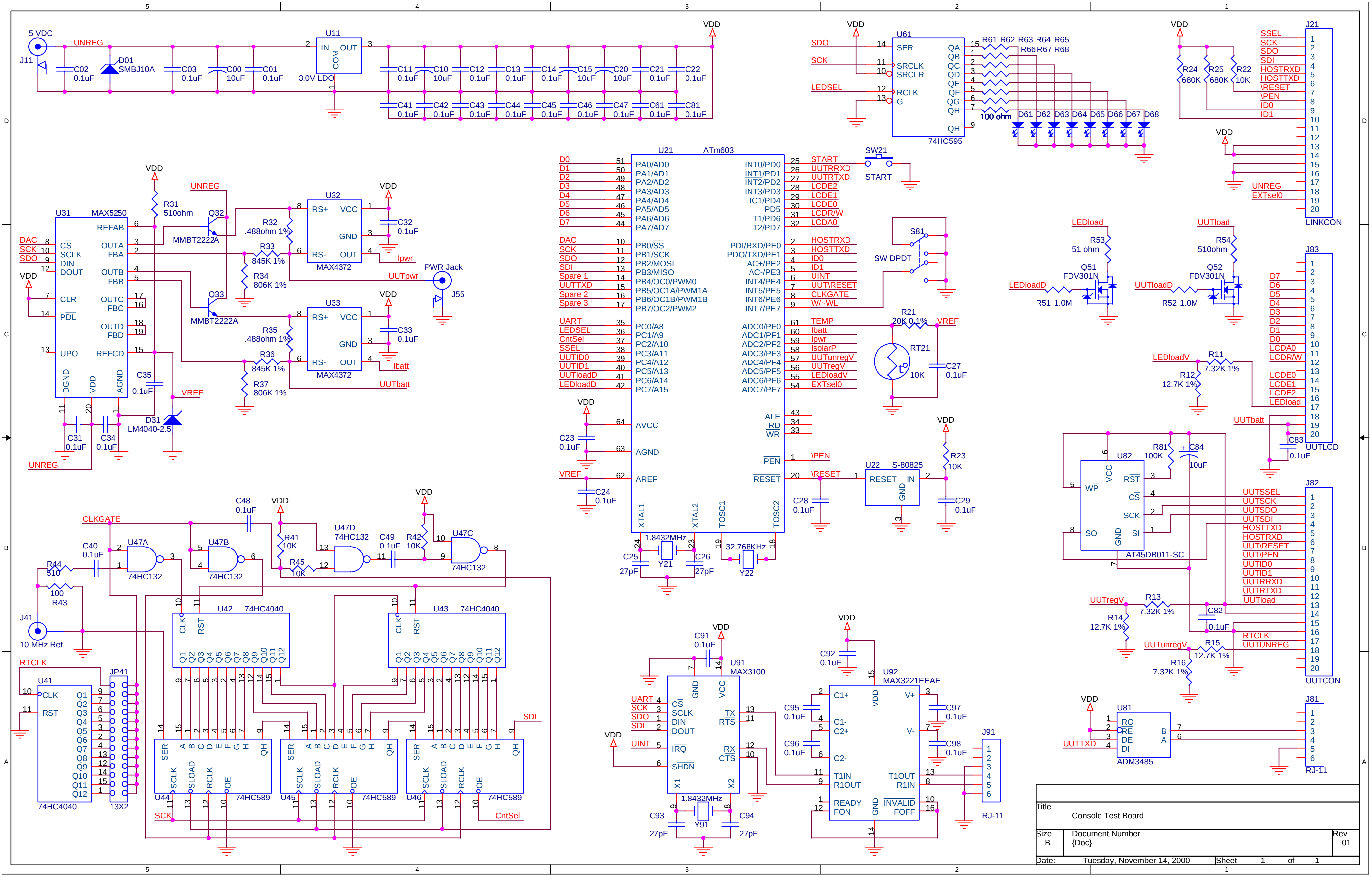
The error code is output to the console tester LED's and to the serial port. The least significant digit of the binary error code is on the LED furthest from the green LED.

Error code 1 is a communication error with the console.

Subract 2 from all other error codes and match it with the number below on the right to find the error string that would be output by the tester to the serial port.

```
flash char errorStr [] [80] =
{
"OVER 20 ma THROUGH POWER JACK. (%d)\n\r",              //  0
"OVER 20 ma THROUGH BATTERY. (%d)\n\r",                 //  1
"RESET DID NOT GO HIGH ON JACK POWER.\n\r",             //  2
"RESET DID NOT GO HIGH ON BATT POWER.\n\r",             //  3
"RESET WENT HIGH TOO EARLY. (3V %d)\n\r",               //  4
"3V REGULATOR OUT OF RANGE. (%d)\n\r",                  //  5
"3V REGULATOR ON BATT OUT OF RANGE. (%d)\n\r",          //  6
"BATTERY DOES NOT SWITCH OFF. (%d)\n\r",                //  7
"RESET WENT HIGH TOO EARLY ON BATT. (3V %d)\n\r",       //  8
"RESET DID NOT SWITCH OFF.\n\r",                        //  9
"RESET WENT LOW TOO LATE. (3V %d)\n\r",                 //  10
"CURRENT CHANGE TOO LOW WHEN 3V LOADED. (%d)\n\r",      //  11
"LOADED 3V REG. OUT OF RANGE. (%d)\n\r",                //  12
"CURRENT TOO LOW WHEN LED ON. (%d)\n\r",                //  13
"LED LOAD PUT 3V OUT OF RANGE. (%d)\n\r",               //  14
"EXTV NOT HIGH (%d)\n\r",                               //  15
"LOADED 3V REG. OUT OF RANGE (ON BATT). (%d)\n\r",      //  16
"CURRENT TOO LOW WHEN LED ON (ON BATT). (%d)\n\r",      //  17
"LED LOAD PUT 3V OUT OF RANGE (ON BATT). (%d)\n\r",     //  18
"EXTV DID NOT GO LOW ENOUGH. (%d)\n\r",                 //  19
"BATV NOT HIGH ENOUGH. (%d)\n\r",                       //  20
"uP CURRENT TOO HIGH. (%d)\n\r",                        //  21
"VREF CURRENT TOO HIGH. (%d)\n\r",                      //  22
"RFM CHIP CURRENT TOO HIGH. (%d)\n\r",                  //  23
"RFM GAIN CURRENT TOO HIGH. (%d)\n\r",                  //  24
"HUM CIRCUIT CURRENT TOO HIGH. (%d)\n\r",               //  25
"BAR CIRCUIT CURRENT TOO HIGH. (%d)\n\r",               //  26
"uP SLEEP CURRENT TO HIGH. (%d)\n\r",                   //  27
"UNIT DID NOT WAKE UP.\n\r",                            //  28
"UNIT DID NOT RETURN A Y.\n\r",                         //  29
"CONSOLE NOT RECEIVING PACKETS.\n\r",                   //  30
"CLOCK CAL TIMED OUT.\n\r",                             //  31
"32KHZ CRYSTAL OUTSIDE OF 50 PPM. (%x %x %x)\n\r",      //  32
"TEMP OUT OF RANGE (UUT %d|%d) +/- 2øF\n\r",            //  33
```

```
"BAR CURRENT SOURCE OUT OF RANGE. BARC %d\n\r",         //  34
"BAR VOLTAGE DOUBLER TOO LOW. MULTS %d\n\r",            //  35
"BAR CIRCUIT OUTPUT OUT OF RANGE.  %d\n\r",             //  36
"INSIDE HUM OUT OF RANGE.  %d\n\r",                     //  37
"D0 THRUOGH D7 NOT ALL HIGH.  %x\n\r",                  //  38
"D0 THRUOGH D7 NOT ALL LOW.  %x\n\r",                   //  39
"PC3..PC7 NOT ALL HIGH.  %x\n\r",                       //  40
"PC3..PC7 NOT ALL LOW.  %x\n\r",                        //  41
"FLASH NOT READ CORRECTLY.  STOPPED AT %d.\n\r",        //  42
"READ PAGE COMMAND NOT UNDERSTOOD.\n\r",                //  43
"NO BLOCK NUMBER SENT.\n\r",                            //  44
"DID NOT RECEIVE COMPLETE PAGE.\n\r",                   //  45
"DID NOT RECEIVE CRC.\n\r",                             //  46
"EEPROM ADDRESS LINE TEST FAILED.\n\r",                 //  47
"EEPROM 0'S TEST FAILED.\n\r",                          //  48
"EEPROM 1'S TEST FAILED.\n\r",                          //  49
"CAL NUMBERS NOT CLEARED.\n\r",                         //  50
"ALARMS NOT CLEARED.\n\r",                              //  51
"RESET WENT LOW TOO SOON. (%d)\n\r"                     //  52
"RFM CHIP NOT DRAWING ENOUGH CURRENT. (%d)\n\r"         //  53
};
```


5 VDC
J11
UNREG
D01 SMBJ10A
U11 3.0V LDO
VDD
U61 74HC595
100 ohm
LINKCON
J21
U31 MAX5250
R31 510ohm
Q32 MMBT2222A
Q33 MMBT2222A
U32 MAX4372
U33 MAX4372
PWR Jack
J55
UUTpwr
UUTbatt
D31 LM4040-2.5
VREF
U21 ATm603
SW21 START
S81 SW DPDT
RT21
Y21 1.8432MHz
Y22 32.768KHz
U22 S-80825
Q51 FDV301N
Q52 FDV301N
J83 UUTLCD
U82 AT45DB011-SC
J82 UUTCON
CLKGATE
U47A 74HC132
U47B 74HC132
U47C 74HC132
U47D 74HC132
J41 10 MHz Ref
U42 74HC4040
U43 74HC4040
RTCLK
U41 74HC4040
JP41 13X2
U44 74HC589
U45 74HC589
U46 74HC589
U91 MAX3100
Y91 1.8432MHz
U92 MAX3221EEAE
J91 RJ-11
U81 ADM3485
J81 RJ-11
Title
Console Test Board
Size B
Document Number {Doc}
Rev 01
Date: Tuesday, November 14, 2000
Sheet 1 of 1

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Vantage Console Errors and Possible Solutions

Error Number and Error String	Possible Solution
1) Could not talk to PCB under test though serial port	Check J61, U21, SCLK, SDO, SDI and RESET
2) Over 20mA though Power Jack	Check VDD to ground for shorts, check D11, J11, and U11.
3) Over 20mA though Battery Power	Check VDD to ground for shorts, check D11, J11, U11, R14 and R15 and or any chip that might be drawing excessive current.
4) Reset did not go high on jack power	Check U61, R65, C64, C65 and U11
5) Reset did not go high on battery power	Check U61, R65, C64, C65, Q11 and U11
6) Reset went high to early	Check U61 and Value of R65 and C64
7) 3V regulator out of range	Check the output of U11
8) 3V regulator on batt out of range	Check input and output of U11 and voltage drop across Q11 Drain to Source, input form U12 to gate. Check Battery Voltage >3.5volts
9) Battery does not switch off	Check input and output of U11 and voltage drop across Q11 Drain to Source, input form U12 to gate. Check Battery Voltage >3.5volts
10) Reset went high to early on battery	Check U61 and Value of R65 and C64
11) Reset did not switch off	Check U61 and Value of R65 and C64
12) Reset went low too late	Check U61, R65, C64, C65 and U11
13) Current change to low when loaded	Check that all components have power applied

14) Loaded 3V Reg out of range	Check U11
15) Current to low when LED on	Check Q21, Q22, R23, R22 and R21
16) LED load put 3V out of range	Check Q21, Q22, R23, R22 and R21
17) EXTV not high	Check input to U12 and output of U12 to be 3 volts and that at junction of R11 and R12 there is 1.5 volts.
18) Loaded 3Vreg out of range on Battery power	Check battery voltage, Voltage drop across Q11 and in and output of U11.
19) Current too low when LED on battery power	Check Q21, Q22, R23, R22 and R21 and check battery voltage
20) LED load put 3V out of range on battery	Check Q21, Q22, R23, R22, R21 and Q11 for drop across Drain to source
21) EXTV did not go low enough	Check that U12 is below 0.2V and that R12 is grounded
22) BATV not high enough	Check value of R14 and R15
23) uP current too high	Check uP (U21) for shorts and or replace U21
24) VREF current too high	Check U42, U41, U32, D31, D32 R86, R87, R37, R38
25) RFM chip current too high	Check U51, FB51, and C51
26) RFM gain current too high	Check Q51 and value of R56, R55 and R54
27) HUM circuit current to high	Check U81, C81, R81, C82 and H81
28) Bar Circuit current too high	Check for .75 volts on R41, Check R37, R38, R41, U42 and U41
29) uP Sleep Current too high	Check U21
30) Unit did not wake up	Check, replace U21
31) Unit did not return a YES	Check U21

32) Console not receiving packets	Check RXD and TXD lines
33) Clock Cal timed out	Check Y21 and that the 10MHz signal is connected to tester
34) 32KHz crystal outside of 50ppm	Replace Y22
35) Temperature outside of range	Check R26, RT21, C28
36) Bar current source outside of range	Check R37, R38, U41 and R41 and U42
37) Bar voltage doubter too low	Check U32, C32, C33, D31, D32, C34, C35, C36 and R86 and R87
38) Bar Circuit output out of range	Check U41, U42, R41, R42, R43, R44, R45, R46, R47 and R48
39) Inside HUM out of range	Check value of R81, C82, R82, R83 and U81
40) DO-D7 not all high	Check connection from U21 to J62 make sure none of the connection are shorted to ground
41) D0-D7 not all low	Check connection from U21 to J62 make sure none of the connection are shorted to VDD
42) PC3-PC7 not all high	Check connection from U21 to J62
43) PC3-PC7 not all low	Check connection from U21 to J62

ISS TESTER DOC.   B.P. 10-9-00

TOGGLE SWITCH: Flipped up towards the board selects a wireless ISS, and down away from board selects wired ISS. Lift up on the switch to move it. The switch is checked when necessary while the board is being tested.

START BUTTON: This push button is used to start the test or to skip a test that the operator can not make pass; for example, the humidity pot adjustment or the dip switch test.

LEDS: D61 through D78 are used to track the progress of the test. If a test has failed, a binary error number is output on D61 through D66 with the least significant bits starting at D61. The error number can be added up and checked against the accompanying error sheet for a description of the problem. Optionally, a terminal emulator program can be connected to the ISS test board using a VantageLink and the test progress and error numbers are printed to the screen. See the separate document on ISS TESTER commands for more information regarding this mode of operation. The right most LED next to the edge of the board (D22) is used to indicate a board has failed. The LED above D22 is toggles on the reception of an ISS packet.

OPERATION: Power the tester up using a ***5V power adapter***. The uP will cycle through the LED's and when finished the ready LED (D21) will be lit. Connect the power jack, battery clip, wind, rain, solar rad, uv, solar charging output, and the RX/TX jack. The ISS test LED can be either on or off. If you are testing a wired ISS, you do not need to connect the battery clip or the solar charging output, and you should have the toggle switch down away from the board; otherwise, the toggle switch should be up for a wireless ISS.

The tester can be used to test wireless "mini" stations as well as ISS's. The power on default is to test ISS boards, but you can use the MODEL command to choose a different board. The MODEL command is described below.

"MODEL 0"	- Test ISS boards. 0 is the power on default.
"MODEL 1"	- Test Wireless Wind.
"MODEL 2"	- Test Wireless Temp.
"MODEL 3"	- Test Wireless Temp Hum

If the command is understood, you will receive an "OK" back and a string telling you what board you are now testing.

The following tests are run by pushing the TEST switch.

1. ***Check reset circuit and ISS low battery detect.*** The battery voltage starts at 3V and the power jack has 0V. The ISS is put into "rain" packet mode. The battery voltage is lowered at .125V increments (25 DAC counts) and the low battery bits in the rain packet are monitored. The battery volatage is lowered until no rain packets are detected.
At this point, if the ISS does not ever detect a low battery or the low battery is detected above 2.625 this test fails. If low battery detect passed, than the battery voltage is raised .25 volts to see if the processor begins to run. If a packet is received, than the reset test passes.

The test above is modified slightly for a wired unit. The primary power is lowered instead of the battery voltage and the low battery detect is ignored.

2. ***Device current and 3V regulator.*** Power is applied through the JACK and 50 samples of the device current are taken over a 1 second period. If 15 or more of those samples are below 4 ma (wired) or 110 uA (wireless) than the current is ok. The 3V regulator is checked to make sure it falls within it's +/- 2% range (600 < AD counts < 627).

3. ***Check battery switch over threshold and battery current.*** Power is applied through the Jack and battery power is at 3V. The power through the jack is ramped down in .025 V increments and the battery current is monitored. If the voltage gets to 2.25V, and no battery current reading was above 40 uA the test fails. If current above 40 uA is detected, the power is held constant and 25 current readings are taken spaced about 10 ms apart. If the minum current reading of the last 20 samples is less than 100 ua, the test passes.

The test above is not done for a wired ISS.

4. ***Check solar charging circuit.*** Power to the jack is 0V and 3V is applied through the battery clip. The solar charging output is set to 2V and the unloaded EXT power is measured. .365 of EXT appears on ADC channel 4. A range of 5.22v (780 counts) to 5.5v (820) is acceptable. The circuit is than loaded and EXT is checked again. A range of 5.08v (760 counts) to

5.42v (810) is acceptable. The DC to DC current is also measured. Typical values are around 45 ma. Currently, anything over 55 ma fails.

5. ***Check wind speed and direction.*** Power is applied through the jack (4.1V) and the battery clip is at 3V. A 56 hz square wave with varying pulse width is used through out to drive the reed relay. First, a signal to test that some falling edge filtering exists on the ISS is applied. The signal closes the reed switch for about .3 ms and no wind speed should be seen. Then to test that some rising edge filtering exists a signal that leaves the reed switch open for only .5 ms is applied. Again, no wind speed is expected. Then the 2 worst case duty cycle waveforms are applied. A waveform to simulate a 20% duty cycle anemometer operating at 175 mph (small cups) is applied - the reed switch down time is 2 ms < ((2.25 hz/mph) /200 mph*.2). Than a waveform to simulate a 40% duty cycle anemometer at 175 mph (small cups) is applied -reed switch open time of 6 ms < ((2.25 hz/mph)/200 mph*.4). Three packets are then checked and must be in the range of 123 mph to 128 mph to pass. During the speed tests the 3 wind direction values are switched in and their values checked. The three acceptable ranges are 905 +/- 15, 375 +/- 10, and 112 +/- 5.

6. ***Check rain circuit.*** The ISS is put into "rain" mode and five 1 ms pulses spaced one packet apart are applied. These pulses should be filtered out and now rain should be detected. Then three 46 ms rain pulses spaced about .5 seconds apart are applied and should be reported by the ISS for the test to pass.

7. ***Check ISS temperature.*** The ISS is put into "temp" mode. The temperature on the test board is compared to the temperature reported by the ISS and if they differ by more than 2 degrees F the test fails.

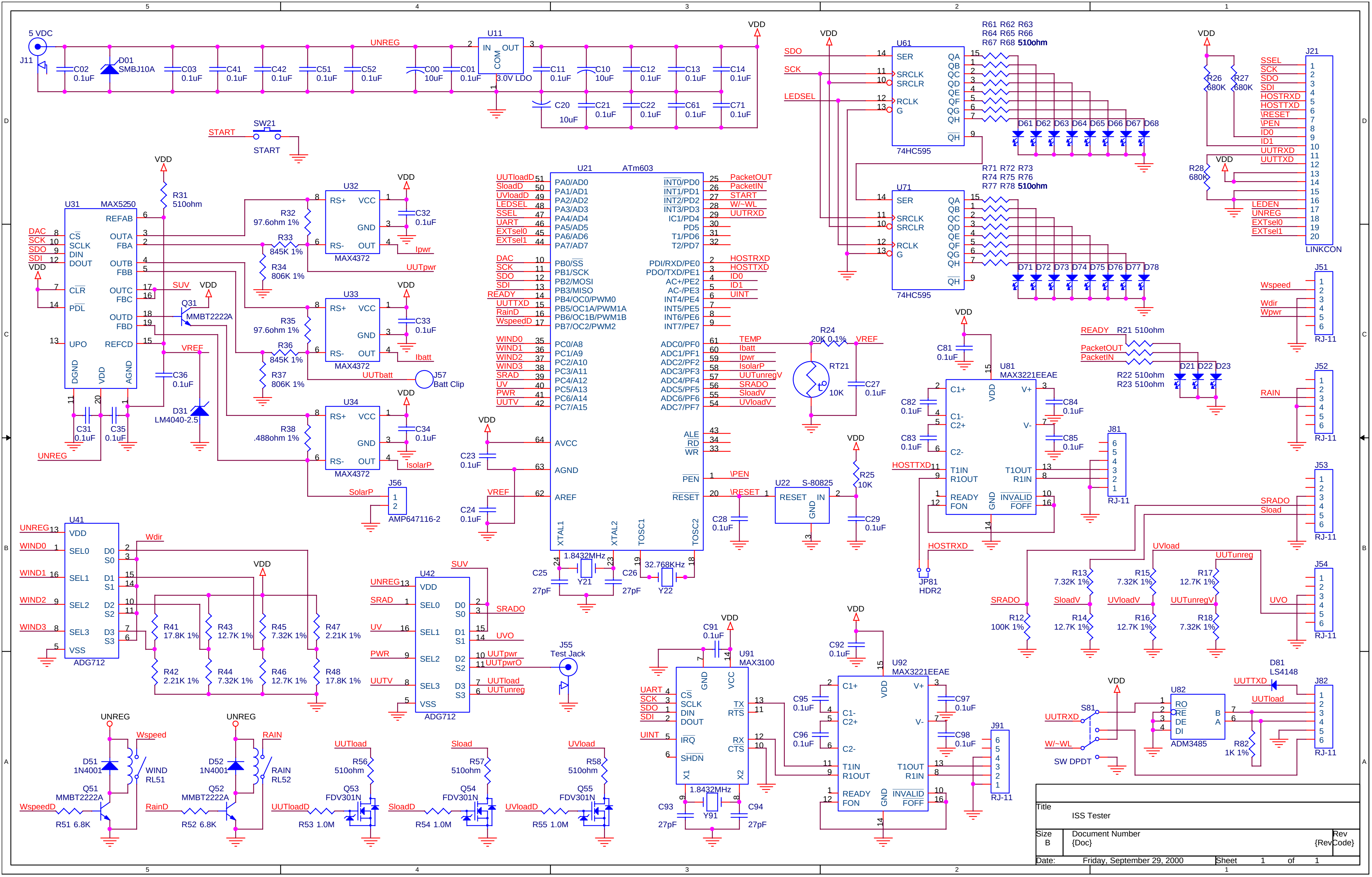
8. ***Check solar rad, power switching, and solar rad supply.*** The ISS is put into "solar" mode and .725V is applied to the ISS solar rad input. The next 2 packets are checked and the solar rad must be in the range 246 > ADC counts < 258. The solarRad variable is set to 0 before each reading so the packet received must be a solar packet with the right value to pass. Also, after each packet is received the solar supply is sampled. If the supply is not seen to go low (< 4 counts), the supply switching test fails. If the test passes, the solar supply is sampled until 3 readings above 10 counts are received before a few second timeout. The maximum value is recorded and must be in the range 760 < AD counts < 800. But for the switching test, the above tests are repeated with a load on the solar supply. The new solar rad range is 246 < AD counts < 280. The maximum value recorded on the supply must be in the range 640 < AD counts < 660.

9. ***Check UV rad and UV rad supply.*** The UV test is the same as the solar rad test with the exception of the supply switching off check, and UV is examined instead of solar rad.

10. ***Check DIP switch.*** The ISS is put in "rain" packet mode and the packet ID (dip switch setting) is monitored. The operator should move each DIP switch, with the exception of the test LED switch to a new position. The test LED switch is checked by moving it to the opposite position and verifying that the green test LED behaves appropriately. If the operator can not make this test pass, he can press the START button again and the test will exit and fail.

11. ***Humidity check and pot preset.*** The 2 columns of 3 LED's are used to direct the operator in preseting the gain and offset pots on the ISS board. First the gain pot is set for a target frequency of 7.225 khz +/- some small value. If the frequency is too low, the lower LED will be on and the pot should be turned CW to raise the reading. If the frequency is too high, the upper LED will be on, and the pot should be turned CCW to lower the reading. Always turn the pots CW if the lower LED is on and CCW if the upper LED is on. When 2 hum packets in a row are received with the middle LED on the pot is set. The same procedure is used for the offset pot.

If all tests have passed, the ready LED will light and no other LED's will be on. If a test has failed, a binary error code is put out on the first 6 LED's and the fail LED will be lit.



5 VDC
J11
UNREG
U11
3.0V LDO
VDD
SW21
START
U31
MAX5250
U32
MAX4372
U33
MAX4372
U34
MAX4372
U21
ATm603
U41
ADG712
U42
ADG712
U22
S-80825
J57
Batt Clip
J56
AMP647116-2
J55
Test Jack
U61
74HC595
U71
74HC595
J21
LINKCON
U81
MAX3221EEAE
U91
MAX3100
U92
MAX3221EEAE
U82
ADM3485
JP81
HDR2
RT21
Y21
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Y22
32.768KHz
Y91
1.8432MHz
RL51
WIND
RL52
RAIN
S81
SW DPDT
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J52
J53
J54
J81
J82
J91
RJ-11
Title
ISS Tester
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Document Number
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Date:
Friday, September 29, 2000
Sheet
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of
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ISS Tester Error Numbers and Possible Solutions

Error Number and Error String	Possible Solution
1) No packets being received from ISS.	Check U21, J91 and J11
2) Low battery detect not seen.	Check U24
3) Low battery detect out of range.	Check U24 value
4) Reset circuit failed.	Check U23
5) Current though jack to high.	Check for shorts on ISS PCB
6) 3 Volt regulator out of range.	Check U11 is 3.0Vdc +/- 2%
7) Battery did not kick in.	Check U12, R13, C15 and Q11
8) Battery current to high.	Check for short on the 3 volt line
9) Charging circuit unloaded has failed.	Check J31, T31, R31, D31, R32, R33 and R34
10) Charging circuit loaded has failed.	Check J31, T31, R31, D31, R32, R33 and R34
11) DC to DC converter current to high.	Check J31, T31, R31, D31, R32, R33 and R34
12) Not enough falling edge filtering on wind speed.	Check R62 and C61
13) Not enough rising edge filtering on wind speed.	Check R62 and C61
14) Direction out of range for wind 0.	Check value of R64 and R63
15) Direction out of range for wind 2.	Check value of R64 and R63
16) Max speed not measuring at 20% duty cycle.	Check R62, C61 R64 and R63
17) Max speed not measuring at 40% duty cycle.	Check R62, C61 R64 and R63
18) Direction out of range for wind 3.	Check value of R64 and R63
19) Not enough filtering on rain input.	Check R72 and C71
20) Rain pulses not recognized.	Check R72 and C71 and connection to U21 pin 21
21) Not getting temperature packets.	Check U22, U21, RT51 and R51
22) Temperature on ISS not matching test fixture.	Check U22, U21, RT51 and R51 also make sure you are not touching temp sensor

23) Solar rad power on ISS not switching off.	Check R87 and Q81
24) Solar rad data out of range.	Check R82 and R83
25) Solar supply not seen high.	Check Q81, R87, R82 and R83
26) Solar supply out of range.	Check Q81, R87, R82 and R83
27) Solar rad data out of range when supply loaded.	Check Q81, R87, R82 and R83
28) Solar supply not seen high when loaded.	Check Q81, R87, R82 and R83
29) Solar supply out of range when loaded.	Check Q81, R87, R82 and R83
30) UV data out of range.	Check Q81, R87, R85, R86, R84, C83 and C84
31) UV supply not seen high.	Check Q81, R87, R85, R86, R84, C83 and C84
32) UV supply out of range.	Check Q81, R87, R85, R86, R84, C83 and C84
33) UV data out of range when supply loaded.	Check Q81, R87, R85, R86, R84, C83 and C84
34) UV supply not seen high when loaded.	Check Q81, R87, R85, R86, R84, C83 and C84
35) UV supply out of range when loaded.	Check Q81, R87, R85, R86, R84, C83 and C84
36) Hum gain pot could not be set.	Check R56 VR52, R57, and C56
37) Hum meas pot could not be set.	Check J51 stuffed and values of VR51, R53, R54, C53 and R55
38) DIP switch test failed.	Replace S21 and or check connections to U21
41) NO current going through power jack. Check that D13 is installed	Check D13 and U11 are installed
42) COULD NOT GET A SOIL PACKET	Check Firmware revision and J11 and J91
43) SOIL SENSOR %d NOT RIGHT %d (%d)	Check connections on test block and R61, R62, R63, R64 and R56
44) TEMP SENSOR %d NOT RIGHT %d (%d).	Check Connections on test block and R51, R52, R53, R54 and R55

Theory of Operation B.P. 8/24/01
UV Calibration Fixture

The UV calibration fixture is composed of 1 main board and up to 8 slave boards. Each slave board can support up to 16 UV sensors with its 2 ADS7870 A/D converters that each support 8 channels. The A/D resolution is 11 bits (0 to 2047 counts) and the maximum input voltage is 2.5V. Data is read out of the A/D chips using the chip's SPI port running in 2-wire mode. The SDI and SDO lines coming from the slave boards are tri state buffered. The buffers and the decoding logic is on the main board. The SPI port runs at 400 kHz and the A/D conversion time is very fast. A single conversion is done internally by the chip in 48 clock cycles and the internal A/D clock is running at 2.5 Mhz. A single conversion can be completed and read by the uP in about .08 ms. All 128 sensors can be read in less than 50 ms (need to check on scope). When the fixture is logging data each sensor is sampled once a second no matter how many slave boards are connected. Data is averaged over each archive period and rounded to the nearest .1 index and then written to the Weather link flash memory on the main board. The recommended archive period is 30 minutes, but can be 1, 5, 10, 15, 30, 1hr, or 2hrs. The data can later be collected by doing an ASCII transfer using ProComm (PGDN,7) or HyperTerminal (Capture Text).

The fixture has two modes of operation – "logging" or "adjusting". In order for the fixture to log data on power up the START command must be entered through the serial port. The time and date can be set using the SETT and the SETD commands. You can adjust the sensors anytime by pressing the adjust key on the main board. When adjusting only the reference and the selected UV sensor are converted and compared. The difference between the two is converted to a voltage using a DAC. The voltage is then sent to a null meter for easy feedback. Every count of the 8-bit DAC corresponds to .02 index or 8 mv. Because the DAC reference is 1.024, a DAC value of 128 will produce 1.024 volts out and the meter will be zeroed. When the sensor is greater than the reference the meter will be to the right of zero and the sensor gain pot should be adjusted CCW. When the sensor is less than the reference the meter will be to the left of zero and the sensor gain pot should be adjusted CW.

UV Tester Commands B.P. 8/16/01

Note, all numbering starts at 0 unless otherwise stated. The fixture has 8 boards referenced 0 through 7 and each A/D chip has 8 channels referenced 0 through 7.

ADREAD - Read A/D channel of Atmel uP.
BAUD - Set the baud rate of the serial connection. Default is 19,200. "BAUD 9600".
BUFFRD - Read buffer of flash logging chip. Binary command.
BUFFWR - Write buffer of flash logging chip. Binary command.
CAL - Enter "CAL 1" when you want to adjust UV sensors. "CAL 0" to stop.

CLKOFF - Used in the calibration of the 32khz crystal.

CLKON - Used in the calibration of the 32khz crystal.

CLREE - Clear the EEPROM of the Atmel uP. Not recommended.

CLRLOG - Clear the data logging flash.

DAC - Write a number to the DAC. “DAC 128” should output ~1 volt.

DEBUG - Turn debugging on or off. “DEBUG 1” or “DEBUG 0”. Shows the values when calibrating sensors.

DMP - Not used.

DMPAFT - Not used.

DMPALL - Sends all log records to the screen in ASCII. Can capture in Procomm by first hitting PGDN and entering file. Each line has month, day, time in military format, and the uv readings for the 128 sensors in .1 index. Board 0 channel 0 are written first than board 0 channel 1 etc.

DMPB - Dump log data for a specific board. “DMPB 0” dumps data for board 0.

EEBRD - Not used.

EEBWR - Not used.

EERD - Read Atmel EEPROM byte.

EEWR - Write Atmel EEPROM byte.

FORCE - Force a record to be written to the log. Will not work if your are in CAL mode or if the clock hour is < 6 or > 20.

GETEE - Not used.

GETT - Get the time on the board.

GETTIME - Not used.

LOG - Turn logging on or off. “LOG 1” to turn on and “LOG 0” to turn off. Opposite of logOff displayed in STATUS command.

NEWX - Not used.

PAGERD - Not used.

PAGEWR - Not used.

PORT - Not used.

RC - Read a channel on a given A/D chip. First use SETCHIP to pick the chip you want than use RC to read 1 of the 8 channels on the chip. “RC 0” reads channel 0.

RECRD - Not used.

RECWR - Not used.

REGRD - Read a register on the A/D chip. “REGRD 31” reads the diagnostic register and should output a 1.

REGWR - Write a register on the A/D chip. “REGWR 6 F” writes a F to register 6. Note, the first number is in decimal and the second argument is in hex.

SAMPLE - Start the board sampling the A/D channels every 1 second. Note, data will not log automatically if the sample is not set. Look at STATUS to check. “SAMPLE 1” turns on. “SAMPLE 0” turns off.

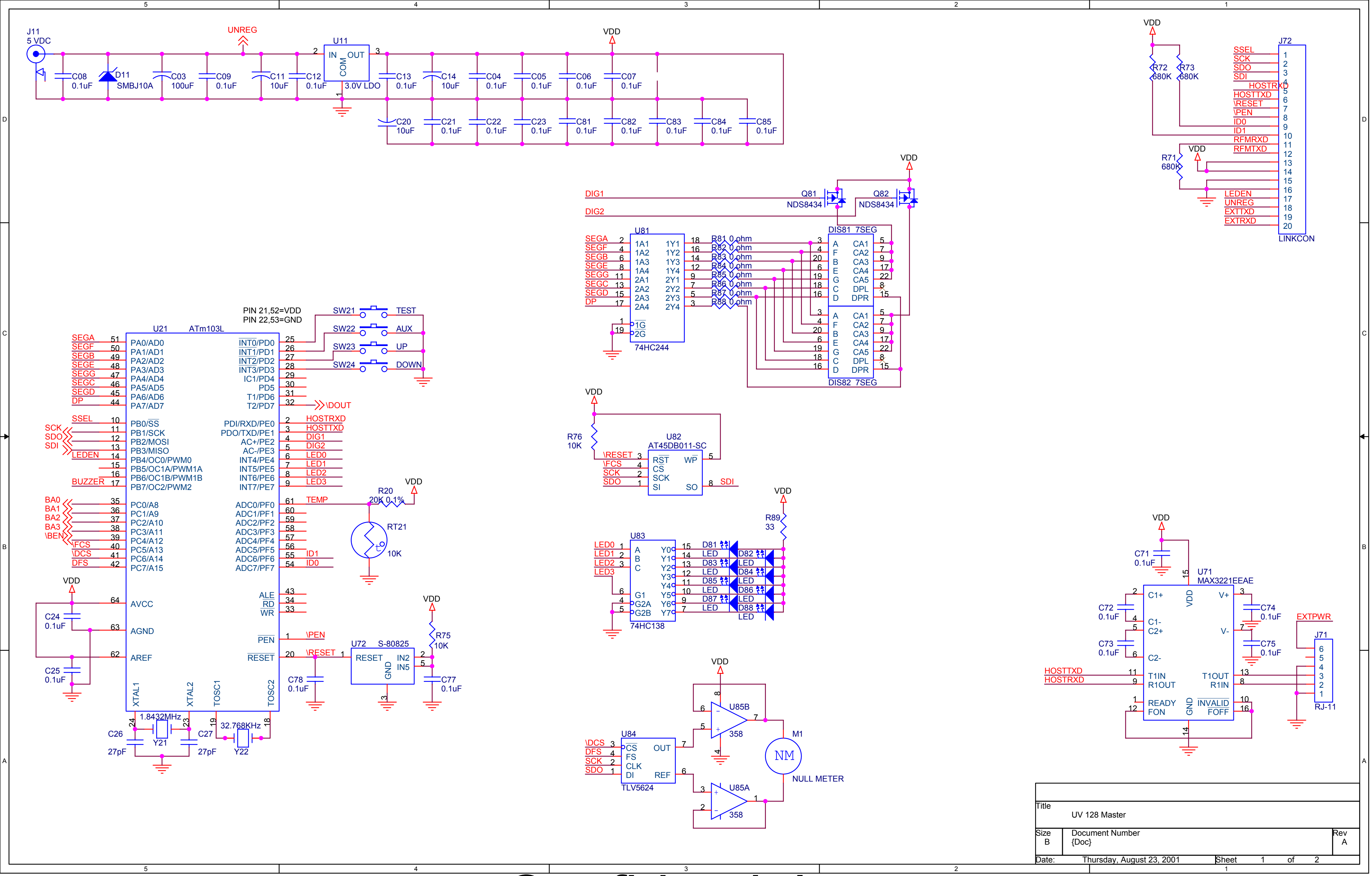
SCAN - Show A/D counts of the selected A/D chip. Press <CR> to scan again and to quit press Q.

SCANR - Same as SCAN but will repeat without your intervention.

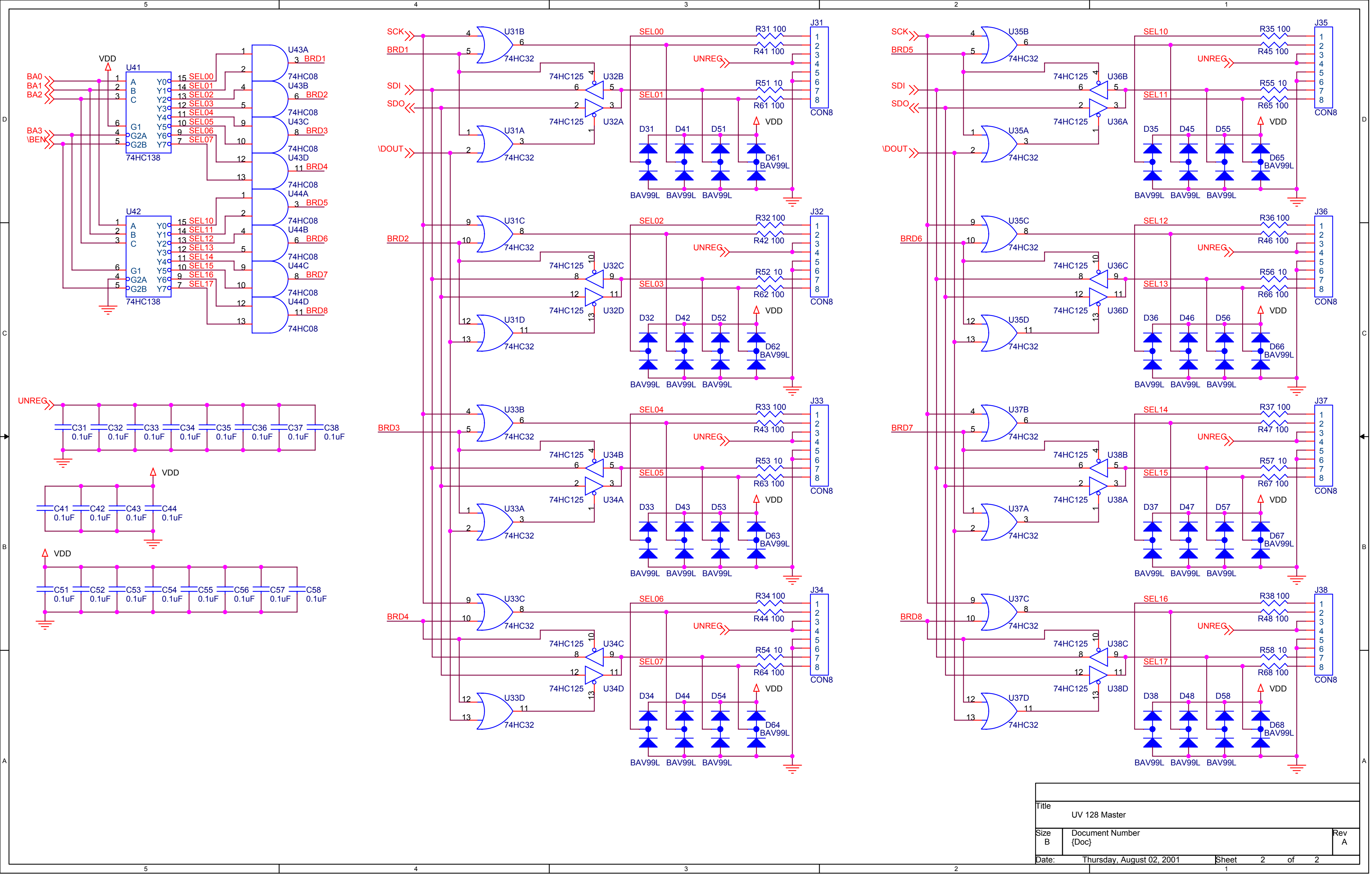
SETBRD - Select a specific A/D chip to work with. “SETBRD 0 0” chooses board 0 A/D chip 0.

SETCHIP - Select a specific A/D chip to work with. “SETCHIP 15” chooses board 7 A/D chip 1.
SETCUR - Select a sensor to CAL. “SETCUR 0 1” chooses the sensor on board 0 channel 1.
SETD - Set the date. “SETD 8 16 01” sets the date to 8/16/01. Note, if a number is less than 10 you need to proceed it with a zero.

SETDIG - Set the value of a digit on the main board. “SETDIG 1 F” writes an F to digit 1.
SETLED - Turn on an slave board LED. “SETLED 7” turns the selected A/D chips channel 7 LED on.
SETPER - Set the archive period of the data logger. “SETPER 10” sets the period to 10 minutes. Number is saved in the EEPROM.
SETREF - Set the board and channel the reference is connected too. “SETREF 0 0” sets the reference to board 0 channel 0.
SETT - Set the clock. “SETT 02 02” sets the time to 2:02 am. Note, if a number is less than 10 you need to proceed it with a zero.
SETTIME - Not used.
SETUP - Initializes the selected A/D chip. This is done automatically at boot up.
SHOW - Shows the current readings of a specified board. “SHOW 0” will show all the readings for board 0.
STATUS - Prints important status information to the screen.
USE - Sets which boards you are logging. “USE 3” selects boards 0 and 1. Each bit corresponds to a board.
VER - Get version of firmware.



Confidential



BA0
BA1
BA2
BA3
\BEN
VDD
U41 74HC138
U42 74HC138
A B C G1 G2A G2B
Y0 Y1 Y2 Y3 Y4 Y5 Y6 Y7
SEL00 SEL01 SEL02 SEL03 SEL04 SEL05 SEL06 SEL07
SEL10 SEL11 SEL12 SEL13 SEL14 SEL15 SEL16 SEL17
U43A U43B U43C U43D U44A U44B U44C U44D 74HC08
BRD1 BRD2 BRD3 BRD4 BRD5 BRD6 BRD7 BRD8
UNREG
C31 C32 C33 C34 C35 C36 C37 C38 0.1uF
C41 C42 C43 C44 0.1uF
C51 C52 C53 C54 C55 C56 C57 C58 0.1uF
SCK
SDI
SDO
\DOUT
U31A U31B U31C U31D U33A U33B U33C U33D 74HC32
U35A U35B U35C U35D U37A U37B U37C U37D 74HC32
U32A U32B U32C U32D U34A U34B U34C U34D 74HC125
U36A U36B U36C U36D U38A U38B U38C U38D 74HC125
R31 100 R41 100 R51 10 R61 100
R32 100 R42 100 R52 10 R62 100
R33 100 R43 100 R53 10 R63 100
R34 100 R44 100 R54 10 R64 100
R35 100 R45 100 R55 10 R65 100
R36 100 R46 100 R56 10 R66 100
R37 100 R47 100 R57 10 R67 100
R38 100 R48 100 R58 10 R68 100
J31 J32 J33 J34 J35 J36 J37 J38 CON8
D31 D41 D51 D61 D32 D42 D52 D62 D33 D43 D53 D63 D34 D44 D54 D64
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BAV99L
Title
UV 128 Master
Size B
Document Number
{Doc}
Rev A
Date: Thursday, August 02, 2001
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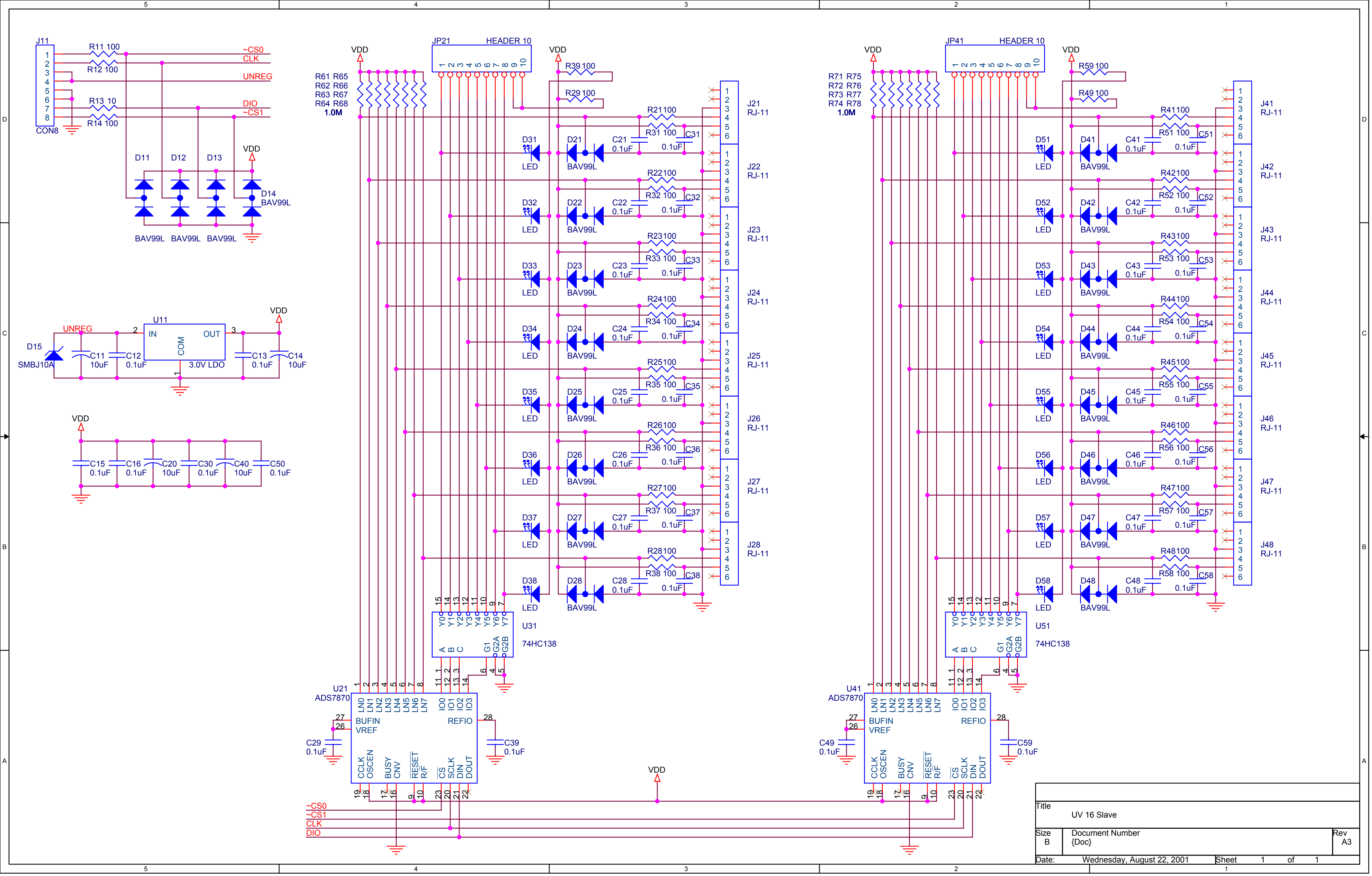
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CON8
R11 100
R12 100
R13 10
R14 100
~CS0
CLK
UNREG
DIO
~CS1
D11
D12
D13
D14
BAV99L
VDD
U11
IN
OUT
COM
3.0V LDO
D15
SMBJ10A
C11 10uF
C12 0.1uF
C13 0.1uF
C14 10uF
C15 0.1uF
C16 0.1uF
C20 10uF
C30 0.1uF
C40 10uF
C50 0.1uF
JP21
HEADER 10
R61 R65
R62 R66
R63 R67
R64 R68
1.0M
J21 RJ-11
J22 RJ-11
J23 RJ-11
J24 RJ-11
J25 RJ-11
J26 RJ-11
J27 RJ-11
J28 RJ-11
LED
U31
74HC138
U21
ADS7870
BUFIN
VREF
REFIO
C29 0.1uF
C39 0.1uF
JP41
HEADER 10
R71 R75
R72 R76
R73 R77
R74 R78
J41 RJ-11
J42 RJ-11
J43 RJ-11
J44 RJ-11
J45 RJ-11
J46 RJ-11
J47 RJ-11
J48 RJ-11
U51
74HC138
U41
ADS7870
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C59 0.1uF
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UV 16 Slave
Size B
Document Number {Doc}
Rev A3
Date: Wednesday, August 22, 2001
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Vantage Link Tester Rev P
OVERVIEW By P.Dillon

The vantage link tester is a standalone fixture for testing the vantage link memory modules Part # 07315.010. The Vantage Link tester is composed of 1 main PCB that can test up to 8 links in only about 8 minutes.

The corresponding LED shows status of the link
Green= passed
Orange=transmit problem, receive problem, too much active current, too much sleep current
Red=memory failure
No Light= Link was not detected Check Flash memory (SCLK, SDI, SDO

Under normal operation pressing SW21 will start the process of testing.
One tester status LED is down by the switch. When the tester is ready it will light green. When a test is in progress it will flash yellow.

J91 can be used for diagnostics and to send commands (See Sheet Serial Command for link tester)

MEMORY TEST
SCK,SDO and SDI are used to send /receive data and TA0,TA1 and TA2 select the link under test. Power for the link is switch using /TEN signal. Testing of the memory link is done by first writing a pattern 0+p, 1+p, 2+p...264+p where p is the page number of the flash then reading back that pattern, then writing zero's and reading back zero's. Then the program will erase the link (writes 1) and check to make sure it is completely erased. This is done for all 512 pages of each link

CHECKING RS232
TX
During the TX phase of the test the TAO/TA1/TA2 line are selected, 200 characters at 19,000 baud is sent from U21 TXD though the analog mux (U22) then level shifted (U71) the appropriated relay is pulled. This character is feed to the MAX3221 (pin8) of the link, the level is then shifted back to 0-3volts and can be seen on pin 5 of the link this is the de multiplex with U43 then mux again though U22 and received by pin 2 of U21.

RX
During the RX phase of testing the TAO/TA1/TA2 line are selected, 200 characters at 19,000 baud is sent from U21 RXD though the analog mux U22 then multiplex using U42 in to pin 6 of the appropriate link then level shifted and transmitted though the relay back to U71 and level shifted back to 0-3volts back to U22 and received by U21.

CHECKING CURRENT

The last test that is done is to check that the current draw of the link is not too excessive this is done with a shunt resistor R39 that drops the voltage seen by the voltage divider R23 /R24 (UXCISNS). The more current that is draw by the link under test cause the voltage across R39 to be higher, which causes the voltage divider to be ½ less that drop. We measure both the active current and the shutdown current using shunt resistor R39 and a voltage divider, plus a second "reference" voltage divider on the Vcc source since it does change with the LED current.

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COMMAND   DESCRIPTION
TEST -    returns 'OK'
LOOP -    sends 0x55 out the SPI port.  Exit by pressing start
          button.
START -   Start a link test.
TSEL -    Cycle through selecting each link.  Exit by pressing
          start button.
CYCLE -   Cycle through lighting each LED.
PORTC n - Do a PORTC = n where n is a hex number.
          LED l n - Set the led at link position l to n.  RED - 1,
          ORANGE - 3, GREEN - 2.
FWR l p - Write pattern to link l page p.  Pattern starts at 0+p
          and increments by 1.
FRD l p - Reads and displays page p from link l.
RXTEST l -Sends logic level 'U'  to link under test and reads back
          in RS232 level 'U' from UART.  Loopbacked 'U' is sent
          out the SPI UART to terminal.  Exit by pressing the
          start button.
TXTEST l -Sends RS232 level 'U'  to link under test and reads back
          in logic level 'U' from UART.  Loopbacked 'U' is sent
          out the SPI UART to terminal.  Exit by pressing the
          start button.

RXTX l -  Perform just the RS232 part of the test on link l.
FTEST l - Perform just the FLASH part of the test on link l.
STATUSLED n - Set the status LED to n.  RED - 1, ORANGE - 3, GREEN
          - 2.
CUR l b - Measure the current on link l under conditions specified
          by b.  "b" is a hex number where the bits 0 through 3
          correspond to EXT, DTR, RLY, and LEN.  The bits are
          active high.  Exit by pushing the start button.

ERASEPG l p - Erase a page p from link l.
ERASEALL l - Erase the entire flash on link l.
ADREAD c n - Return total of n reads of channel c.
VER -     Returns date of firmware in tester.
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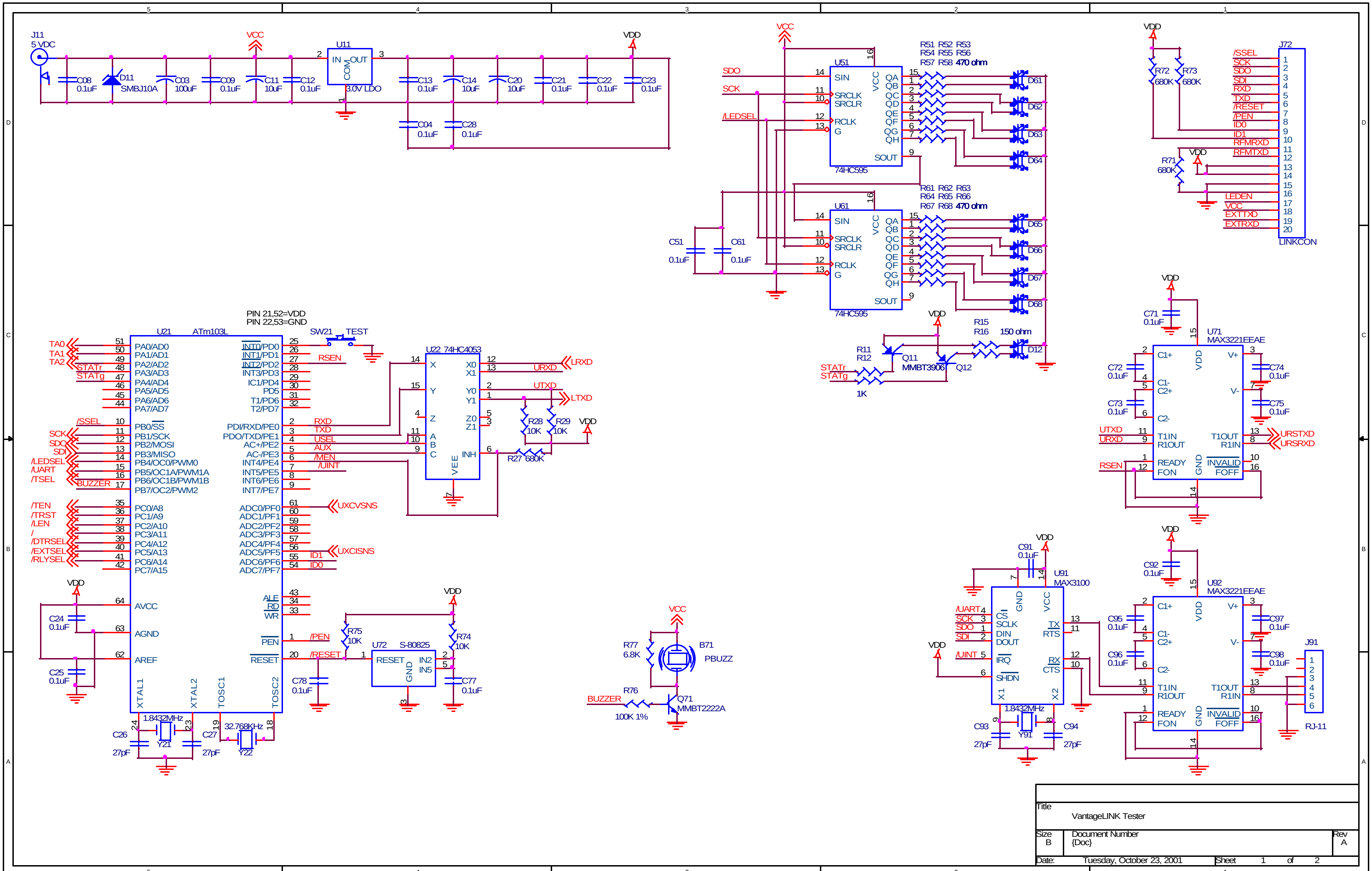
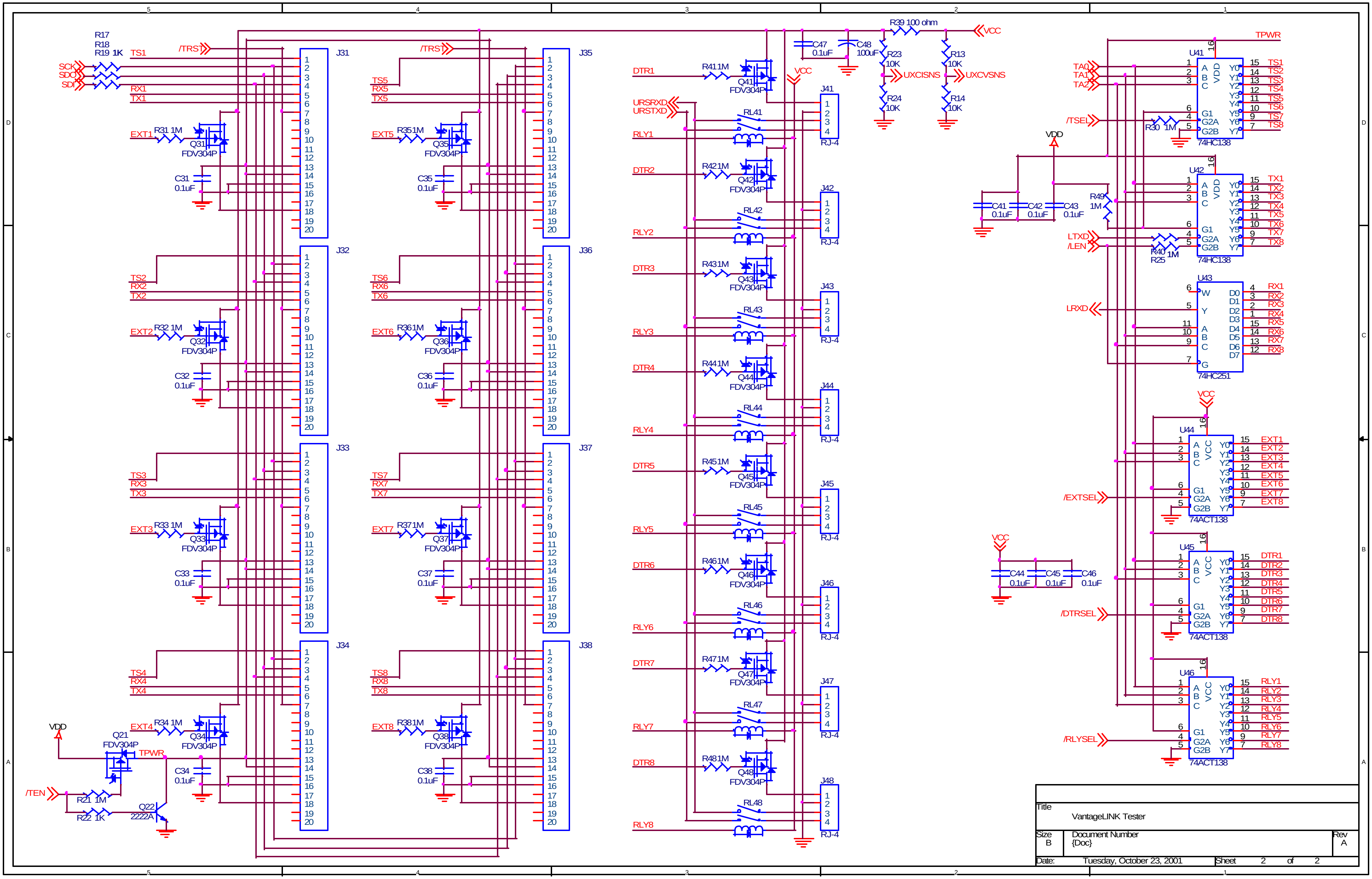


Confidential


SCK
SDO
SDI
R17
R18
R19 1K
TS1
/TRST
RX1
TX1
EXT1
R31 1M
Q31
FDV304P
C31
0.1uF
J31
J32
J33
J34
J35
J36
J37
J38
TS2
RX2
TX2
EXT2
R32 1M
Q32
C32
TS3
RX3
TX3
EXT3
R33 1M
Q33
C33
TS4
RX4
TX4
EXT4
R34 1M
Q34
C34
VDD
Q21
FDV304P
TPWR
/TEN
R21 1M
R22 1K
Q22
2222A
TS5
RX5
TX5
EXT5
R35 1M
Q35
C35
TS6
RX6
TX6
EXT6
R36 1M
Q36
C36
TS7
RX7
TX7
EXT7
R37 1M
Q37
C37
TS8
RX8
TX8
EXT8
R38 1M
Q38
C38
DTR1
R41 1M
Q41
URSRXD
URSTXD
RLY1
RL41
J41
RJ-4
DTR2
R42 1M
Q42
RL42
RLY2
J42
DTR3
R43 1M
Q43
RL43
RLY3
J43
DTR4
R44 1M
Q44
RL44
RLY4
J44
DTR5
R45 1M
Q45
RL45
RLY5
J45
DTR6
R46 1M
Q46
RL46
RLY6
J46
DTR7
R47 1M
Q47
RL47
RLY7
J47
DTR8
R48 1M
Q48
RL48
RLY8
J48
VCC
C47
0.1uF
C48
100uF
R39 100 ohm
R23
10K
R24
10K
R13
10K
R14
10K
UXCISNS
UXCVSNS
TA0
TA1
TA2
/TSEL
R30 1M
U41
74HC138
U42
74HC138
LTXD
/LEN
R40 1M
R25
R49
1M
C41
0.1uF
C42
0.1uF
C43
0.1uF
U43
74HC251
LRXD
U44
74ACT138
/EXTSEL
U45
74ACT138
/DTRSEL
U46
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/RLYSEL
C44
0.1uF
C45
0.1uF
C46
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VantageLINK Tester
Size
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Document Number
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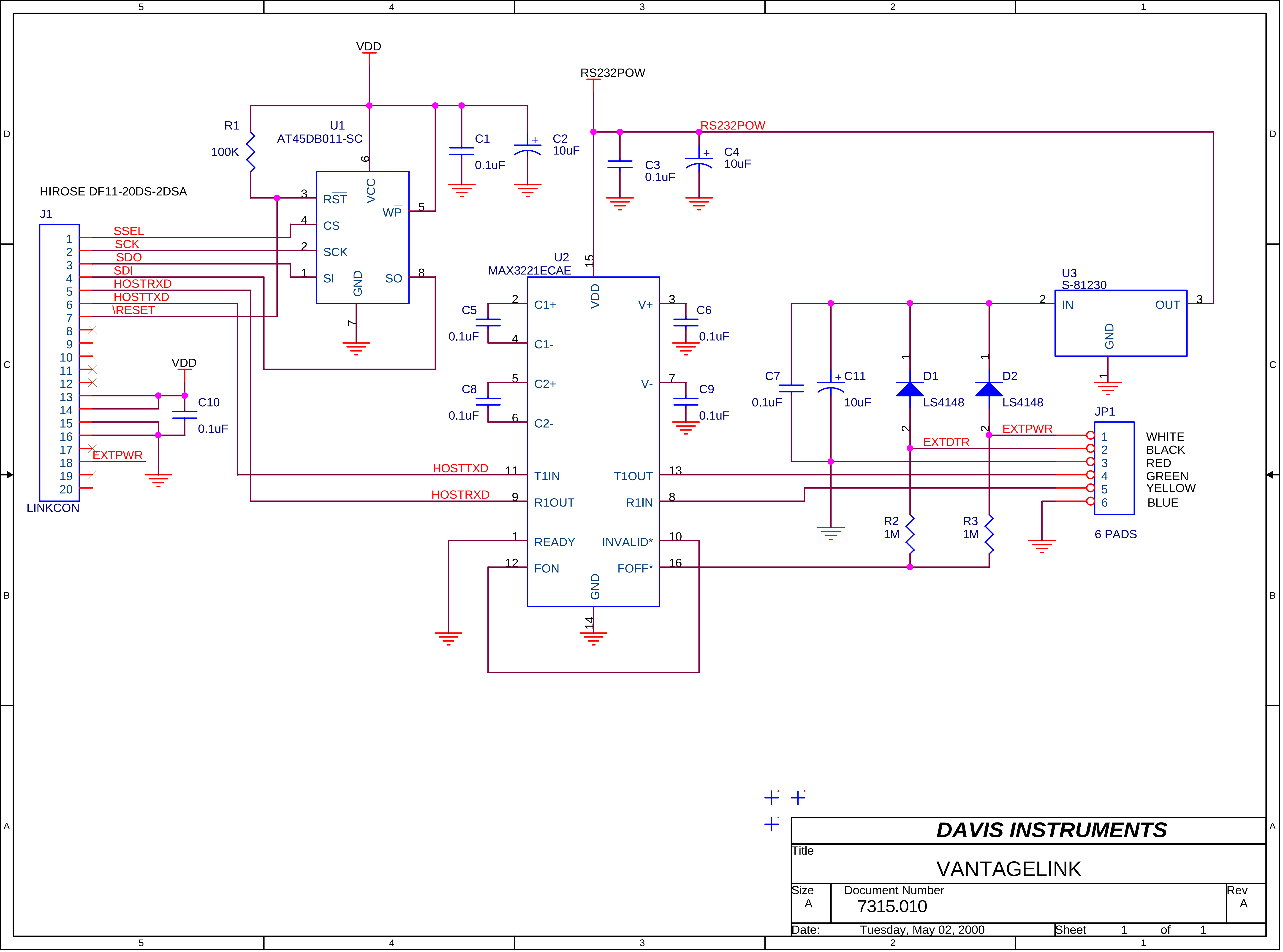
Rev
A
Date: Tuesday, October 23, 2001
Sheet 2 of 2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RS232POW
R1
100K
U1
AT45DB011-SC
RST
CS
SCK
SI
VCC
WP
SO
GND
C1
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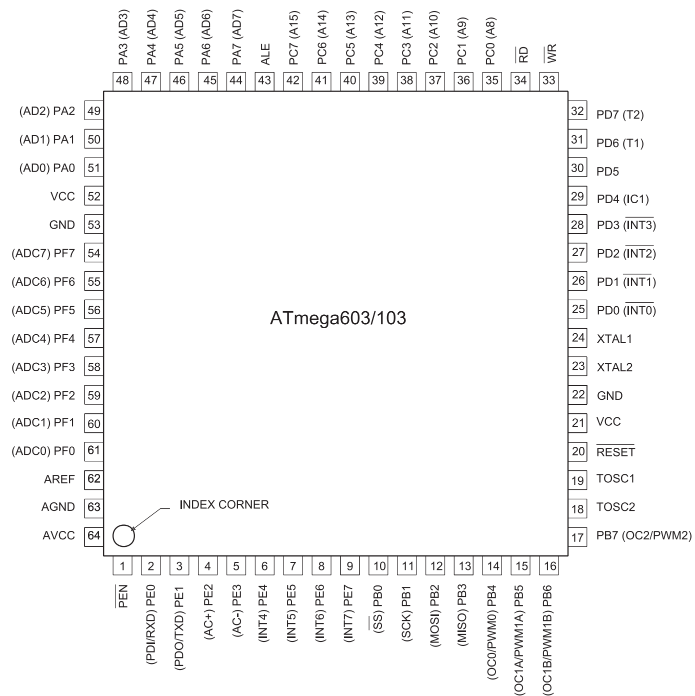
C2
10uF
C3
0.1uF
C4
10uF
HIROSE DF11-20DS-2DSA
J1
LINKCON
SSEL
SCK
SDO
SDI
HOSTRXD
HOSTTXD
\RESET
EXTPWR
C10
0.1uF
U2
MAX3221ECAE
C1+
C1-
C2+
C2-
V+
V-
T1IN
R1OUT
T1OUT
R1IN
READY
FON
INVALID*
FOFF*
C5
C6
C8
C9
U3
S-81230
IN
OUT
C7
C11
D1
D2
LS4148
EXTDTR
R2
R3
1M
JP1
WHITE
BLACK
RED
GREEN
YELLOW
BLUE
6 PADS
DAVIS INSTRUMENTS
Title
VANTAGELINK
Size
A
Document Number
7315.010
Rev
A
Date: Tuesday, May 02, 2000
Sheet 1 of 1

Pin Configuration

TQFP



Description

The ATmega603/103 is a low-power CMOS 8-bit microcontroller based on the AVR RISC architecture. By executing powerful instructions in a single clock cycle, the ATmega603/103 achieves throughputs approaching 1 MIPS per MHz allowing the system designer to optimize power consumption versus processing speed.

The AVR core is based on an enhanced RISC architecture that combines a rich instruction set with 32 general purpose working registers. All the 32 registers are directly connected to the Arithmetic Logic Unit (ALU), allowing two independent registers to be accessed in one single instruction executed in one clock cycle. The resulting architecture is more code efficient while achieving throughputs up to ten times faster than conventional CISC microcontrollers.

The ATmega603/103 provides the following features: 64K/128K bytes of In-system Programmable Flash, 2K/4K bytes EEPROM, 4K bytes SRAM, 32 general purpose I/O lines, 8 Input lines, 8 Output lines, 32 general purpose working registers, Real Time Counter (RTC), 4 flexible timer/counters with compare modes and PWM, UART, programmable Watchdog Timer with internal oscillator, an SPI serial port and three software selectable power saving modes. The Idle Mode stops the CPU while allowing the SRAM, timer/counters, SPI port and interrupt system to continue functioning. The Power Down mode saves the register contents but freezes the oscillator, disabling all other chip functions until the next interrupt or hardware reset. In Power Save mode, the timer oscillator continues to run, allowing the user to maintain a timer base while the rest of the device is sleeping.

The device is manufactured using Atmel's high-density nonvolatile memory technology. The on-chip ISP Flash allows the program memory to be reprogrammed in-system through a serial interface or by a conventional nonvolatile memory programmer. By combining an 8-bit RISC CPU with a large array of ISP Flash on a monolithic chip, the Atmel ATmega603/103 is a powerful microcontroller that provides a highly flexible and cost effective solution to many embedded control applications.

The ATmega603/103 AVR is supported with a full suite of program and system development tools including: C compilers, macro assemblers, program debugger/simulators, in-circuit emulators, and evaluation kits.

RFM®

TX6000

916.50 MHz Hybrid Transmitter

- ***Designed for Short-Range Wireless Data Communications***
- ***Supports RF Data Transmission Rates Up to 115.2 kbps***
- ***3 V, Low Current Operation plus Sleep Mode***
- ***Stable, Easy to Use, Low External Parts Count***

The TX6000 hybrid transmitter is ideal for short-range wireless data applications where robust operation, small size, low power consumption and low cost are required. All critical RF functions are contained in the hybrid, simplifying and speeding design-in. The TX6000 includes provisions for both on-off keyed (OOK) and amplitude-shift keyed (ASK) modulation. The TX6000 employs SAW filtering to suppress output harmonics, facilitating compliance with FCC 15.249 and similar regulations.

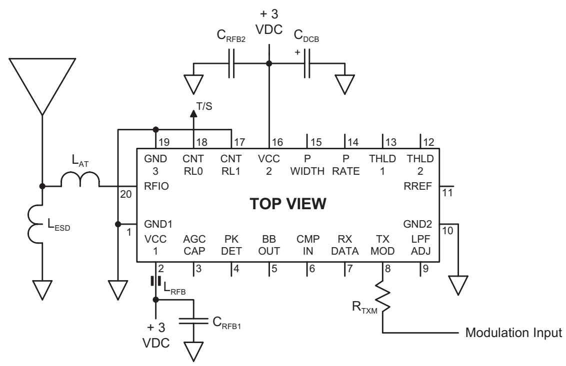
Absolute Maximum Ratings

Rating	Value	Units
Power Supply and All Input/Output Pins	-0.3 to +4.0	V
Non-Operating Case Temperature	-50 to +100	°C
Soldering Temperature (10 seconds)	230	°C

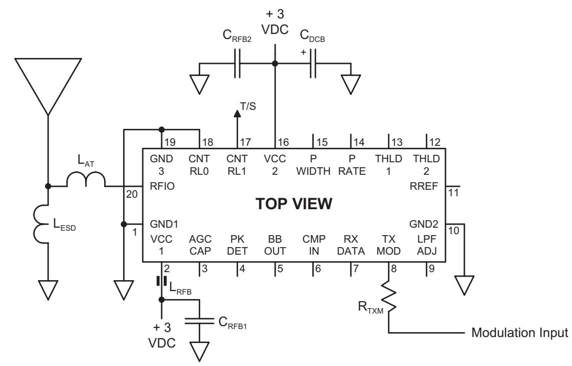
Electrical Characteristics

Characteristic	Sym	Notes	Minimum	Typical	Maximum	Units
Operating Frequency	f_O		916.30		916.70	MHz
Modulation Types			OOK & ASK			
Data Rate					115.2	kbps
Transmitter Performance						
Peak Input Current, 3 Vdc Supply	I_{TP}				12	mA
Peak Output Power	P_O			0.75		mW
Turn On/Turn Off Time, OOK	t_{ON}/t_{OFF}				40	µs
Turn On/Turn Off Time, ASK	t_{ON}/t_{OFF}				1	µs
2nd Harmonic Emission					-36	dBm
3rd - 10th Harmonic Emissions					-42	dBm
Non-harmonic Spurious Emissions					-50	dBm
Sleep Mode Current	I_S				5	µA
Sleep to Transmit Switch Time	t_{TOR}				46	µs
Transmit to Sleep Switch Time	t_{RTO}				40	µs
Control Input Logic Low Level					200	mV
Control Input Logic High Level		1	Vcc - 200			mV
Power Supply Voltage Range	V_{CC}		2.7		3.5	Vdc
Operating Ambient Temperature	T_A		-40		+85	°C

Transmitter OOK Configuration



Transmitter ASK Configuration



Transmitter Set-Up, 3.0 Vdc, -40 to +85 ^{0}C

Item	Symbol	OOK	OOK	ASK	Units	Notes
Nominal NRZ Data Rate	DR_{NOM}	2.4	19.2	115.2	kbps	see page 1
Minimum Signal Pulse	SP_{MIN}	416.67	52.08	8.68	µs	single bit
Maximum Signal Pulse	SP_{MAX}	1666.68	208.32	34.72	µs	4 bits of same value
TXMOD Resistor	R_{TXM}	8.2	8.2	8.2	K	±5%, for 0.25 mW output
DC Bypass Capacitor	C_{DCB}	10	10	10	µF	tantalum
RF Bypass Capacitor 1	C_{RFB1}	27	27	27	pF	±5% NPO
RF Bypass Capacitor 2	C_{RFB2}	100	100	100	pF	±5% NPO
RF Bypass Bead	L_{RFB}	Fair-Rite	Fair-Rite	Fair-Rite	vendor	2506033017YO or equivalent
Series Tuning Inductor	L_{AT}	10	10	10	nH	50 ohm antenna
Shunt Tuning/ESD Inductor	L_{ESD}	100	100	100	nH	50 ohm antenna

CAUTION: Electrostatic Sensitive Device. Observe precautions when handling.

Notes:

1. Do not allow the voltage applied to a control input pin to exceed Vcc + 200 mV.
2. The companion receiver to the TX6000 is the RX6000. Please see RFM’s web site at www.rfm.com for details.

Transmitter Theory of Operation

Introduction

RFM's TX-series hybrid transmitters are specifically designed for short-range wireless data communication applications. These transmitters provide robust operation, very small size, low power consumption and low implementation cost. All critical RF functions are contained in the hybrid, simplifying and speeding design-in. The transmitters can be readily configured to support a wide range of data rates and protocol requirements. TX-series transmitters feature excellent suppression of output harmonics and virtually no other RF emissions, making them easy to certify to short- range (unlicensed) radio regulations.

Transmitter Block Diagram

Figure 1 is the general block diagram of the transmitter. Please refer to Figure 1 for the following discussions.

Antenna Port

The only external RF components needed for the transmitter are the antenna and its matching components. Antennas presenting an impedance in the range of 35 to 72 ohms resistive can be satisfactorily matched to the RFIO pin with a series matching coil and a shunt matching/ESD protection coil. Other antenna impedances can be matched using two or three components. For some impedances, two inductors and a capacitor will be required. A DC path from RFIO to ground is required for ESD protection.

Transmitter Chain

The transmitter chain consists of a SAW coupled-resonator oscillator followed by a modulated buffer amplifier. The SAW coupled resonator output filter suppresses transmitter harmonics to the antenna.

Transmitter operation supports two modulation formats, on-off keyed (OOK) modulation, and amplitude-shift keyed (ASK) modulation. When OOK modulation is chosen, the transmitter output turns completely off between "1" data pulses. When ASK modulation is chosen, a "1" pulse is represented by a higher transmitted power level, and a "0" is represented by a lower transmitted power level. OOK modulation provides compatibility with first-generation ASH technology, and provides for power conservation. ASK modulation must be used for high data rates (data pulses less than 200 µs). ASK modulation also reduces the effects of some types of interference and allows the transmitted pulses to be shaped to control modulation bandwidth.

The modulation format is chosen by the state of the CNTRL0 and the CNTRL1 mode control pins, as discussed below. In the OOK mode, the oscillator amplifier TXA1 and buffer amplifier TXA2 are turned off when the voltage to the TXMOD input falls below 220 mV. In the OOK mode, the data rate is limited by the 40 µs turn-on and turn-off time of the oscillator. In the ASK mode TXA1 is biased ON continuously, and the output of TXA2 is modulated by the TXMOD input current. Minimum output power occurs in the ASK mode when the modulation driver sinks about 10 µA of current from the TXMOD pin.

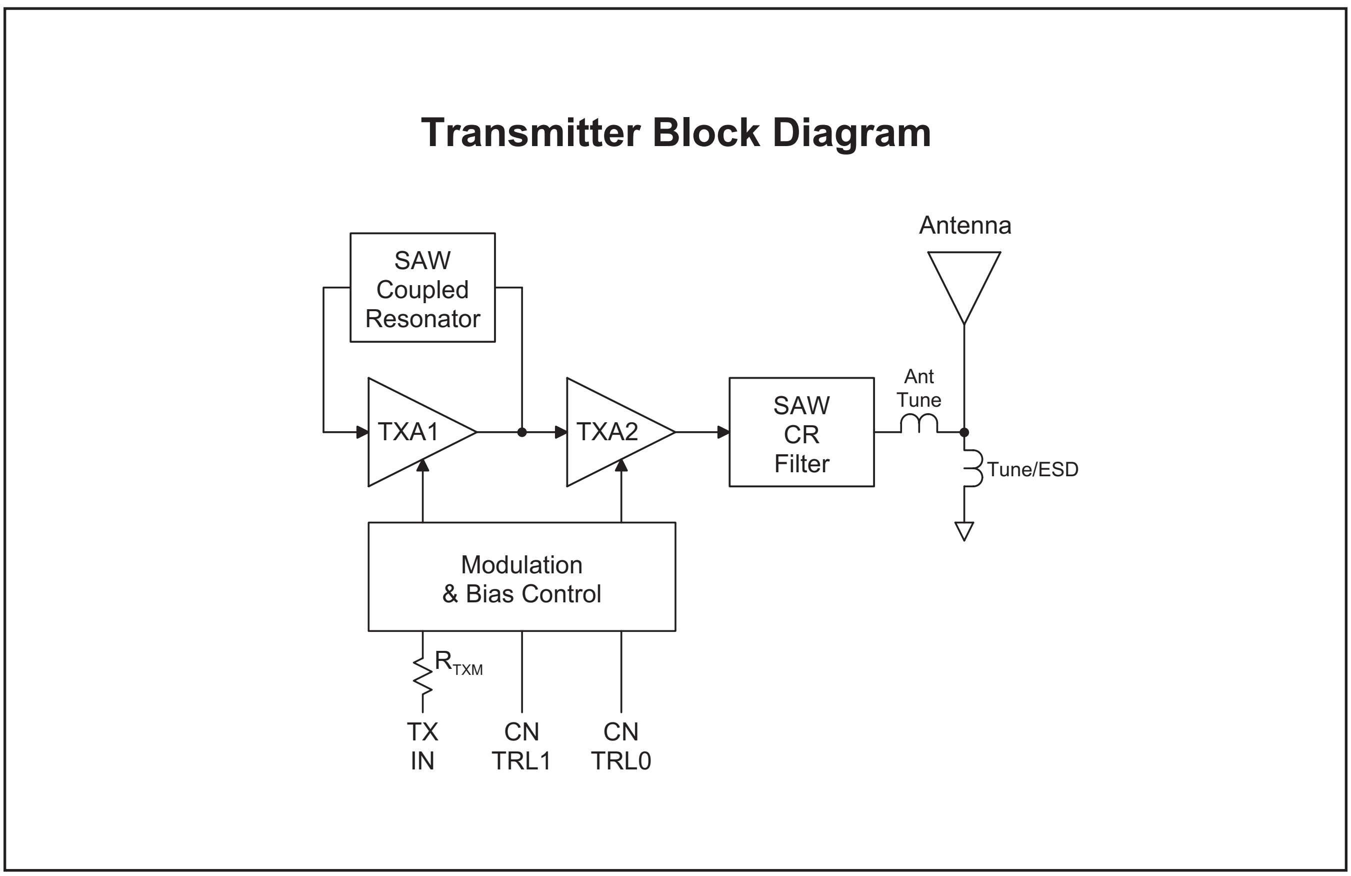


Figure 1

The transmitter RF output power is proportional to the input current to the TXMOD pin. A series resistor is used to adjust the peak transmitter output power. Maximum saturated output power requires 450 μA of input current.

Transmitter Mode Control

The three transmitter operating modes – transmit ASK, transmit OOK, and power-down (sleep), are controlled by the Modulation & Bias Control function, and are selected with the CNTRL1 and CNTRL0 control pins. Setting CNTRL1 high and CNTRL0 low place the unit in the ASK transmit mode. Setting CNTRL1 low and CNTRL0 high place the unit in the OOK transmit mode. Setting CNTRL1 and CNTRL0 both low place the unit in the power-down mode. (Note that the resistor driving TXMOD must also be low in the power-down mode to minimize power-down current.) CNTRL1 and CNTRL0 are CMOS compatible inputs. These inputs must be held at a logic level; they cannot be left unconnected.

Turn-On Timing

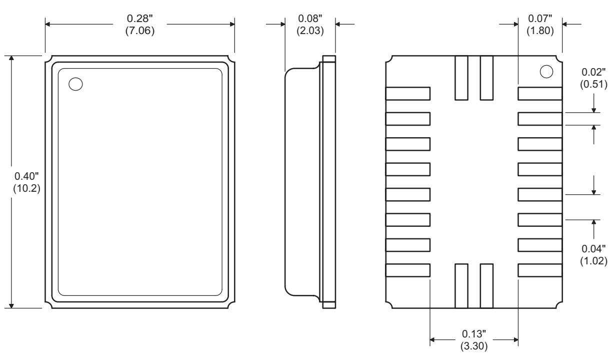
The maximum time required for either the OOK or ASK transmitter mode to become operational is 5 ms after the supply voltage reaches 2.7 Vdc. The total turn-on time to stable transmitter operation for a 10 ms power supply rise time is 15 ms.

Sleep and Wake-Up Timing

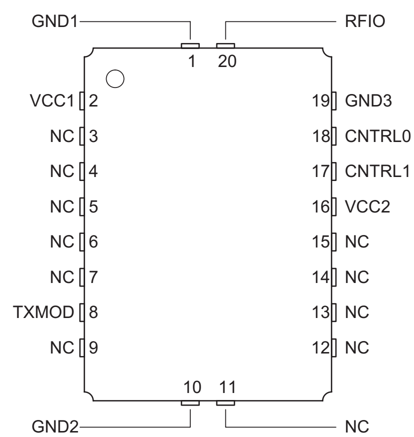
The maximum transition time from either transmit mode to the sleep mode (t_{TOS} and t_{TAS}) is 40 μs after CNTRL1 and CNTRL0 are both low (1 μs fall time).

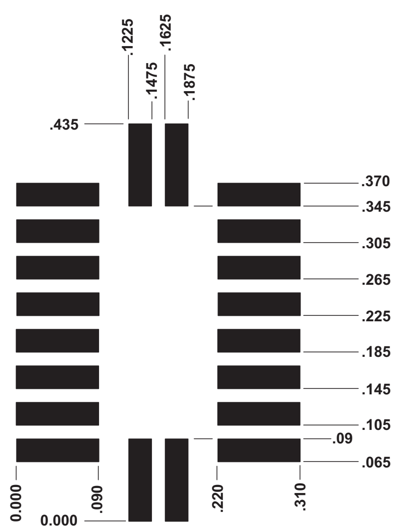
The maximum time required to switch from the sleep mode to either transmit mode (t_{STO} and t_{STA}) is 46 μs. Most of this time is due to the start-up of the transmitter oscillator.

SM-20H Outline Drawing



Transmitter Pin Out





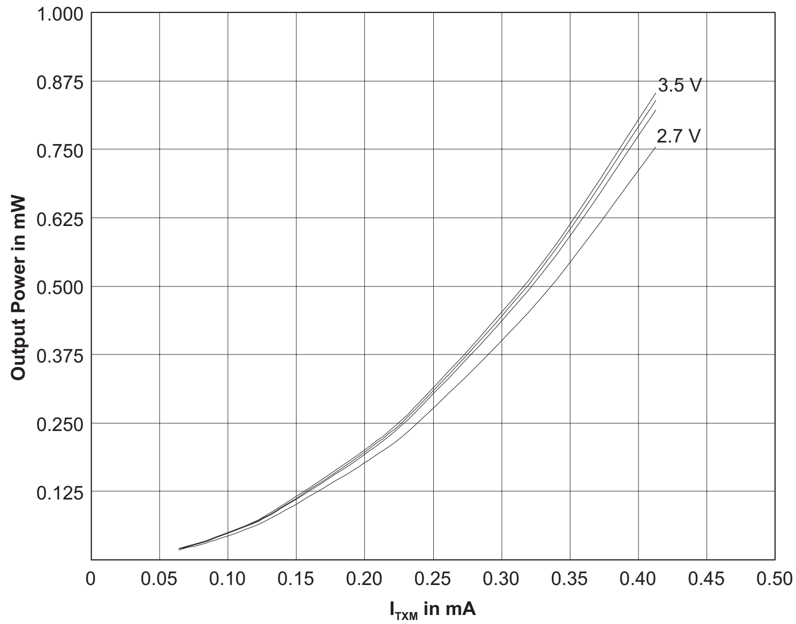
Dimensions in inches.

SM-20H PCB Pad Layout

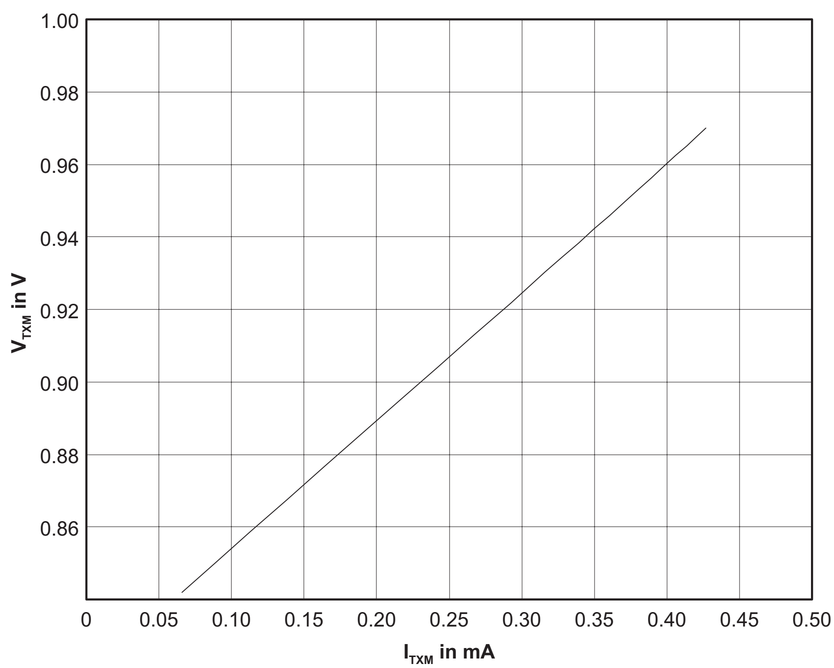
Pin Descriptions

Pin	Name	Description
1	GND1	GND1 is the RF ground pin. GND2 and GND3 should be connected to GND1 by short, low-inductance traces.
2	VCC1	VCC1 is the positive supply voltage pin for the transmitter output amplifier and the transmitter base-band circuitry. VCC1 is usually connected to the positive supply through a ferrite RF decoupling bead which is bypassed by an RF capacitor on the *supply side*. See the description of VCC2 (Pin 16) for additional information.
3	NC	No connection. Printed circuit board pad may be grounded or floating.
4	NC	No connection. Printed circuit board pad may be grounded or floating.
5	NC	No connection. Printed circuit board pad may be grounded or floating.
6	NC	No connection. Printed circuit board pad may be grounded or floating.
7	NC	No connection. Printed circuit board pad may be grounded or floating.
8	TXMOD	The transmitter RF output voltage is proportional to the input current to this pin. A series resistor is used to adjust the peak transmitter output voltage. Maximum saturated output power requires 450 µA of input current. In the ASK mode, minimum output power occurs when the modulation driver sinks about 10 µA of current from this pin. In the OOK mode, input signals less than 220 mV completely turn the transmitter oscillator off. Internally, this pin appears to be a diode in series with a small resistor. Peak transmitter output power P_O for a 3 Vdc supply voltage is approximately: $P_O = 4.8*(I_{TXM})^2$, where P_O is in mW, and the peak modulation current I_{TXM} is in mA. A ±5% resistor is recommended. A starting point resistor value for FCC Part 15.249 applications is 8.2 K. In the OOK mode, this pin is usually driven with a logic-level data input (unshaped data pulses). OOK modulation is practical for data pulses of 200 µs or longer. In the ASK mode, this pin accepts analog modulation (shaped or unshaped data pulses). ASK modulation is practical for data pulses 8.7 µs or longer. This pin must be low in the power-down (sleep) mode. Please refer to the *ASH Transceiver Designer's Guide* for additional information on modulation techniques.
9	NC	No connection. Printed circuit board pad may be grounded or floating.
10	GND2	GND2 is an IC ground pin. It should be connected to GND1 by a short, low inductance trace.
11	NC	No connection. Printed circuit board pad may be grounded or floating.
12	NC	No connection. Printed circuit board pad may be grounded or floating.
13	NC	No connection. Printed circuit board pad may be grounded or floating.
14	NC	No connection. Printed circuit board pad may be grounded or floating.
15	NC	No connection. Printed circuit board pad may be grounded or floating.
16	VCC2	VCC2 is the positive supply voltage pin for the transmitter oscillator. Pin 16 must be bypassed with an RF capacitor, and must also be bypassed with a 1 to 10 µF tantalum or electrolytic capacitor. See the *ASH Transceiver Designer's Guide* for additional information.
17	CNTRL1	CNTRL1 and CNTRL0 select the transmit modes. CNTRL1 high and CNTRL0 low place the unit in the ASK transmit mode. CNTRL1 low and CNTRL0 high place the unit in the OOK transmit mode. CNTRL1 and CNTRL0 both low place the unit in the power-down (sleep) mode. CNTRL1 is a high-impedance input (CMOS compatible). An input voltage of 0 to 200 mV is interpreted as a logic low. An input voltage of Vcc - 200 mV or greater is interpreted as a logic high. An input voltage greater than Vcc + 200 mV should not be applied to this pin. A logic high requires a maximum source current of 40 µA. A logic low requires a maximum sink current of 25 µA (1 µA in sleep mode). This pin must be held at a logic level; it cannot be left unconnected.
18	CNTRL0	CNTRL0 is used with CNTRL1 to control the operating modes of the transmitter. See the description of CNTRL1 for more information.
19	GND3	GND3 is an IC ground pin. It should be connected to GND1 by a short, low inductance trace.
20	RFIO	RFIO is the transmitter RF output pin. This pin is connected directly to the SAW filter transducer. Antennas presenting an impedance in the range of 35 to 72 ohms resistive can be satisfactorily matched to this pin with a series matching coil and a shunt matching/ESD protection coil. Other antenna impedances can be matched using two or three components. For some impedances, two inductors and a capacitor will be required. A DC path from RFIO to ground is required for ESD protection.

RF Output Power vs I_{TXM}



V_{TXM} vs I_{TXM}



Note: Specifications subject to change without notice.

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