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AN ANALOG DATA TELEMETRY SYSTEM FOR REMOTE MONITORING APPLICATIONS, VERSION I

by

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AN ANALOG DATA TELEMETRY TRANSMITTER

INTRODUCTION

The interest in measuring various natural parameters <u>in situ</u> and transmitting these data from remote sites to a location convenient for data collection is increasing. Along with that, the problems of operating a remote station on a continuous basis for a long period of time within a reasonable power budget become very real. The system described here was designed to be used in volcanic gas monitoring experiments and was developed as a result of frustration with the large power consumption of some existing digital data telemetry systems. With the increasing availability of a wide variety of CMOS integrated circuits, the prospects for designing a system with extremely low power requirements was greatly enhanced. Additional design goals were simplicity, flexibility, and a low cost. All of these criteria have been included in the present design and the result is a versatile data telemetry transmitter capable of being used in a variety of applications.

DESCRIPTION

The heart of this system is an Analog Device AD537 monolithic voltage-to-frequency converter. The AD537 contains an input amplifier, used as an op amp, an accurate internal reference generator, a precision oscillator system, and a high current output stage capable of sinking up to 20 mA. In addition, it requires an operating current of only 1.2 mA drawn from a single positive supply anywhere in the range 5 to 36 volts. Only a single external RC network is required to produce a full scale frequency of up to 100 kHz, and the linearity and long term stability are extremely good. The AD537 is mounted in a ceramic 14-pin dual in-line package (DIP) and an extended operating temperature range version (-55 to +125°C) is available.

The clocking, counting, and driving portion of the system consists of a 4049 hex inverting buffer, a 4081 quad 2-input AND gate, and a 4020 14-stage binary ripple counter. The clock is composed of 2 sections of the 4049 and an RC network. The output of the clock is determined by the following relationship:

$$T = -RC \quad \ln \frac{(V_{DD}-V_{Tr})}{V_{DD}} + \ln \frac{V_{Tr}}{V_{DD}} \quad = 1.386 \text{ RC}$$

where $V_{Tr} = \frac{1}{2} V_{DD}$

Since continuous transmission is not always used, it is desirable to be able to switch the radio transmitter on and off in timed cycles. In addition, a small pump is required for the sensor in volcanic gas monitoring systems and it is convenient to be able to switch it on and off as well. Transistors Q1 and Q2 are provided for these purposes. Jumper selectable outputs from the 4020 counter provide the timing logic to trigger the radio transmitter and pump at the appropriate moments. A typical timing scheme is shown in figure 1.

The system described here is configured to have 4 DC signal inputs. Two of the inputs are used for reference signals (0 and 100 mV.). A temperature sensor and a hydrogen gas sensor use the other two inputs. A 4052 analog multiplexer is used to switch between the four inputs. The 4052 is also driven by jumper-selectable outputs from the 4020 counter. A complete schematic is shown in figure 2.

Since it is often desirable to operate in the standard seismic audio channels (680 Hz, 1020 Hz, 1360 Hz, etc.), a mercury battery (B1) is used between the output of the multiplexer and the input to the V/F converter to bias all of the sensor input signals up to the appropriate level. For example, a value of 1.02 volts for B1 would bring input signals in the range 0 to 100 mV

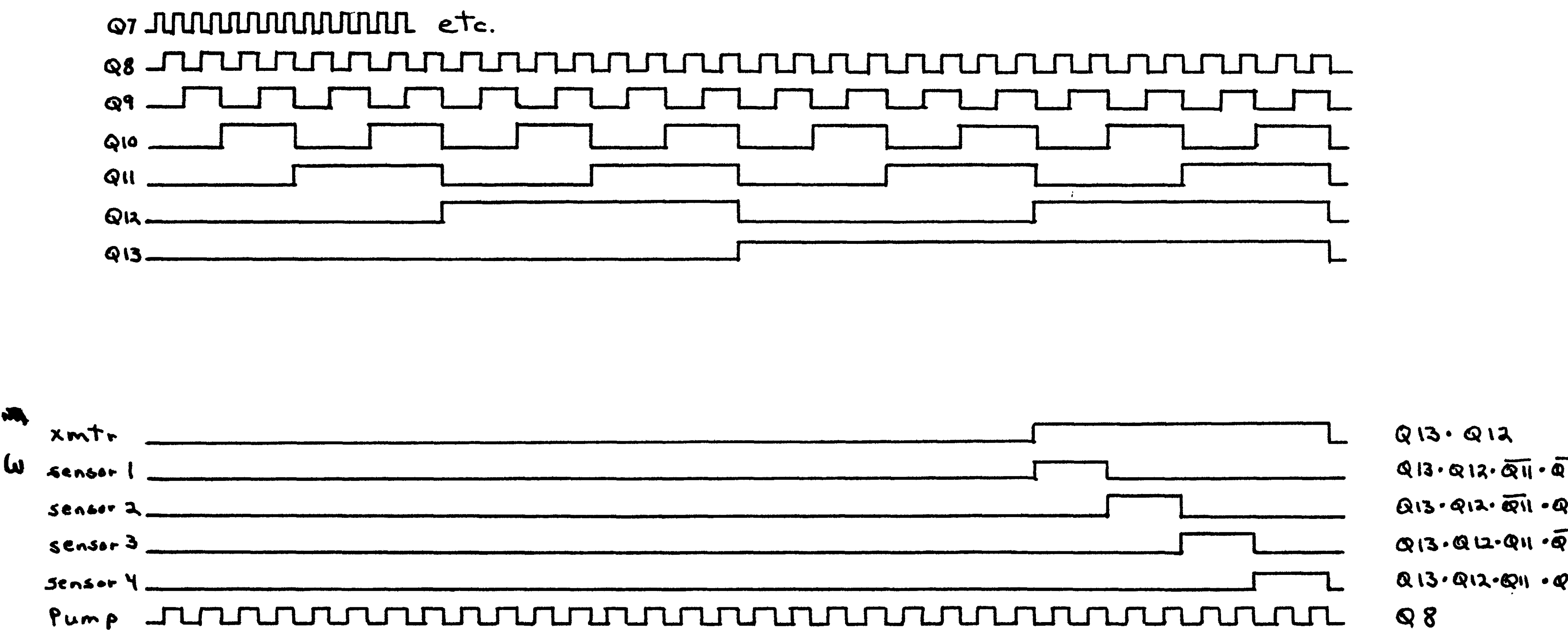


Figure 1. Timing Diagram

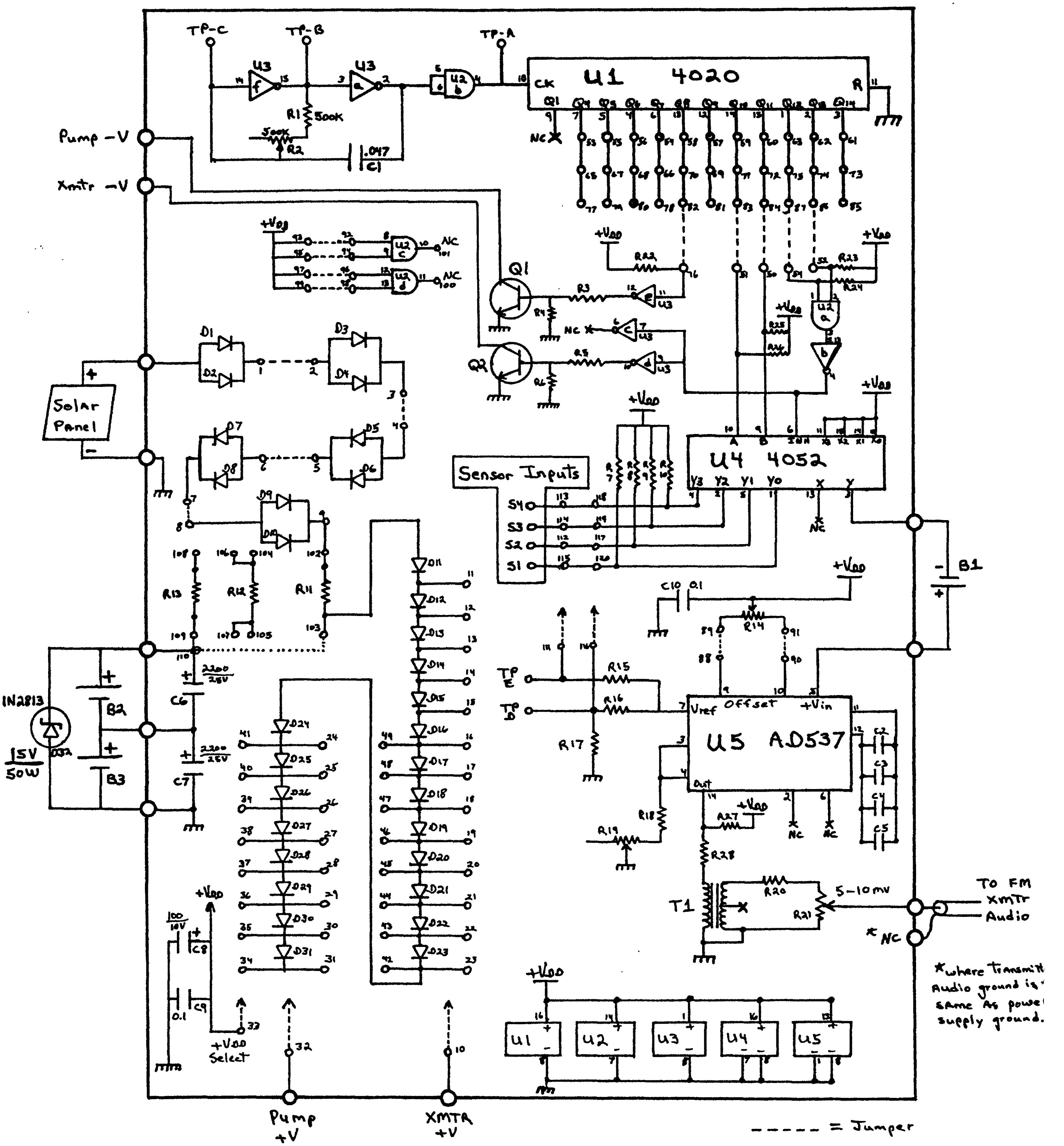


Figure 2. Complete schematic of the analog data telemetry transmitter

up to the range 1020 to 1120 mV, and the resulting frequency range out of the V/F converter would be 1020 to 1120 Hz. A photograph of the circuit board is shown in figure 3.

Capacitor C2 is the timing capacitor for the AD537 and its value is chosen by the relationship, $freq_{out} = V_{in}/10RC$. Therefore, with the standard 1 mA of drive current, a 0.001 μF timing capacitor will give a 100 kHz full scale frequency and a 0.01 μF value will give 10 kHz, etc. If needed, C3, C4, and C5 can be added in parallel with C2 to achieve non-standard values of capacitance. The combination of R18 and R19 is the scaling resistance for the AD537. In this case, R = V/I, where V is the full-scale input voltage to pin 5 of the AD537 and I is the full-scale current (1 mA). Therefore, a 10 volt range would require a 10 K ohm resistor. All of the frequency determining components used with the AD537 should have a low temperature coefficient.

If it is necessary to operate the system and charge the batteries using a solar panel, D1 and D2 should be installed along with a jumper wire from hole 1 to hole 9. If additional voltage drop is required, D3-D10 can be installed along with the appropriate jumper wires. If the board is to be powered from batteries only, D1-D10, R11-R13, and the external zener diode can be eliminated. A jumper wire from hole 110 to hole 103 should be installed in that case. Suitable voltages to power the radio transmitter, pump, and control circuitry can be obtained by jumper wires from hole 10, hole 32, and hole 33 respectively, to the desired tap on the diode string (hole 11-hole 49).
12 volts is a good operating voltage for the control circuitry since the AD537 frequency output appears to be most stable above 7 vdc, while above 18 vdc the AD537 gets noticeably warm. The total power consumption for the circuit board (not including pump and radio transmitter) is 10-20 mA depending on the AD537 output load.

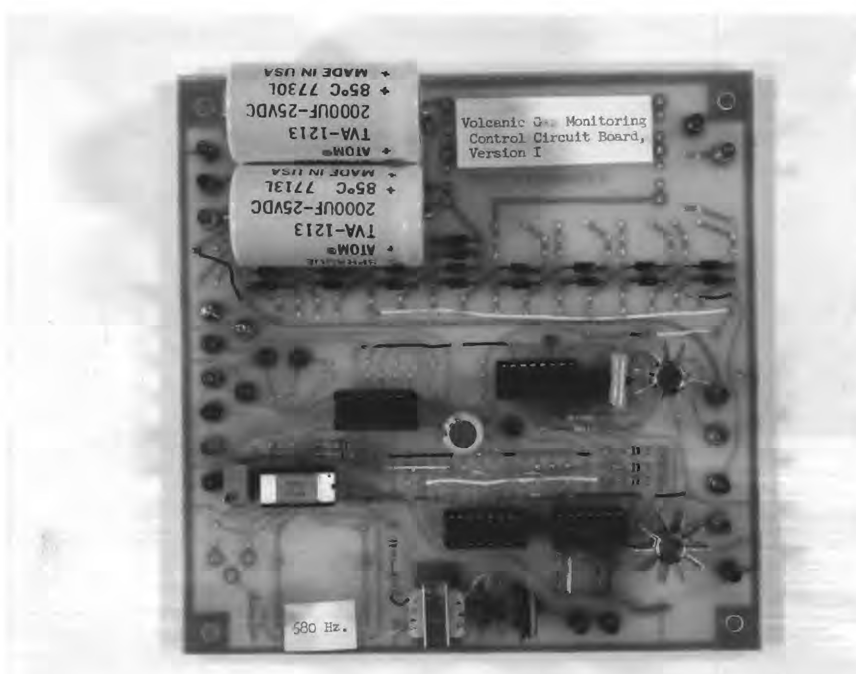


Figure 3. Photograph of circuit board layout

This system is designed to be used with a standard constant bandwidth seismic discriminator, such as the U.S.G.S. Model J101 or the Develco Model 6203, at the receiving site. When using the U.S.G.S. Model J101, the recommended zero reference frequency can be set below the standard constant bandwidth frequency (for example: 970 Hz rather than 1020 Hz) to ensure good capture when frequency multiplexing with other carrier signals. A small chart recorder (i.e., Rustrak DC recorder) that prints a series of dots on pressure-sensitive chart paper can be used at the discriminator output to record the data. The output from each of the four channels appears as a continuous line on the chart paper.

PARTS LIST

C1 - .047 uf disc ceramic
C2 -]
C3 -| polystyrene timing capacitors
C4 -| see note 1
C5 -]
C6 - 2200 uf, 25v, electrolytic
C7 - 2200 uf, 25v, electrolytic
C8 - 100 uf, 25v, electrolytic
C9 - 0.1 uf, disc ceramic
C10 - 0.1 uf, disc ceramic

R1 - 500K ohm, 1/4 watt
R2 - 500K ohm trimpot (or fixed)
R3 -]
R4 -| see note 2
R5 -|
R6 -]
R7 -]
R8 -| (100K ohm, 1/4 watt - used only if
R9 -| nothing connected to sensor input)
R10 -]
R11 -]
R12 -| 10 watt - see note 3
R13 -]
R14 - 20K ohm pot - optional, see note 4
R15 - 91K ohm, 5%, 1/4 watt, see note 5
R16 -] optional
R17 -] see note 6
R18 -] scaling resistance, see note 7
R19 -] low temp. coefficient trimmer (cermet)
R20 - 100K ohm, 1/4 watt - See note 11
R21 - 20K or 25K ohm trimmer - See note 11
R22 - 100K ohm, 1/4 watt
R23 - 100K ohm, 1/4 watt
R24 - 100K ohm, 1/4 watt
R25 - 100K ohm, 1/4 watt
R26 - 100K ohm, 1/4 watt
R27 - 15K ohm, 1/4 watt
R28 - 100K ohm, 1/4 watt - See note 11

T1 - Audio Driver, 10K primary, 2K secondary, (Calectro D1-722)

Q1 - HEP S3002 or S3010 or similar NPN transistor
Q2 - HEP S3002 or S3010 or similar NPN transistor

D1-D31 - 1N4001 series silicon diodes - see note 8
D32 - 1N2813, 50 watt, 15v, zener diode - not necessary if solar panel not used

B1 - see note 9
B2 -] Rechargeable Nicad Storage
B3 -] Batteries, 6v, 14 A.H.

U1 - 4020 CMOS IC
U2 - 4081 CMOS IC
U3 - 4049 CMOS IC
U4 - 4052 CMOS IC
U5 - AD537 V/F Converter

Misc: binding posts, transistor heat sinks, gold plated IC sockets, zener diode heat sink

Note 1 - C2 is the timing capacitor and its value is chosen by the relationship, $freq_{out} = V_{in}/10RC$. Therefore with 1 mA of drive current a 0.001 uF timing capacitor will give a 100 kHz full scale frequency and 0.01 uF will give 10 kHz (Maximum frequency is 150 kHz). If needed, C3, C4, and C5 can be added in parallel with C2 to achieve non-standard values of capacitance.

Note 2 - Select values of R3 and R5 that will drive Q1 and Q2. These values can be found by inserting a potentiometer at R3 or R5 and varying it until drive is achieved. Then the pot can be removed and its value measured and a fixed resistor substituted. The HEP S3002 and S3010 can be driven by 470 ohm resistors. Space is provided on the board for divider resistors (R4 and R6) if needed.

Note 3 - The value for the limiting resistor (R11) is calculated by:

$$R = \frac{E_{in} - E_{out}}{I_{load} + I_{zdl}},$$

where E_{in} is the unregulated source voltage, E_{out} is the regulated output voltage of the zener, I_{load} is the maximum current load, and I_{zdl} is the nominal current through the zener (normally 10% of I_{load}). Space is provided for two other resistors (R12 and R13) so that a value close to the calculated value of R can be achieved through the use of either series or parallel resistors with the appropriate use of jumper wires in holes 102-109.

Note 4 - R14 is an optional 20K ohm pot used only when trimming the input amplifier offset. If used, jumpers 88-89 and 90-91 should be installed.

Note 5 - With a 91K ohm, 5%, resistor installed at R15 and a jumper from hole 111 to one of the sensor inputs (holes 112-115), a value of 10K ohm resistance from a thermistor will develop 100 mv at that sensor input. Similarly, 5K ohms will develop 52.1 mv and 1K ohms will develop 10.9 mv. A calibration curve can then be drawn relating temperature in °C to this millivoltage.

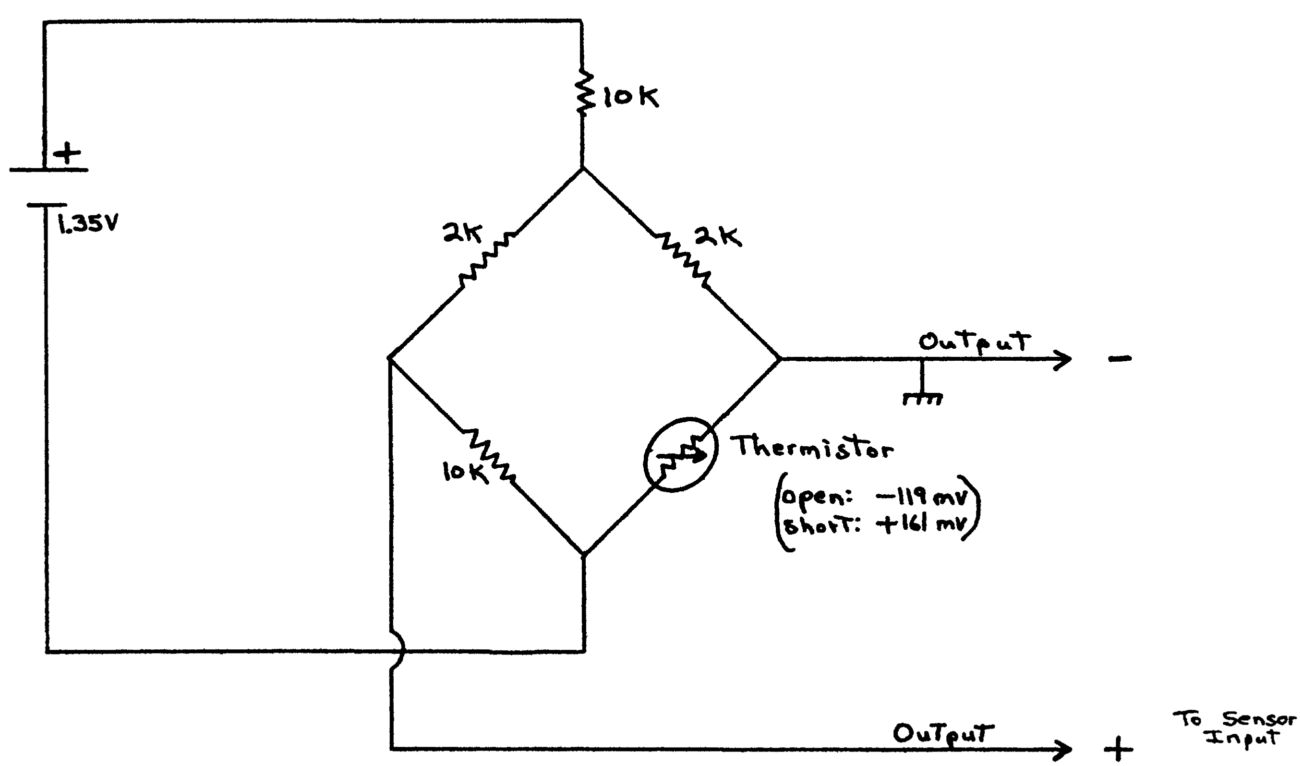
Note 6 - Should a specific voltage be desired at one of the sensor inputs for ID or some other purpose, a 91K, 5%, resistor can be installed at R16 and a jumper connected from hole 116 to one of the sensor input holes (117-120). Then a 10K ohm resistor at R17 would develop 100 mv at the sensor input, 5.6K ohms at R17 would develop 58 mv, 2K ohms at R17 would develop 21.5 mv, and so on.

Note 7 - The combination of R18 and R19 is the scaling resistance for the AD537. In this case, R - V/I, where V is the full-scale input voltage to pin 5 of the AD537, and I is the full-scale current (1 mA). Therefore, a 10 volt range would require a 10K ohm resistor, and so on. R19 should have a low temperature coefficient such as cermet type trimmers.

Note 8 - D1 and D2 should be installed along with a jumper wire from hole 1 to hole 9. If additional voltage drop is required, D3-D10 can be installed with the appropriate jumper wires. If the board is not to be powered from a solar panel (i.e., batteries only), D1-D10, R11-R13, and the zener diode can be eliminated. A jumper from hole 110 to hole 103 should be installed in that case. Appropriate voltages to power the transmitter, pump, and control circuitry can be obtained by jumper wires from hole 10, hole 32, and hole 33 respectively, to the appropriate hole on the diode string.

Note 9 - B1 is a source of bias voltage to the AD537 if needed. For example, if a mercury cell were used there it would provide 1.35 volts of bias in addition to the voltage (0-100 mV) from the sensor. The frequency output range from the AD537 would therefore be 1350-1450 Hz.

Note 10 - Typical temperature bridge used with this system.



Note 11 - Output circuitry depends on specific telemetry or radio system being used. The values listed are compatible with a Repco Model 810-041 transmitter.