National Radio Astronomy Observatory

VLB Array Program

VLB Array Electronics Memo No 128

Snow Gauge Interfaces to VLBA Weather Station

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We purchased an ultrasonic snow depth gauge from Campbell Scientific Inc. The model number was UDG01. A copy of the instruction manual is included as Appendix A. It was decided to put it at the Pie Town VLBA site and interface it into the weather station. No binary ports were available. There are some unused analog voltage monitor points. It was decided to convert the binary number to an analog voltage, using a D/A converter. This voltage was patched into an unused analog input slot (RA=OF). The logic was placed on a small "shalloway" card. The schematic, board layout, component location, I/O pin list, and wirewrap program input are included in Appendix B.

The interface logic simulates a data logger described in the snow gauge manual. Chip 3C periodically polls the snow gauge by generating the CP1, CP2 and CP3 signals. After an appropriate delay the clock signal on CP2 shifts the binary data (LSB first) out of the snow gauge into the shift register chips 2D and 2E. At the end of the shift sequence the binary number is latched and displayed (in Hex) in chips 2A, 3A, 4A, and 5A. Twelve of the 16 bits are also latched into chips 3E and 3F which drive the D/A inputs. The SG voltage from the D/A is then fed to the digital card of the weather station. CP1 control line has to have a tristate drive (chip 2F) since it is bidirectional.

The unit was mounted on the side of the weather station tower approximately 7 feet in the air. The snow gauge measures distance to the ground or snow. If the input voltage is V_o then the distance in inches.

$$D = 8.414\sqrt{\frac{TA+273}{291}}\;(10-V_o)$$

T_A equals ambient temperature in degrees celsius. Bill Meredith generated a screen program to display the information along with the tipping rain gauge information. It is the PRECIP screen under the WEA main menu. The snow depth displayed on the screen assumes a mounting height of 89 inches. This may vary some in the initial installation. We need to note the displayed number when there is no snow and use that as a reference for further readings. The alternative is to be able to vary an offset in the screen program to account for different mounting heights or prairie dogs digging the dirt up under the sensor. We propose to add a low concrete pad under the sensor at Pie Town to reduce the latter problem. We temporarily staked a two foot square of plywood to the ground as an interim measure. Test are ongoing. We will compare the results this winter with the heated tipping rain gauge also installed at Pie Town.

APPENDIX A

UDG01
Ultrasonic Depth Gauge
OPERATOR'S MANUAL

VERSION 7/90

WARRANTY AND ASSISTANCE

The UDG01 Ultrasonic Depth Gauge is warranted against defects in materials and workmanship. This warranty applies for twelve months from date of shipment. We will repair or replace products which prove to be defective during the warranty period provided they are returned prepaid to CAMPBELL SCIENTIFIC CANADA Corp. CAMPBELL SCIENTIFIC CANADA Corp. will return warranted equipment by surface carrier prepaid. No other warranty is expressed or implied. CAMPBELL SCIENTIFIC CANADA Corp. is not liable for consequential damages.

Products may not be returned without prior authorization. To obtain a Returned Materials Authorization (RMA), contact CAMPBELL SCIENTIFIC CANADA Corp., phone (403) 461-5158. An RMA number will be issued in order to facilitate Repair Personnel in identifying an instrument upon arrival. Please write this number clearly on the outside of the shipping container. Include description of symptoms and all pertinent details.

CAMPBELL SCIENTIFIC CANADA Corp. does not accept collect calls.

Non-warranty products returned for repair should be accompanied by a purchase order to cover the repair.

campbell scientific canada corp.
9525 41 ave · edmonton · alberta · canada · t6e 5x7 · (403) 461 5158
188 st clair st · chatham · ontario · canada · n7l 3j6 · (519) 354 7356

INTRODUCTION

The UDG01 depth sensor measures the distance from the sensor to a surface. The most common applications are monitoring snow depth or water level. The primary components of this depth sensor are the Polaroid Ultrasonic transducer and the Texas Instrument Sonar Ranging Module. Both components are specified to −25 °C although they can be tested to −40 °C. Together they form a means of "ranging" in a target by bouncing an ultrasonic wave, or series of pulses off the surface and listening for the return echo. The time from transmit to the return of the echo is the basis for obtaining the distance. Since the speed of sound in air varies with air temperature, an independent temperature measurement is required. In order to measure the UDG01, the data acquisition system used must have the following features:

1) Measure air temperature and store the temperature data in a memory location accessible by the program. This information is required so that a temperature correction can be applied to the distance measurement.

2) Have at least 3 control ports which can be controlled and act as both input and output. Alternatively, if the control ports cannot accept inputs, then an analog channel can be used. The analog input can be single-ended with a 5 volt range and have the capability of being selectively activated in order to read the 0 to 5 volt serial output train.

Goodison et al. (1988a) described factors which can affect the accuracy of measurement when used in snow monitoring. They discussed the effect of the nature of the snow surface, of blowing or falling snow at the time of the measurement and the effect of the temperature of the air through which the acoustic waves travel deviating from that measured by the temperature sensor. The nature of the snow surface is almost impossible to assess. Scattering of the acoustical signal as a result of blowing or falling snow is a problem which is difficult to solve. Invalid data are easily identified and interpolation can be made on relatively short periods.

In order to assess the effect of the temperature distribution and of vertical wind on the measurement, a simple relation describing the air temperature distribution between the sensor and measurement surface was used . This relation takes into account the stability of the air layer and uses air temperature and horizontal velocity at a certain height, surface temperature and roughness. The values used were representative of the normal atmospheric conditions. At values for the extremes of these conditions, a deviation of less than 0.1% was determined for an unstable atmosphere and of less than 0.05% for a stable atmosphere. A similar analysis was done to look at the influence of vertical wind on the measurement. Under very strong vertical wind speeds (5 m s^{-1}) the potential deviation due to vertical wind was less than 0.03%.

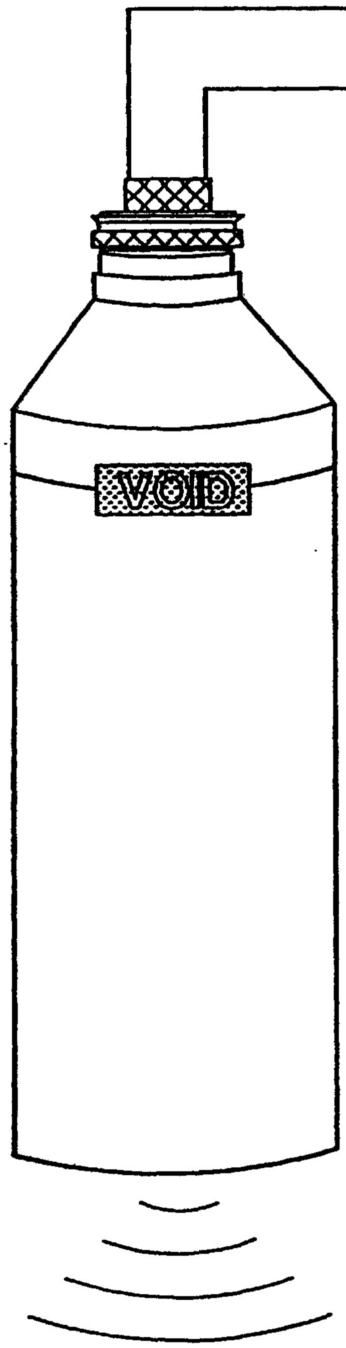
OPERATION

The UDG01 was designed to be a simple device to operate. If you are not electronically or technically minded, simply follow the datalogger program as is and don't worry about all the technical information included. This information is there for those of you who need or want a more detailed description of what is actually happening.

The UDG01 is a sealed unit and must not be opened except if you are using more than one sensor on a single datalogger. If you are using two or more sensors the UDG01 needs to be opened to select the sensor address identification (See the section on Address Jumper Identification.)

There is only one way to open the sensor and that is described in the section on "Address Jumper Identification ." Any attempts to open the sensor otherwise will void the warranty. There is a VOID label near the top of the sensor, if there are any attempts to open the sensor it will activate the VOID LABEL and cancel the warranty.

SPECIFICATIONS



POWER REQUIREMENTS: + 12 VOLTS D.C.

POWER CONSUMPTION: 200 μA (Quiescent)

65 mA (Active for .2 sec.)

OUTPUT: 16 bit binary coded message

EFFECTIVE MEASUREMENT RANGE: .6 TO 10 meters

ACCURACY: ±1 cm or 0.4 % of Distance to Target (whichever is greatest)

RESOLUTION: 0.5 mm

OPERATING TEMPERATURES: - 25 TO + 50 °C Standard

Extended Temperature Range Available (consult factory)

DIMENSIONS: Overall Length 22 cm

Cylinder Diameter 7.3 cm

WEIGHT: 1 Kg.

Power: Although the 12 Volt supply is connected when one first connects the sensor, the UDG01 is not powered up until the internal solid state switch has been activated by the data acquisition system.

ADDRESS JUMPER IDENTIFICATION

The UDG01 is sent from our plant configured as address 0. The UDG01 can have up to 16 addresses. If you are using more than one UDG01 on the same datalogger, you will need to change the address jumpers.

There is only one way to open the UDG01 to access the jumpers. The UDG01 should only be opened in your office or laboratory. It is not recommended that this be done in the field. While you have the sensor opened, it is a good time to verify and/or replace the desiccant pack.

With a Phillips screwdriver, remove the two screws that hold the ultrasonic transducer in place at the end of the cylinder. Carefully pull out the assembly which remains attached to the circuit board. The wires are long enough to allow the transducer and its teflon base to simply hang down out of the way. At the end of the circuit board, on the right hand side as you face the cylinder end with the component side of the circuit board facing down, will be two sets of jumpers. (See Figure 1b.) The one on the left represents the least significant address bit while the one on the right, the most significant bit. The 16 possible addresses, the jumper configuration, the binary code (two groups of two) and the control port pulse sequence are all shown in Figure 1a.

MONITORING THE UDG01 WITH A CR10

CONNECTIONS TO CR10

CAUTION: The order in which connections are made is critical. ALWAYS CONNECT GROUND FIRST, followed by 12V and then the Control Ports. In disconnecting the sensor the reverse order should be followed. The CLEAR lead should be connected to the GROUND (SHIELD). The 10K resistor enclosed, is required with the 21X MICROLOGGER only.

BLACK w/RED	---	GROUND
RED	---	+12 VOLT
BLACK w/WHITE	---	CONTROL PORT 3 SDE (SERIAL DEVICE ENABLE)
WHITE	---	CONTROL PORT 2 SC CLOCK
GREEN	---	CONTROL PORT 1 DATA

<u>WARNING</u> ! DO NOT FIRE THE CIRCUIT BOARD WITHOUT THE POLAROID SENSOR BEING ATTACHED OR DAMAGE COULD OCCUR.

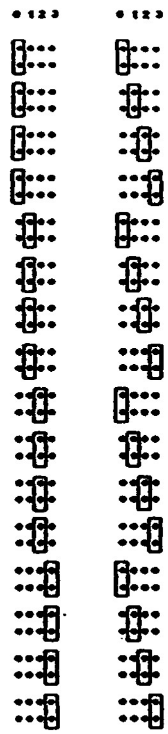
Program: The example program is written for the CR10. It is an example only and the concepts illustrated here are likely to be only fragments of a larger program. This program is used to make distance measurements using the UDG01 Ultrasonic Depth Sensor. An address must first be sent to select 1 of up to 16 depth sensors. After the sensor is selected, a measurement is made and the result "shifted" to the control port of the datalogger. We will eventually convert this entire program into one of our standard system PROM programs. For the time being here is a complete listing of the instructions used.

```
*  1    Table 1 Programs

01: 0.0000  Sec. Execution Interval, User selectable
```

The following instruction measures air temperature and converts the measurement from degrees Celsius to degrees Kelvin. The result will be used later in the program to compensate for changes in the speed of sound due to temperature. Please note that in this example, one of our 107 temperature probes is used. You might well be using some other type of air temperature sensor. The important thing to remember is the location where the temperature information is being stored.

Figure 1a. Address Jumper Identification



ADDRESS	BINARY CODE 0 - 3	BINARY CODE 0 - 3
00	00	00
01	00	01
02	00	10
03	00	11
10	01	00
11	01	01
12	01	10
13	01	11
20	10	00
21	10	01
22	10	10
23	10	11
30	11	00
31	11	01
32	11	10
33	11	11

CONTROL PORT 1 PULSE SEQUENCE

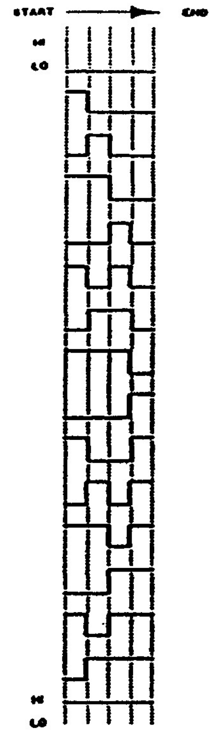
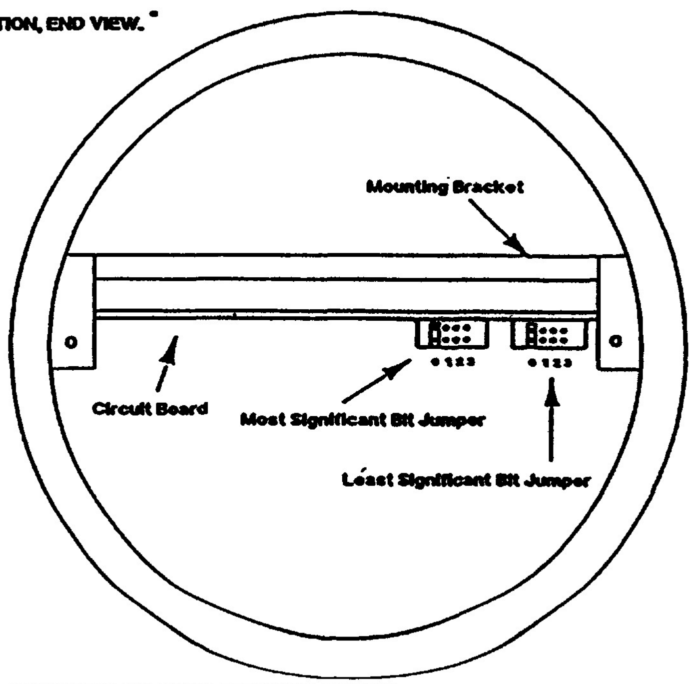


FIGURE 1b. Address Jumper Location

UDG01 CROSS SECTION, END VIEW. *



*NOTE: Polaroid Transducer Wires not shown connected to board
No other components shown
Address Jumpers Shown with Factory Setting

```
01: P11     Temp 107 Probe
 01: 1      Rep
 02: 1      IN Chan
 03: 1      Excite all reps w/EXchan 1
 04: 1      Loc [:T1  Deg K]
 05: 1      Mult
 06: 273.15 Offset
```

The following set of instructions configures the three control ports and addresses the UDG01. (The address used in this example is '0000', the factory setting.) Control Port 3 , the serial device enable line is used to control the sensor. At first it is set high to reset the UDG01. Control Port 2, the Clock line is pulsed to receive each and every data bit from Control Port 1, the data line. Control Port 1 is used to at first send 1,0,0,0, to the UDG01. The 1 will be used by the UDG01 to prevent any other data from entering before its time while the three 0's are for future potential use. Control Port 1 then sends the UDG01 address which in this case is 0000. Remember that for every data bit sent from Control Port 1, Control Port 2 is pulsed to receive the data. The first time Control Port 2 is pulsed is to make certain that the UDG was reset. The next seven pulses shift the first seven bits of the message. The eight bit of the message is read when Control Port 2 is set high.

Figure 2. is a diagrammatical representation of the control port changes which occur up until the actual reception of the data from the UDG01.

```
02: P20     Set Port(s)
 01: 9999   C8..C5=nc/nc/nc/nc
 02: 9130   C4..C1=nc/high/1ms/low

03: P86     Do
 01: 72     Pulse Port 2

04: P86     Do
 01: 41     Set high Port 1

05: P86     Do
 01: 72     Pulse Port 2

06: P86     Do
 01: 51     Set low Port 1
```

In this example we can create a Loop to repeat six times. All this Loop is doing is pulsing Control Port 2. This is simply because the end of the message as we have just seen is all 0's. At present, the only thing that will change in the message are the last four bits, the address of the UDG01. If you are only using one UDG01, you will not have to change your program.

With two or more sensors, the message must be changed since the address of the devices will be different. For example if the address of the UDG01 is 01, your initial message will be 1,0,0,0,1,0,0,0. This means that your Loop instruction should be changed to 3 Loop Counts instead of the 6 shown. Following this will be the instruction to Set Port 1 High, then Pulse Port 2 to receive that bit, followed by Set Port 1 Low. Pulsing Port 2 twice and then Setting Port 2 High ends this sequence. As mentioned earlier, the 8th bit is read when Port 2 is set High.

Another example is if the address of the sensor was 03, then the message on Control Port 1 would be 1,0,0,0,1,1,0,0 . This would mean that the Loop Count would have to be 3 followed by Set Port 1 High and Pulse Port 2 twice. Set Port 1 low, Pulse Port 2 and finally Set Port 2 High.

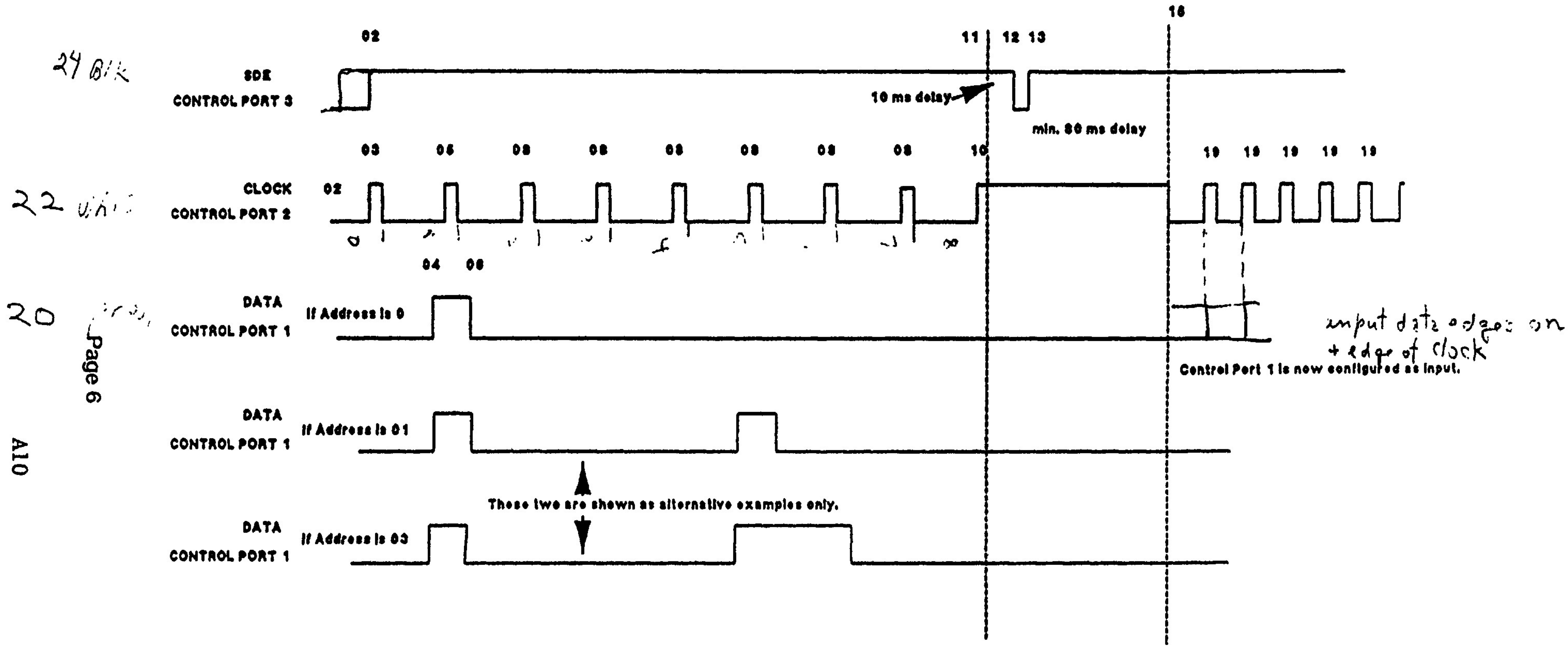


Figure 2. Diagramatic description of control port status up to the reception of data. Alternate examples of control port 1 are shown for other address ID's. The numbers appearing near the lines are the instructions of the CR10 program example. Data are being strobed by the leading edge of the clock line.

07: P87 Beginning of Loop
 01: 0 Delay
 02: 6 Loop Count

08: P86 Do
 01: 72 Pulse Port 2

09: P95 End

10: P86 Do
 01: 42 Set high Port 2

At this point in the program, the UDG01 has been properly addressed is now powered and is ready to perform the measurement. If you are using several UDG01's, you could convert the rest of the program into a subroutine and call it from this point in the program. Remember that subroutines are placed in Table 3 (*3) of the datalogger. Since you would be using several sensors and therefore calling the subroutine several times, you need to avoid having the data from each and every UDG01 end up in the same location. This can be accomplished by using Instruction 31 "n" times, where n is the number of UDG01's on the same datalogger. Instruction 31 simply takes data from one location and puts it in another.

The following program is used to create a 10ms delay between the time that the UDG is selected and prior to any measurement being made. This is done to allow the circuitry time to power up after it has been selected. Note that there is no excitation channel connected because this instruction is simply used to create a delay and not excite any device.

11: P22 Excitation with Delay
 01: 1 EX Chan
 02: 1 Delay w/EX (units=.01sec)
 03: 0 Delay after EX (units=.01sec)
 04: 0 mV Excitation

The next two programs initiate the measurement.

12: P86 Do
 01: 53 Set low Port 3

13: P86 Do
 01: 43 Set high Port 3

The following instruction creates an 80ms delay. This is necessary for the sound wave to have enough time to travel a minimum of 10 meters and be reflected back before continuing in the program.

14: P22 Excitation with Delay
 01: 1 EX Chan
 02: 8 Delay w/EX (units=.01sec)
 03: 0000 Delay after EX (units=.01sec)
 04: 0.0000 mV Excitation

Next we need to configure port 1 for input and set Port 2 low.

15: P20 Set Port(s)
 01: 9999 C8..C5=nc/nc/nc/nc
 02: 9908 C4..C1=nc/nc/low/input

The next two instructions set location 3 to 1, and location 4 to 0. Location 3 contains the exponent for the mantissa 2. Location 4 will contain the unprocessed pulse count.

```
16: P30    Z=F
 01:1      F
 02:0      Exponent of 10
 03:3      Z Loc [:2 exp n ]

17: P30    Z=F
 01:0      F
 02:0      Exponent of 10
 03:4      Z Loc [:# pulses ]
```

Loc 3 [illegible] 4 [illegible] add 1 to loc 4 if input = 1 on that loop

The following instructions "shift" the encoded pulse total to the datalogger, decodes the total and stores the total in location 4.

```
18: P87    Beginning of Loop
 01:0      Delay
 02:16     Loop Count

19: P86    Do
 01:72     Pulse Port 2

20: P91    If Flag/Port
 01:41     Do if port 1 is high
 02:30     Then Do

21: P33    Z=X+Y
 01:3      X Loc 2 exp n
 02:4      Y Loc # pulses
 03:4      Z Loc [:# pulses ]

22: P95    End

23: P37    Z=X*F
 01:3      X Loc 2 exp n
 02:2      F
 03:3      Z Loc [:2 exp n ]

24: P95    End
```

LSB of data clocked at + edge [illegible] MSB after [illegible] pulse first pulse

inches .020542

Program $\sqrt{\frac{T_1}{T_2}} \cdot .52176 \cdot N - 16$ = mm to target

The following instructions are used to temperature compensate the measurement and convert the result into "distance to target". The result is stored in millimeters and can be found in location 7. The equation used is a form of the equation for the speed of sound in air. It is $\sqrt{(T1/T2)} \cdot 0.52176 \cdot N =$ Distance, where T1 is the present temperature, T2 is the fixed reference temperature of 18 °C (291 °K), 0.52176 is a constant resulting from the frequency of the crystal used in the UDG01 and the speed of sound and N is the number of pulses generated by the crystal while the sound wave travelled to and from the surface.

```
25: P30    Z=F
 01:291    F
 02:0      Exponent of 10
 03:2      Z Loc [:T2 (291K)]
```

$FFFF_H = 65535$
x .52176 = 34193 mm = 34 meters -
10 meters max = 10,000 mm ⇒ 19166 counts
⇒ 4 Add$_H$ 15 bit max

to D/A
[illegible] max = 4096 x 2 = 8192 ⇒ 168" = 14 ft

```
26: P38    Z=X/Y
 01: 1     X Loc T1  Deg K
 02: 2     Y Loc T2 (291K)
 03: 5     Z Loc [:T1/T2   ]

27: P39    Z=SQRT(X)
 01: 5     X Loc T1/T2
 02: 6     Z Loc [:sqrtT1/T2]

28: P36    Z=X*Y
 01: 4     X Loc # pulses
 02: 6     Y Loc sqrtT1/T2
 03: 7     Z Loc [:Result  ]

29: P37    Z=X*F
 01: 7     X Loc Result
 02: .52176 F
 03: 7     Z Loc [:Result  ]
```

This next instruction simply removes a built in offset of 16 from the calculated distance.

```
30: P34    Z=X+F
 01: 7     X Loc Result
 02: -16    F
 03: 7     Z Loc [:Result  ]
```

The measurement is now complete and the last instruction returns the UDG to the quiescent mode.

```
31: P20    Set Port(s)
 01: 9999  C8..C5=nc/nc/nc/nc
 02: 9000  C4..C1=nc/low/low/low

32: P      End Table 1
```

MONITORING THE UDG01 WITH A 21X

Program: The example program is written for the 21X. It is an example only and the concepts illustrated here are likely to be only fragments of a larger program.This program is used to make distance measurements using the UDG01 Ultrasonic Depth Sensor. An address must first be sent to select 1 of up to 16 depth sensors. After the sensor is selected, a measurement is made and the result "shifted" to the control port of the datalogger. The program can be made into a subroutine and called when required.

CONNECTIONS to 21X.

Caution: The order in which the connections are made is critical. ALWAYS CONNECT GROUND FIRST, followed by +12V and then the Control Ports. In disconnecting the sensor the reverse order should be followed. The CLEAR lead should be connected to the GROUND (SHIELD).

BLACK w/RED	— GROUND
RED	— +12 VOLT
BLACK w/WHITE	— CONTROL PORT 3 SDE (SERIAL DEVICE ENABLE)
WHITE	— CONTROL PORT 2 CLOCK
GREEN	— SE ANALOG CHANNEL (2 in this example)

A 10K resistor is connected between Control Port1 and the Single-Ended Analog Channel. The resistor is incorporated in a separate light green lead that was sent with the UDG01.

1 Table 1 Programs

Enter desired execution interval.

01: 0.0000 Sec. Execution Interval

The following instruction measures air temperature and converts the measurement from degrees Celsius to degrees Kelvin. The result will be used later in the program to compensate in changes in the speed of sound due to temperature. Please note that in this example, one of our 107 temperature probes is used. You might well be using some other type of air temperature sensor. The important thing to remember is the location where the temperature information is being stored.

```
01: P11     Temp 107 Probe
 01: 1      Rep
 02: 1      IN Chan
 03: 1      Excite all reps w/EXchan 1
 04: 1      Loc [:T1 Deg K ]
 05: 1      Mult
 06: 273.15 Offset
```

The following set of instructions configures the three control ports and addresses the UDG01. (The address used in this example is '0000', the factory setting.) Control Port 3 , the serial device enable line is used to control the sensor. At first it is set high to reset the UDG01. Control Port 2, the Clock line is pulsed to receive each and every data bit from Control Port 1, the data line. Control Port 1 is used to at first send 1,0,0,0, to the UDG01. The 1 will be latched through the UDG01 to prevent any other data from entering before its time while the three 0's are for future potential use. Control Port 1 then sends the UDG01 address which in this case is 0000. Remember that for every data bit sent from Control Port 1, Control Port 2 is pulsed to receive the data. The first time Control Port 2 is pulsed is to make certain that the UDG01 was reset. The next seven pulses shift the first seven bits of the message, the eighth bit is read when Port 2 is set High.

```
02: P20     Set Port
 01: 1      Set high
 02: 3      Port Number

03: P20     Set Port
 01: 0      Set low
 02: 1      Port Number

04: P20     Set Port
 01: 1      Set high
 02: 2      Port Number

05: P20     Set Port
 01: 0      Set low
 02: 2      Port Number

06: P20     Set Port
 01: 1      Set high
 02: 1      Port Number

07: P20     Set Port
 01: 1      Set high
 02: 2      Port Number
```

08: P20 Set Port
01: 0 Set low
02: 2 Port Number

09: P20 Set Port
01: 0 Set low
02: 1 Port Number

In this example we can create a Loop to repeat six times. All this Loop is doing is pulsing Control Port 2. This is simply because the end of the message as we have just seen is all 0's. At present, the only thing that will change in the message are the last four bits, the address of the UDG01. If you are only using one UDG01, you will not have to change your program.

With two or more sensors, the message must be changed since the address of the devices will be different. For example if the address of the UDG01 is 01, your initial message will be 1,0,0,0,1,0,0,0. This means that your Loop instruction should be changed to 3 Loop Counts instead of the 6 shown. Following this will be the instruction to Set Port 1 High, then Pulse Port 2 to receive that bit and then Set Port 1 low. Port 2 must then be pulsed twice and then finally, Port 2 is set High. As mentioned earlier, the 8th bit is read when Port 2 is set High.

Another example is if the address of the sensor was 03, then the message on Control Port 1 would be 1,0,0,0,1,1,0,0 . This would mean that the Loop Count would have to be 3 followed by Set Port 1 High and Pulse Port 2 twice, to receive these codes. Port 1 is then set low and Port 2 is pulsed once only and finally, Port 2 is set High.

10: P87 Beginning of Loop
01: 0 Delay
02: 6 Loop Count

11: P20 Set Port
01: 1 Set high
02: 2 Port Number

12: P20 Set Port
01: 0 Set low
02: 2 Port Number

13: P95 End

14: P20 Set Port
01: 1 Set high
02: 2 Port Number

At this point in the program, the UDG01 has been properly addressed, is now powered and is ready to perform the measurement. If you are using several UDG01's, you could convert the rest of the program into a subroutine and call it from this point in the program. A reminder that subroutines are placed in Table 3 (*3) of the datalogger. Since you would be using several sensors and therefore calling the subroutine several times, you need to avoid having the data from each and every UDG01 end up in the same location. Using a subroutine will save you a lot of programming steps. The first part of this program, however, the first part of the program, the initialization and addressing must be done for each and every sensor used.

The following instruction is used to create a 10ms delay between the time that the UDG is selected and prior to any measurement being made. This is done to allow the circuitry time to power up after it has been selected. Note that there is no excitation channel connected because this instruction is simply used to create a delay and not excite any device.

```
15: P22    Excitation with Delay
 01: 1     EX Chan
 02: 1     Delay w/EX (units=.01sec)
 03: 0     Delay after EX (units=.01sec)
 04: 0     mV Excitation
```

The next two programs initiate the measurement.

```
16: P20    Set Port
 01: 0     Set low
 02: 3     Port Number

17: P20    Set Port
 01: 1     Set high
 02: 3     Port Number
```

The following instruction creates an 80ms delay. This is necessary for the sound wave to have enough time to travel a minimum of 10 meters and be reflected back before continuing in the program.

```
18: P22    Excitation with Delay
 01: 1     EX Chan
 02: 8     Delay w/EX (units=.01sec)
 03: 0000  Delay after EX (units=.01sec)
 04: 0.0000  mV Excitation

19: P20    Set Port
 01: 0     Set low
 02: 2     Port Number
```

The next two instructions set location 3 to 1, and location 4 to 0. Location 3 contains the exponent for the mantissa 2. Location 4 will contain the unprocessed pulse count.

```
20: P30    Z=F
 01: 1     F
 02: 3     Z Loc [:2 exp n  ]

21: P30    Z=F
 01: 0     F
 02: 4     Z Loc [:# pulses ]
```

The following instructions "shift" the encoded pulse total to the datalogger, decodes the total and stores the total in location 4.

```
22: P87    Beginning of Loop
 01: 0     Delay
 02: 16    Loop Count

23: P20    Set Port
 01: 1     Set high
 02: 2     Port Number
24: P20    Set Port
```

```
24: P20     Set Port
 01: 0      Set low
 02: 2      Port Number

25: P1      Volt (SE)
 01: 1      Rep
 02: 5      5000 mV slow Range
 03: 2      IN Chan
 04: 8      Loc [:HI OR LO ]
 05: 1      Mult
 06: 0.0000 Offset

26: P89     If X<=>F
 01: 8      X Loc HI OR LO
 02: 3      >=
 03: 3000   F
 04: 30     Then Do

27: P33     Z=X+Y
 01: 3      X Loc 2 exp n
 02: 4      Y Loc # pulses
 03: 4      Z Loc [:# pulses ]

28: P95     End

29: P37     Z=X*F
 01: 3      X Loc 2 exp n
 02: 2      F
 03: 3      Z Loc [:2 exp n ]

30: P95     End
```

The following instructions are used to temperature compensate the measurement and convert the result into "distance to target". The result is stored in millimeters and can be found in location 7. The equation used is a form of the equation for the speed of sound in air. It is √(T1/T2)*0.52176*N = Distance, where T1 is the present temperature, T2 is the fixed reference temperature of 18 °C (291 °K), 0.52176 is a constant resulting from the frequency of the crystal used in the UDG01 and the speed of sound and N is the number of pulses generated by the crystal while the sound wave travelled to and from the surface.

```
31: P30     Z=F
 01: 291    F
 02: 2      Z Loc [:T2 (291K)]

32: P38     Z=X/Y
 01: 1      X Loc T1 Deg K
 02: 2      Y Loc T2 (291K)
 03: 5      Z Loc [:T1/T2 ]

33: P39     Z=SQRT(X)
 01: 5      X Loc T1/T2
 02: 6      Z Loc [:sqrtT1/T2]

34: P36     Z=X*Y
 01: 4      X Loc # pulses
 02: 6      Y Loc sqrtT1/T2
 03: 7      Z Loc [:Result ]
```

35: P37 Z=X*F
 01:7 X Loc Result
 02:.52176 F
 03:7 Z Loc [:Result]

36: P34 Z=X+F
 01:7 X Loc Result
 02:-16 F
 03:7 Z Loc [:Result]

The measurement is now complete and the last 3 instructions return the UDG to the quiescent mode.

37: P20 Set Port
 01:0 Set low
 02:1 Port Number

38: P20 Set Port
 01:0 Set low
 02:2 Port Number

39: P20 Set Port
 01:0 Set low
 02:3 Port Number

40: P End Table 1

FIELD INSTALLATION

The UDG01 has two mounting options for either a tripod or a tower installation (see Figures 3a. and 3b). The UDG01 small mounting elbow will screw into a ½ inch thread. Both mounting arms the 019UDGTow and the 019UDGTri have a common 1¼ in. pipe with a reduction to ½ in. to accept the UDG01. Once the sensor has been installed, the result will show the distance from the sensor to the surface. You should make an independent measurement of this to confirm the accuracy of the results. After this, the choice is whether to leave the results as simply the distance to target or to remove this initial distance as an offset. It will depend on the monitoring application. If it is snow accumulation you are wanting, it is probably best to "zero" the initial distance and as the snow accumulates below your sensor, the measurement will simply show snow depth. To do this, your multiplier must be -1. and the offset would be positive.

For example, let us suppose that the sensor is installed at 5 meters or 5000 mm above the surface. In order to obtain accumulation, your offset would be +5016 while the multiplier would be -1. At first, the UDG01 would produce an initial uncorrected reading of +5016. By making the offset +5016 (incorporating the distance to surface with the 16 built in offset) and the multiplier -1., the results would be 0.0 . Let's assume that 20 cm of snow falls. The sensor would normally read 4816 (4800, the distance to target + 16 mm built in offset). With the -1 multiplier and the offset of +5016, the final reading would be -4816 +5016 = 200 mm. If the value to be output is greater the 6999, you must use high resolution data. Also, if you wish to obtain greater accuracy and take advantage of the 0.5 mm resolution of the UDG01, you must also high resolution data.

Otherwise, if you wish to work with the distance to target and use that as a reference, then as the distance fluctuates up or down, as for example in a water level application, you would use you initial distance measurement to correct the data.

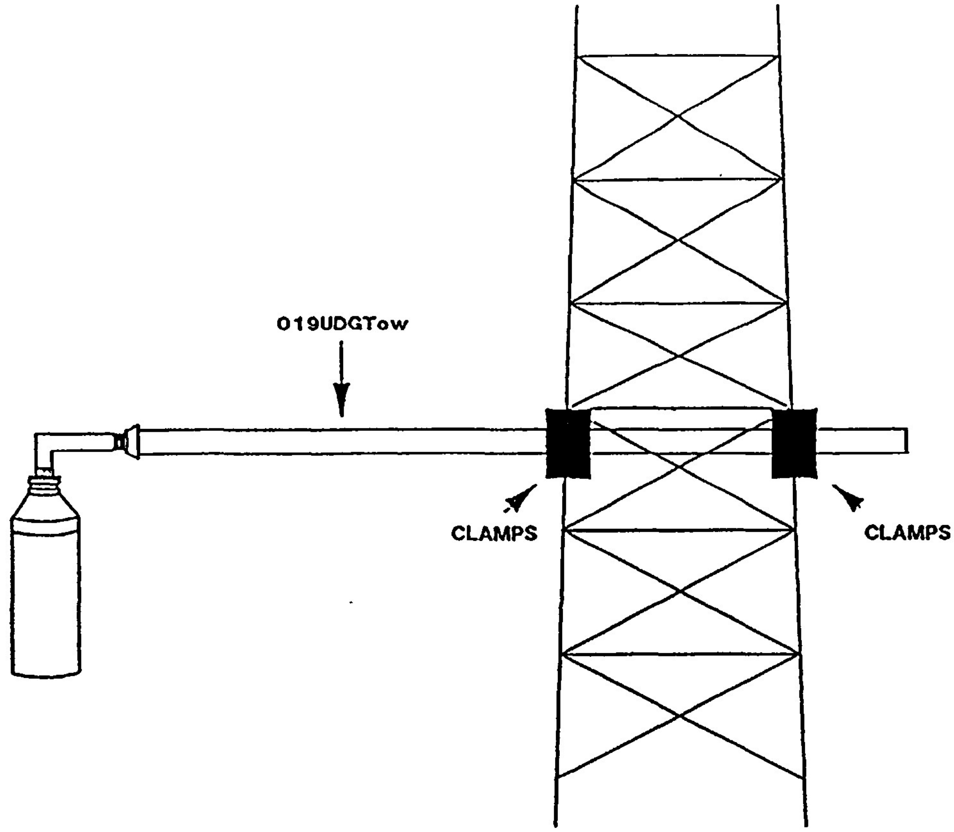


FIGURE 3a. Diagramatic representation of UDG01 mounted to tower.

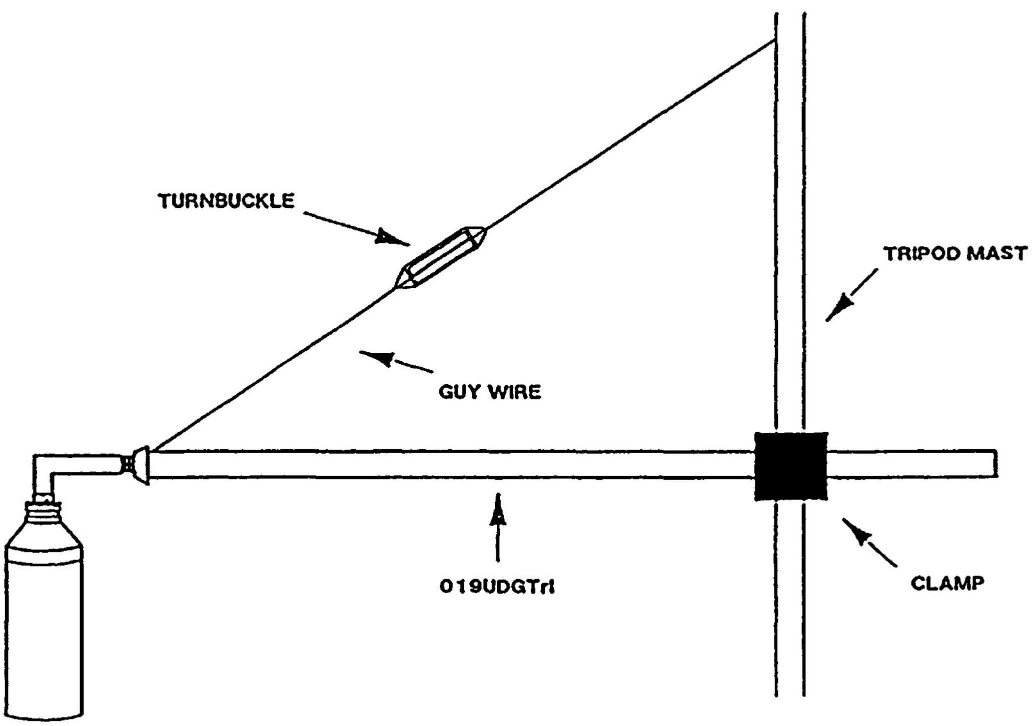


FIGURE 3b. Diagramatic representation of UDG01 monted to CM10 Tripod Mast.

DATA INTERPRETATION

Figure 4. is a graph from our previous depth sensor. This graph is shown to give you an idea of the type of signal you would obtain when monitoring snow depth. After installation at the end of May, the sensor measured an initial snowfall which then gradually compacted, and/or sublimated until the next event on June 14. There is a data gap after this which is as a result of the measurement being done during the snowfall event. Another missing data point is seen on June 28 and is either again as a result of snow falling during the time of measurement or blowing snow.

Figure 5. contains two graphs of a UDG01 measurement series on a fixed distance. Figure 5a. is for the UDG01 at room temperature while Figure 5b. is the UDG01 in a strongly varying temperature regime from - 18 ^{0}C to - 60 ^{0}C. Please note the stability of the signal over this wide range of temperatures.

REFERENCES

Here is a short list of references material which deals with the original acoustic sensor as it was developed by the Atmospheric Environment Service. Most of the technical details are different than those of the UDG01. We included this reference list in order to give you a better understanding of field conditions and data interpretation . These references also present graphed data which will assist in interpreting data when using the sensor in a snow depth monitoring application.

Goodison, B.E., J.R. Metcalfe, R.A. Wilson, 1988a. Performance of a Canadian Automatic snow depth sensor. Proc. WMO Technical Conference, TECO-88, Leipzig, German Democratic Republic. May 25-June 1, 1988 (in press).

Goodison, B.E., J.R. Metcalfe, R.A. Wilson and K. Jones, 1988. The Canadian Automatic Snow Depth Sensor: A Performance Update. Proc. Western Snow Conference, Kalispell, Montana. 1988.

SNOW DEPTH

AGASSIZ ICE CAP

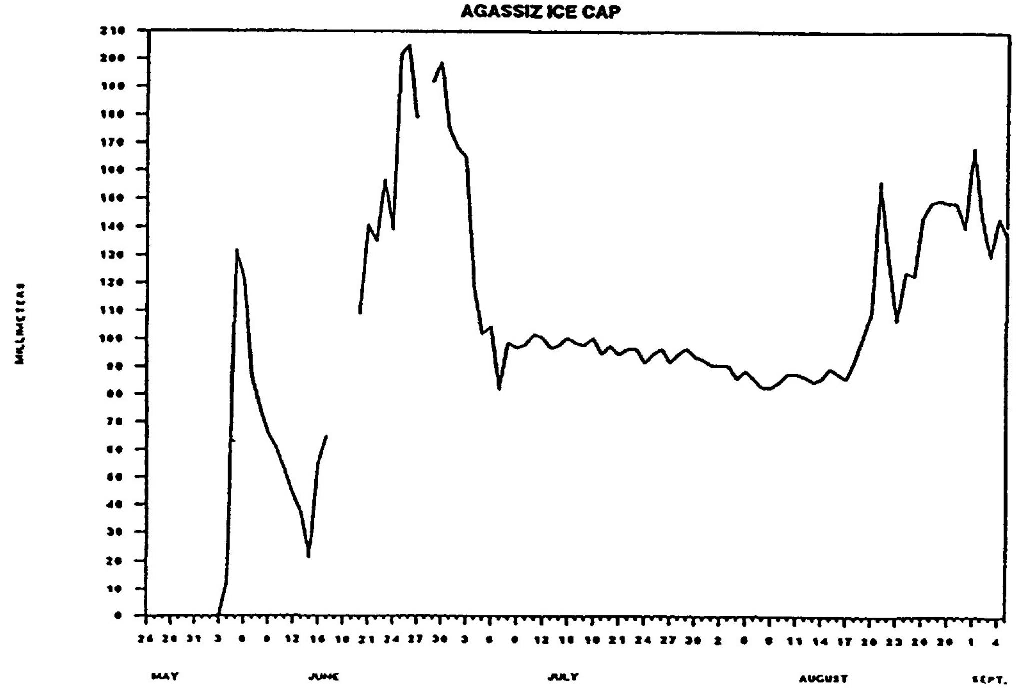


FIGURE 4. DAILY SNOW DEPTH DATA FROM AGASSIZ ICE CAP, ELLESMERE IS.

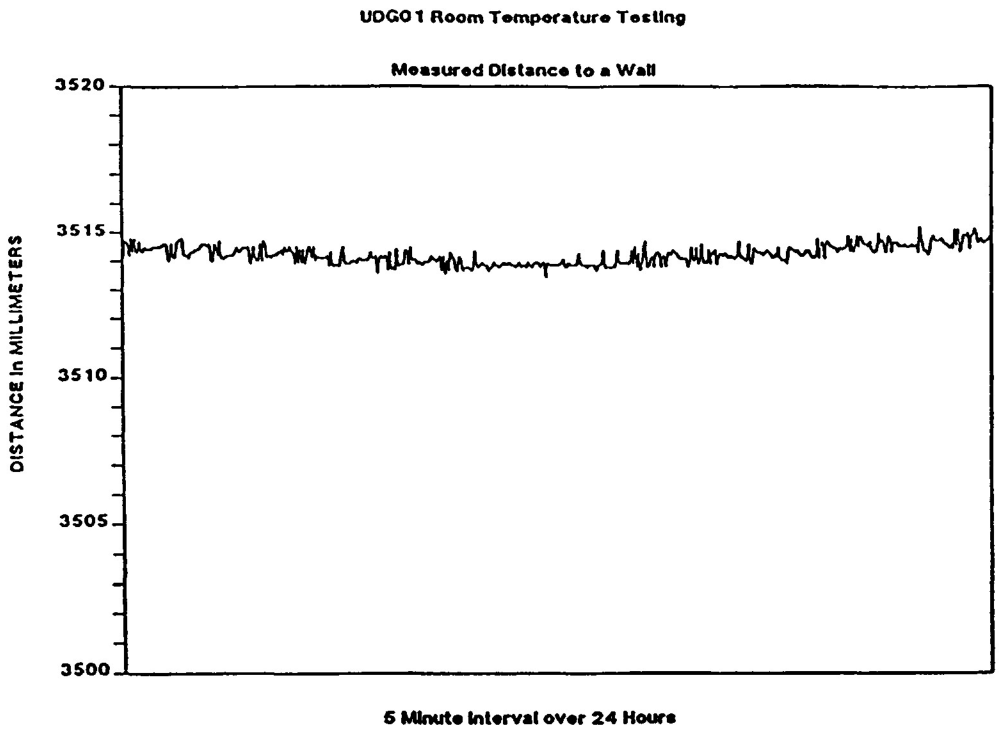


FIGURE 5a. Measurement of a fixed distance at room temperature.

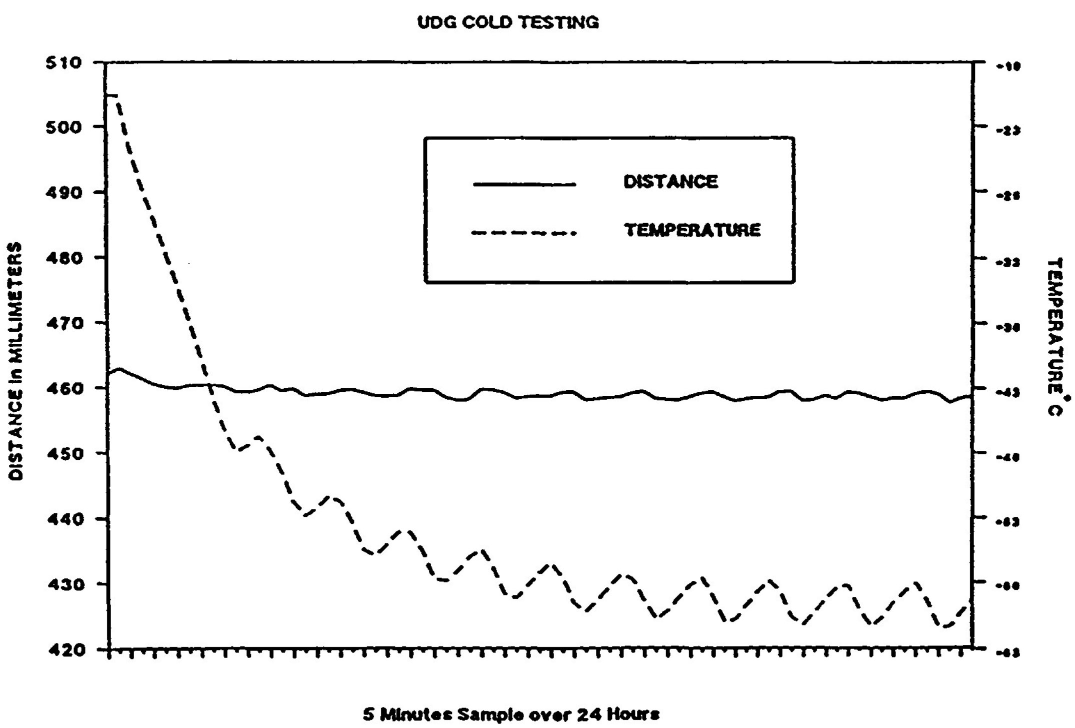
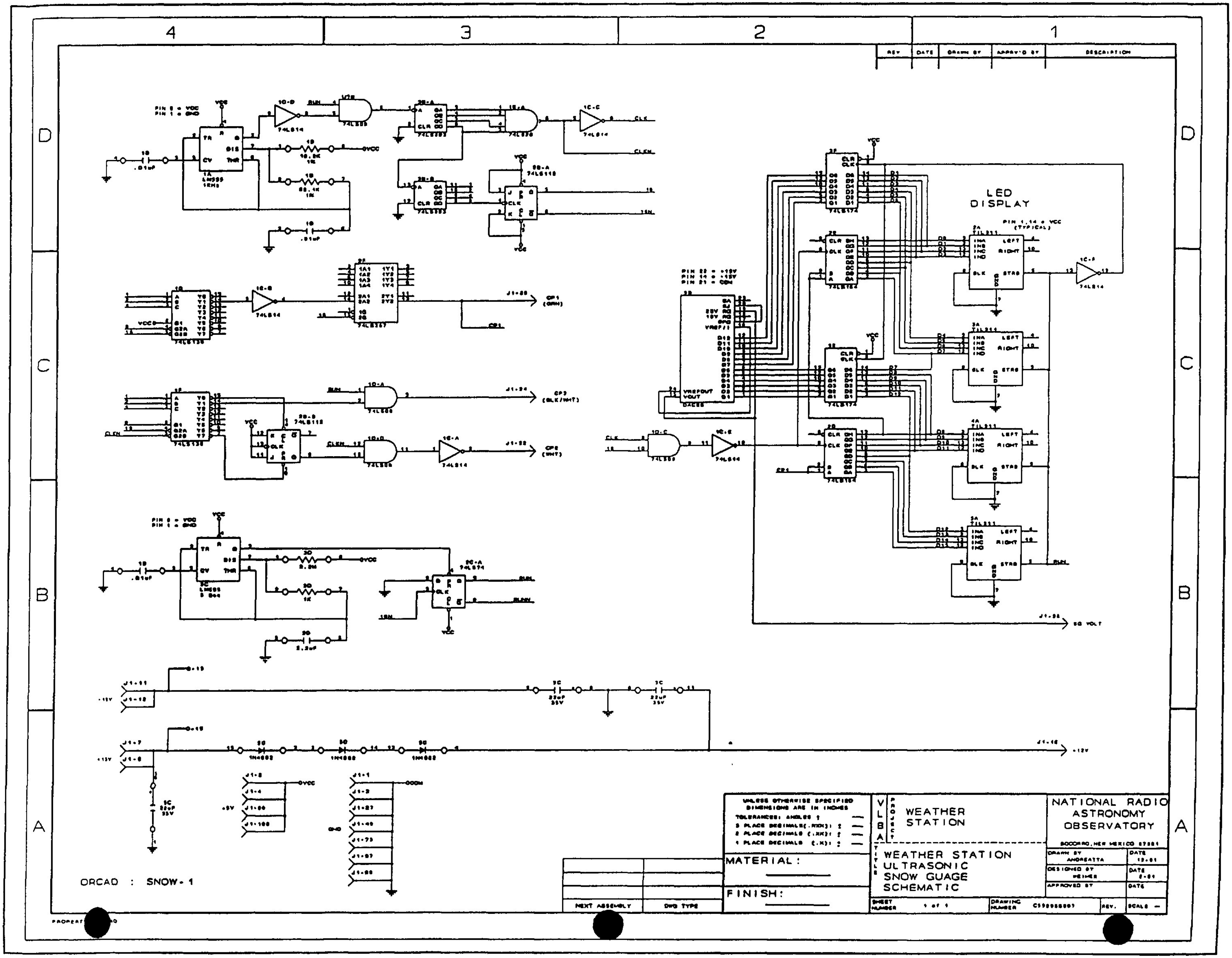


FIGURE 5b. Measurement of a fixed distance under a wide temperature range. (-18°C to - 60°C)


4
3
2
1
D
C
B
A
LED DISPLAY
ORCAD : SNOW - 1
V L B A
WEATHER STATION
NATIONAL RADIO ASTRONOMY OBSERVATORY
WEATHER STATION ULTRASONIC SNOW GUAGE SCHEMATIC
MATERIAL:
FINISH:
NEXT ASSEMBLY
DWG TYPE

REV	DATE	DRAWN BY	APPRV'D BY	DESCRIPTION

JAN 1 4 1992

ACAD : SNOWASSY

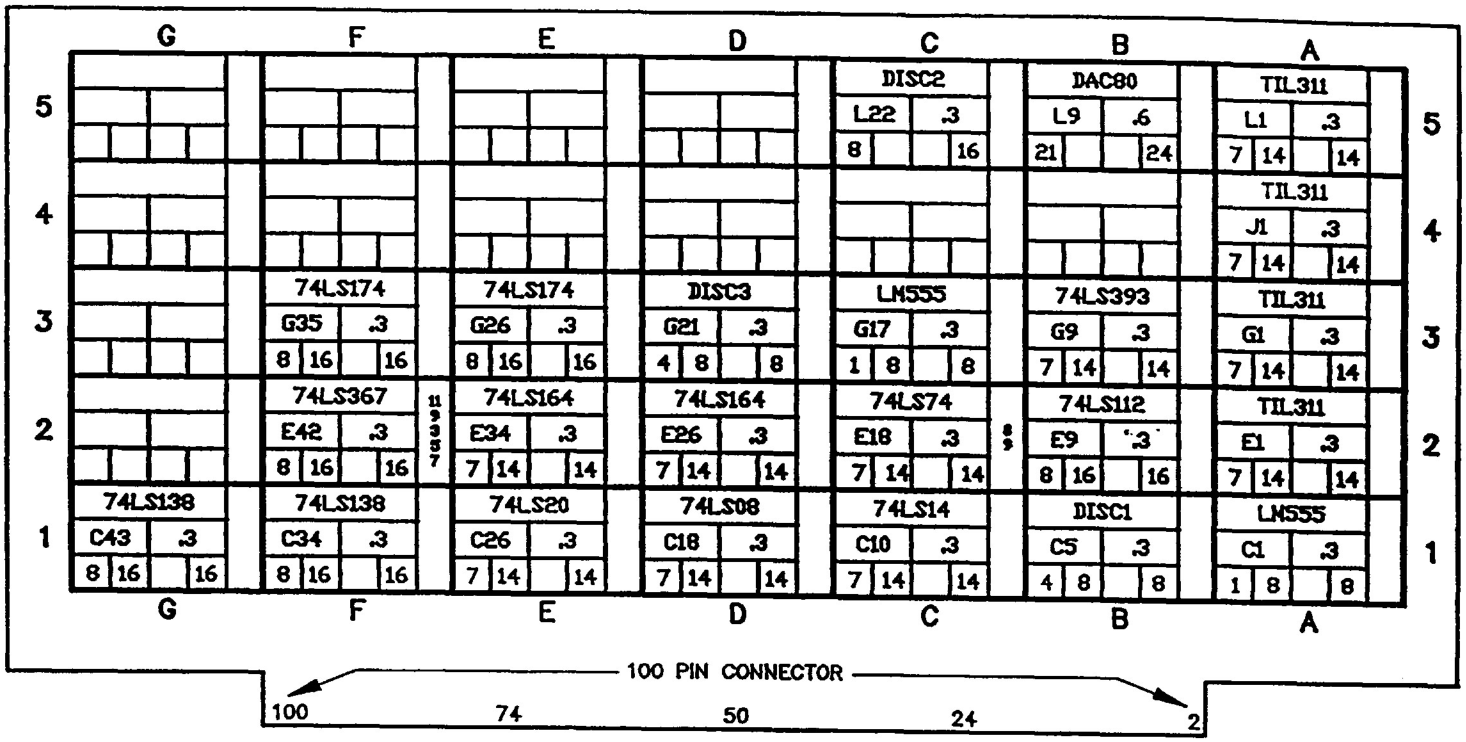
V L A	PROJECT	WEATHER STATION	NATIONAL RADIO ASTRONOMY OBSERVATORY SOCORRO, NEW MEXICO 87801
TITLE	WEATHER STATION ULTRASONIC SNOW GUAGE ASSEMBLY	DRAWN BY ANDREATTA	DATE 12-91
		DESIGNED BY WEIMER	DATE 12-91
		APPROVED BY	DATE

C55006S007	SCHEMATIC
NEXT ASSEMBLY	DWG. TYPE

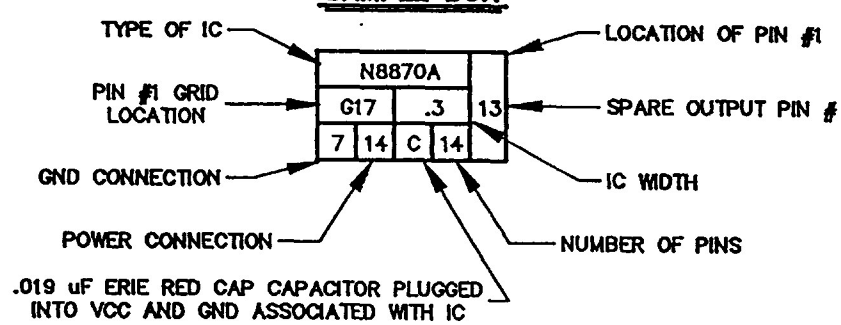
SHEET NUMBER	DRAWING NUMBER	REV.	SCALE
1 of 6	A55006A012		—

WIRE WRAP BOARD COMPONENET LOCATION

LOCATION ______



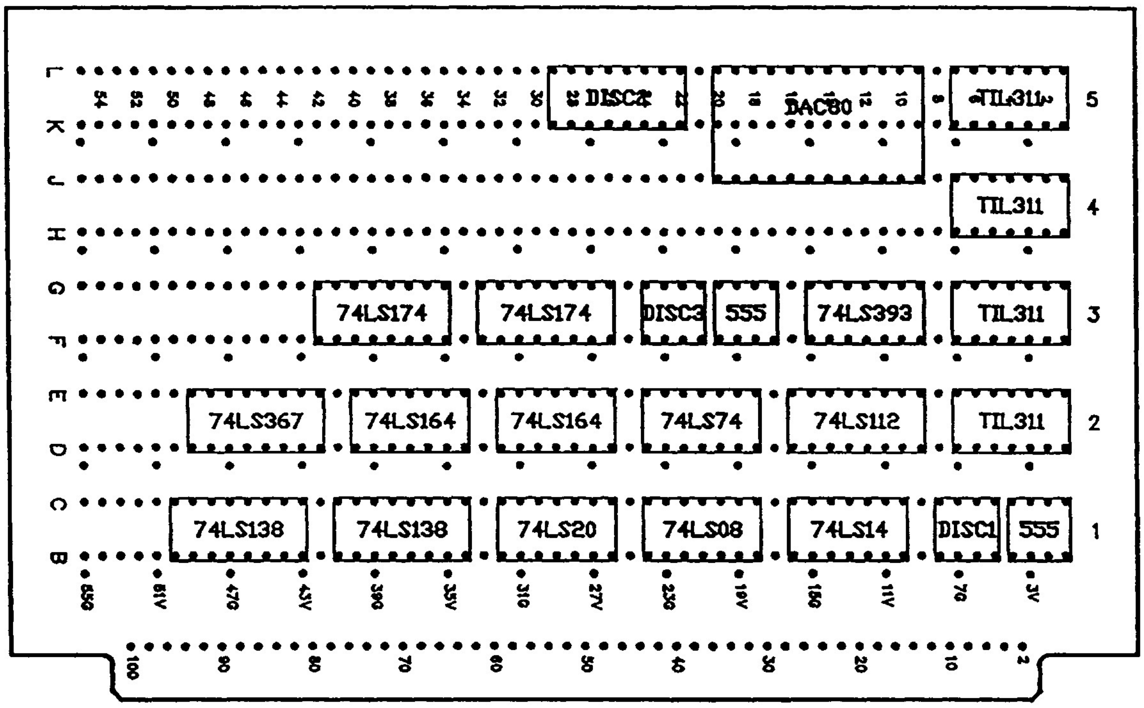
SAMPLE BOX



NOTES :

1. TOP VIEW, COMPONENT SIDE
2. THIS COLUMN NOT AVAILABLE
3. VCC CONNECTOR PINS : P2,4,98,100
   GND CONNECTOR PINS : P1,3,27,49.73,97,99

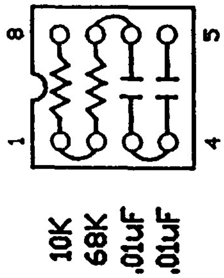
DWG. NO.	A55006A012	SHT. NO.	2 of 6	REV.



DWG. NO.	A55006A012	SHT. NO.	3 of 6	RE

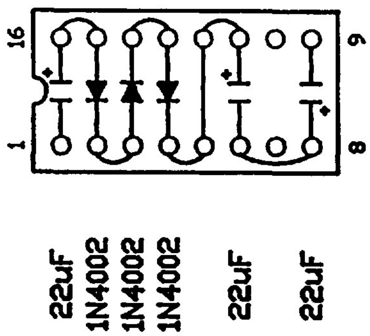
DISCRETE CHIP LAYOUT

DISC1



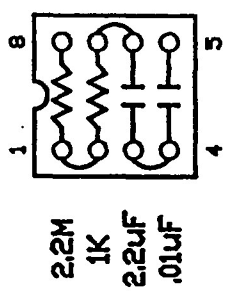
LOCATION = 1B
PIN #1 = C5
RESISTORS ARE 1%

DISC2



LOCATION = 5C
PIN #1 = L22
CAPACITORS ARE 35V

DISC3



LOCATION = 3D
PIN #1 = G21

PARTS LIST

DISCRIPTION	QUANITY
74LS08	1
74LS14	1
74LS20	1
74LS74	1
74LS112	1
74LS138	2
74LS164	2
74LS174	2
74LS367	1
74LS393	1
LM555 TIMER	2
TIL311 HEX DISPLAY WITH LOGIC	4
DAC80 12 BIT D/A CONVERTER	1
8 PIN X .3' HEADER	2
16 PIN X .3' HEADER	1
SHALLOWAY BOARD (SMALL)	1
.01uF CERAMIC CAPACITOR	3
2.2uF CERAMIC CAPACITOR	1
22uF, 35V CAPACITOR	3
1N4002 DIODE	3
5%, 1/4W, 1K OHM RESISTOR	1
1%, 1/4W, 10.2K OHM RESISTOR	1
1%, 1/4W, 68.1 OHM RESISTOR	1
5%, 1/4W, 2.2M OHM RESISTOR	1

DWG. NO.	SHT. NO.	REV.
C55006A012	5 of 6	

NAME	BACK PIN #	TO	FROM	NAME	FRONT PIN #	TO	FROM
GND	1	BLK (RED)	- UGD01	+5	2	PS TB4-11	
GND	3	TB4-19		+5	4		
	5				6		
+15V	7		TB4-17	+15V	8		TB4-[illegible]
	9				10		
-15V	11		TB4-15	-15V	12		TB4-15
	13				14		
	15			+12V	16	RED -	UGD01
	17				18		
	19			CP1	20	GRN -	UGD01
	21			CP2	22	WHT -	UGD01
	23			CP3	24	BLK -	UGD01
	25				26		
GND	27			SGVOLT	28	J1 - 46 - A2	
	29				30		
	31				32		
	33				34		
	35				36		
	37				38		
	39				40		
	41				42		
	43				44		
	45				46		
	47				48		
GND	49				50		
	51				52		
	53				54		
	55				56		
	57				58		
	59				60		
	61				62		
	63				64		
	65				66		
	67				68		
	69				70		
	71				72		
GND	73				74		
	75				76		
	77				78		
	79				80		
	81				82		
	83				84		
	85				86		
	87				88		
	89				90		
	91				92		
	93				94		
	95				96		
GND	97			+5	98		
GND	99	TB4-19		+5	100	PS TB4-11	

DWG. NO.	A55006A012	SHT. NO.	6 of 6	REV.

```
*   THIS IS THE INITIAL VERSION OF AN INTERFACE TO INPUT THE
*   CAMPBELL SCIENTIFIC SNOW GAUGE. IT READS IN A 16 BIT SERIAL
*   DATA STREAM AND CONVERTS 12 BITS WORTH TO AN ANALOG VOLTAGE.
*   DATE 12 FEB 1991
*   GENERATED BY R WEIMER
*   VERSION 1
*   MODIFIED 28 FEB 1991
*   FIXED SOME PROBLEMS
*
DECLARE
*LCN     #PINS    PIN1LCN   TYPE     VCC      GND    COMMENTS
1A       8        C1        1        8        1      *555
1B       8        C5        1        8        4      *DISC1
1C       14       C10       1        14       7      *74LS14
1D       14       C18       1        14       7      *74LS08
1E       14       C26       1        14       7      *74LS20
1F       16       C34       1        16       8      *74LS138
1G       16       C43       1        16       8      *74LS138
2A       14       E1        1        14       7      *TIL311
2B       16       E9        1        16       8      *74LS112
2C       14       E18       1        14       7      *74LS74
2D       14       E26       1        14       7      *74LS164
2E       14       E34       1        14       7      *74LS164
2F       16       E42       1        16       8      *74LS367
3A       14       G1        1        14       7      *TIL311
3B       14       G9        1        14       7      *74LS393
3C       8        G17       1        8        1      *555
3D       8        G21       1        8        4      *DISC3
3E       16       G26       1        16       8      *74LS174
3F       16       G35       1        16       8      *74LS174
4A       14       J1        1        14       7      *TIL311
5A       14       L1        1        14       7      *TIL311
5B       24       L9        2        0        21     *DAC80
5C       16       L22       1        0        8      *DISC2
*
*
*
*
WIRELIST
*   EXTRA GROUNDS AND VCC
S 5A14 5A1 S 4A14 4A1 S 3A14 3A1 S 2A14 2A1
S 5A7 5A8 S 4A7 4A8 S 3A7 3A8 S 2A7 2A8
S 3E16 3E1 S 3F16 3F1 S 1A8 1A4 S 3B7 3B2 3B12
S 2B16 2B15 2B13 2B12 2B11 2B4 2B3 2B2 S 5C1 @K23G
*   SHEET 2
S 3C8 3C4 S 2C14 2C1 S 2C7 2C2 S 1G16 1G6
*   +15 / -15 VOLTS AND +12 VOLTS OUT
S P7 5C16 5B22 S P8 5C16 S P11 5C9 5B14 S P12 5C9 S P16 5C11
*   SHEET 1 - DISPLAY
S 2C5 2A5 3A5 4A5 5A5 1D1 1D4 1C13
S 2D3 5A12 S 2D4 5A13 S 2D5 5A2 S 2D6 5A3 3E3 S 2D10 4A12 3E4
S 2D11 4A13 3E6 S 2D12 4A2 3E11 S 2D13 4A3 3E13 2E1 2E2
S 2E3 3A12 3E14 S 2E4 3A13 3F3 S 2E5 3A2 3F4 S 2E6 3A3 3F6
S 2E10 2A12 3F11 S 2E11 2A13 3F13 S 2E12 2A2 3F14 S 2E13 2A3
*   D/A AREA
S 5B16 5B24 S 5B17 5B20 S 5B15 5B19 P28
S 3E2 5B1 S 3E5 5B2 S 3E7 5B3 S 3E10 5B4
S 3E12 5B5 S 3E15 5B6 S 3F2 5B7 S 3F5 5B8
S 3F7 5B9 S 3F10 5B10 S 3F12 5B11 S 3F15 5B12
S 1C12 3E9 3F9
```

FILE =\WW\CAMSNO.IN

```
*  SHIFT REG AREA
S P20 2F13 2D1 2D2 S 1C6 1D9 S 2B5 1D10 1F4 1G5 2F15
S 1D8 1C11 S 1C10 2D8 2E8
*  CLOCK AREA
S 1B1 1A7 S 1B7 1A2 1A6 S 1B5 1A5 S 1A3 1C9 S 1C8 1D5
S 1D6 3B1 S 3B6 1E5 3B13 S 3B8 2B1 1F6 1G4
S 3B3 1E1 S 3B4 1E2 S 3B5 1E4 S 1E6 1C5 1D12 1F5
S 3B11 1F1 1G1 S 3B10 1F2 1G2 S 3B9 1F3 1G3 S 2B6 2C3
*  SHEET 2 - START / RUN AREA
S 3D1 3C7 S 3D7 3C2 3C6 S 3D5 3C5 S 3C3 2C4
*  DECODER AREA
S 1G14 1C3 S 1C4 2F14
S 1F7 2B10 S 1F15 2B14 S 1F14 1D2 S 1D3 P24
S 2B9 1D13 S 1D11 1C1 S 1C2 P22
*
*
END
```