Telemetry of meteorological information from unattended lighthouses

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ABSTRACT

A relatively simple system is described which makes it possible to transmit wind velocity, air temperature, and relative humidity from a remote point to a central location, over either an RF carrier or a land line.

TELEMETRY OF METEOROLOGICAL INFORMATION FROM UNATTENDED LIGHTHOUSES

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While there are a number of systems now available to transmit data from one location to another, most of them are designed for high-speed operation using PCM or some other equally complex method. The requirements for meteorological telemetry for making marine forecasts are quite simple and so lend themselves to a slow-speed transmission system. In most cases, wind direction need only be broken down into eight separate 45° segments and be sampled once an hour. Air temperature and relative humidity may also be transmitted at the same rate.

As long as a high signal-to-noise ratio is assumed, air temperature and relative humidity may be measured by using suitable sensors to control the frequency of oscillators whose outputs may be counted, and then displayed and recorded for future processing. These sensing devices are much cheaper than shaft encoders with their associated circuitry, while the decoding equipment can also be made less complex than that for use with PCM and other high-capacity systems.

Let us examine a block diagram of a simple narrow-band, slow-speed telemetry system (Fig. 1). The anemovane used is a standard Department of Transport unit whose commutator has been modified to provide a separate grounding switch closure for each of the eight directional segments to be transmitted. Thus, depending on the position of the vane, one of eight audio oscillators (600.9 to 979.9 Hz) is energized when direction is sampled. Resonant reed filters are used in transistor circuits both to generate and to decode these audio tones. A keying tone (634.5 Hz) is sent for 2 seconds immediately preceding the direction information, in order to minimize false signals caused by noise in the system.

The temperature probe is made up of an oscillator containing thermistors whose frequency varies with temperature (see Fig. 2). For this location the temperature probe has been designed so that its frequency changes from 700 to 4100 Hz for a temperature range of +25°C to -30°C. A frequency divider is used to reduce this frequency range to 350–2050 Hz for transmission by narrow band FM.

The hygrometry probe is a commercial unit supplied by Hygrodynamics Inc., Silver Spring, Maryland. It provides a dc output voltage which varies directly with the relative humidity present. An adjustable potentiometer allows a range of 0–100% relative humidity to be represented by an output dc voltage of 0–5 volts. To make this compatible with our temperature recording system, it was necessary to provide a voltage-to-frequency converter which had a high input impedance (>200 kΩ) to match the transducer and a linear characteristic to provide an uncramped scale for read-out purposes. The resultant audio frequency is then counted and displayed at the receiving site in the same manner as is done for the temperature measurement.

These objectives were accomplished by using the circuit shown in Fig. 3. Q2 operates as part of a relaxation oscillator whose frequency is controlled by the combination of the 0.01-μF capacitors (three in series) and the charging resistor represented by Q1 and the 220-kΩ resistors. Q1 provides this charging current in response to the control of IC1 while Q3 acts as a buffer between the oscillator and the low input impedance modulator. CR1 provides temperature compensation for Q2. Much care was required in the design of the voltage regulator circuits (CR2-4) to insure suitable operation over the ranges of temperature (−15°C to +5°C) and supply voltage (−20 to −17 volts).

One model of this equipment is now in use at Rogers Pass, British Columbia, to transmit meteorological data from two mountain peaks to a receiving station in the valley where it is used in avalanche control work. Caustic potash batteries supply the power for seven months of operation at the remote station in this case, but rectified ac supplied from a diesel generator could be used if it were available.

As in the case of the wind direction information, a keying tone (313.0 Hz) is transmitted for several seconds immediately before the temperature or relative humidity signal. Its purpose is to energize the temperature or relative humidity decoder circuits only when these data are to be sent and thus to minimize interference from noise.

Wind speed is transmitted by generating a two-tone sequential signal (2 seconds for each tone 634.5, 669.9 Hz) each time 'a mile of wind' passes the anemovane cups. The resulting pulses occurring in an hourly period can be added together to produce the wind speed in mph.

The audio bandwidth required for this system is from 300 to 2000 Hz or 1700 Hz, well within the limits of 300–3000 Hz available from commercial telephone circuits or land lines. However, for maritime use, the choice of a wired circuit or RF link can be decided upon according to the existing conditions over the path under consideration.

At the receiving end of the system the decoder chassis obtains its signal either from a receiver or a line amplifier depending upon the kind of link employed. The wind velocity data are handled differently from those of air temperature and relative humidity. In the case of wind direction, resonant reed filters channel the signal to the appropriate detector circuit and produce a pen deflection on a 20-pen Esterline-Angus recorder. The operation of this part of the system may be seen by examining Fig. 4.

By design, the *wind velocity keying tone* must be received immediately prior to that representing direction or speed. This keying tone is a 634.5-Hz sine wave generated by RF2 and applied to the input of IC35, a high input impedance amplifier having a low output impedance suitable for driving a diode detector circuit.

When the voltage on the trigger of Q46 rises to a certain level, it fires, turning on PL1 (*velocity key lamp*) and connecting the anode of CR23 to ground through the low ON impedance of Q46. This action stops the charging of the capacitor on the base of Q66 which will conduct as soon as the 470-ohm resistor can discharge the capacitor to a point below the cut-off level for Q66. When this happens the Darlington combination of Q66 and Q67 will drive a pen to show that the velocity key is on.

An output, V_X, to supply another circuit known as the *wind velocity key duration detector* (Fig. 5) is taken from the base of Q66. This voltage is fed through the zener diode CR46 and an inverter IC29 to the input of a 4-bit shift register which is 'clocked' at a 2-Hz rate.

An examination of the truth table for the shift register would show that, for a positive voltage (V_W) to be produced at the output of the 4-input AND gate (IC28, A, B), V_X must be low during the 10-μsec sampling period for at least four consecutive clock periods (2 seconds). If such is the case, V_W will turn on Q94 producing a positive output voltage V_E of approximately 6 volts. This is sufficient to forward bias Q57-65 so that if any direction tone is then received, it will turn on the appropriate pen. The timing circuit containing Q97 will also be energized at this time.

The gate voltage V_E is only present for a period (approximately 4 seconds) determined by the RC network (15 kΩ and 160 μF) associated with Q97. Q96 insures that this timing period does not start until the keying tone has ceased to be received. At the end of this 4-sec period, a pulse from Q97 turns on Q98, which then shuts off Q94 by removing the positive bias from Q100. Q98 is turned off through Q99 when the keying signal is received (i.e., V_X falls from +8V to +1.4V).

Let us examine how the temperature signal is handled for display purposes (Figs. 7–9). The temperature keying tone sets all of the flip-flops to the same state and holds them there until it is no longer present. Upon its completion, the ripple-through counter made up of flip-flops 12–14 starts and after one second has enabled the AND gate IC2 so that the temperature signal which is then being sent may be fed to the 11-bit binary counter (flip-flops numbers 1–11). IC2 is disabled after exactly 1 second by its inputs from the 3-bit counter mentioned above. Thus, at this time the temperature signal has been fed into the 11-bit binary counter for exactly one second thereby storing the frequencies (cycles/second) in the counter in binary form.

By feeding from suitable outputs on flip-flops numbers 12–14, a readout voltage is developed through IC11A and combined with the output of AND gates IC16A-18B to turn on the appropriate pens of a multipen recorder for 1 second whenever a binary '1' is present. This display is produced 4 seconds after the temperature signal begins. Feedback is applied to inhibit flip-flops numbers 12–14 when they have reached their maximum count so that the main counter is only fed with a single one second 'burst' of temperature signal.

The second 3-bit counter (numbers 15–17 flip-flops) is fed from a $\frac{1}{2}$-Hz source and supplies a 'turn-off' voltage through IC13C, IC13D, and IC12B to extinguish the lamps which indicate the state of flip-flops numbers 1–11. IC13A inhibits the $\frac{1}{2}$-Hz input when the counter (IC14B-15B) has reached its maximum count (twenty seconds after the completion of the temperature key tone).

The average current drain of one of the remote telemetry stations operating at Rogers Pass, British Columbia, is 26 mA. (The standby current is 6 mA rising to 400 mA when the 700-mW transmitter is turned on.) The total power required at Rogers Pass, for a 7-month season is only 140 ampere-hours. For maritime remote telemetry the equipment may be supplied from a battery pack for a long period of time.

Actual tests have demonstrated that the transmitter power output may be reduced to 70 mW over an eight mile line-of-sight path (corner reflector antennas at both ends of the link) and still transmit data reliably between the two points concerned.

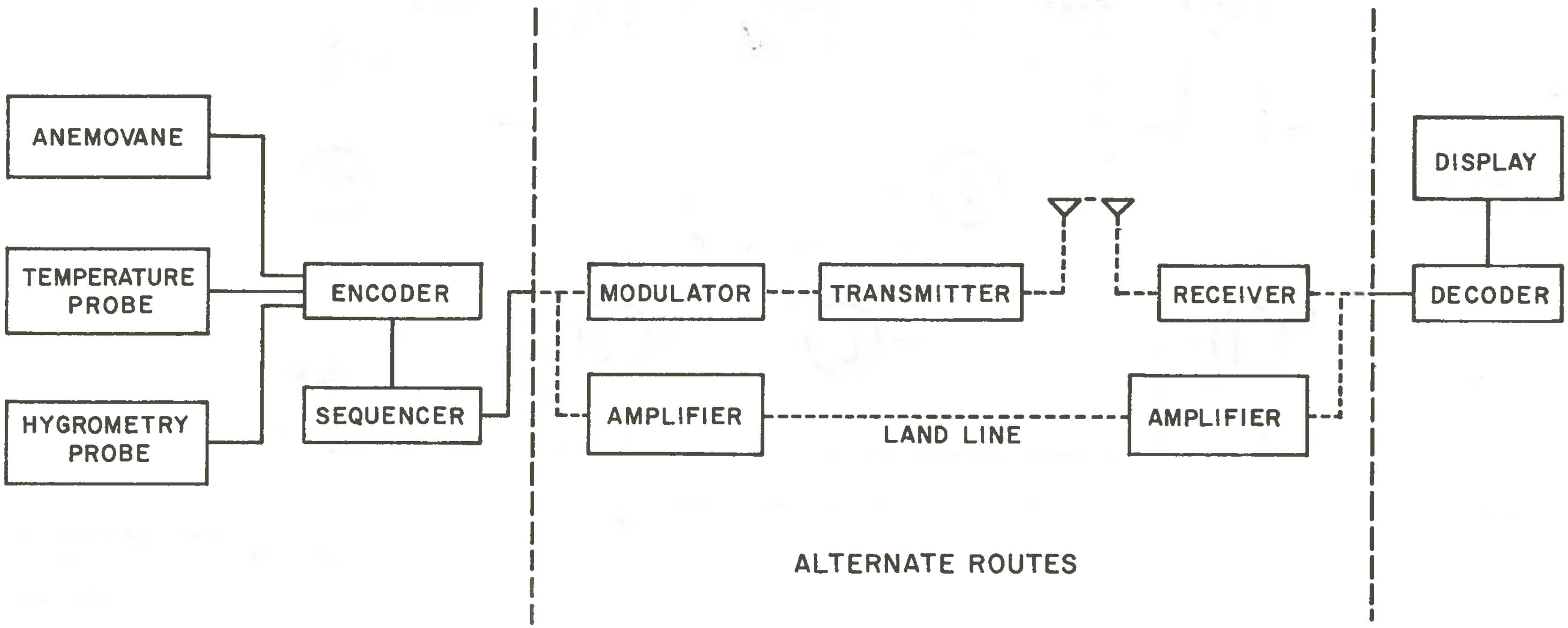
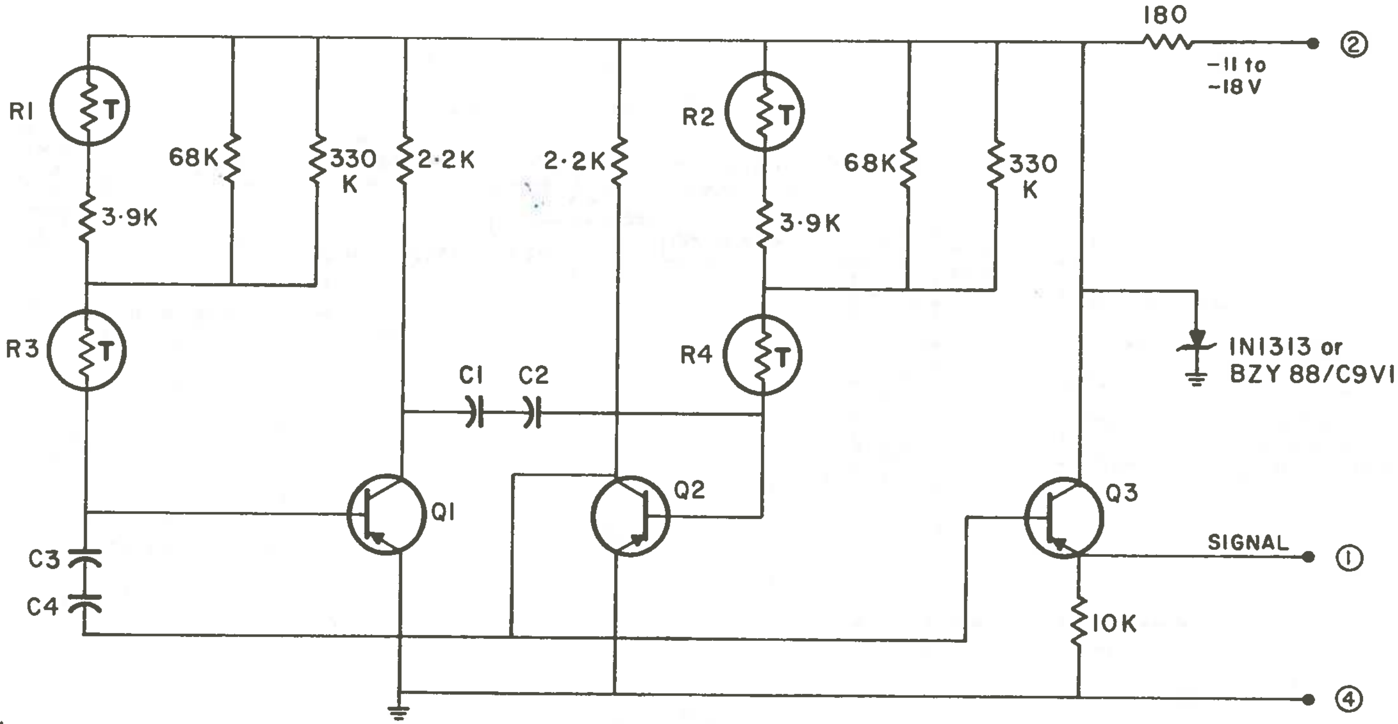


Fig. 1 - Block Diagram of Telemetry System



R1-R2-FENWALL RB38L1
8000Ω ± 10% AT 25°C

R3-R4-1000Ω ± 10% AT 25°C

Q1-Q2-Q3- 2N1307 (GA2684)

C1-C2-C3-C4-MALLORY MYLAR CAPS 1133
0·033μF, 100V

Fig. 2 - Temperature Probe Oscillator Circuit

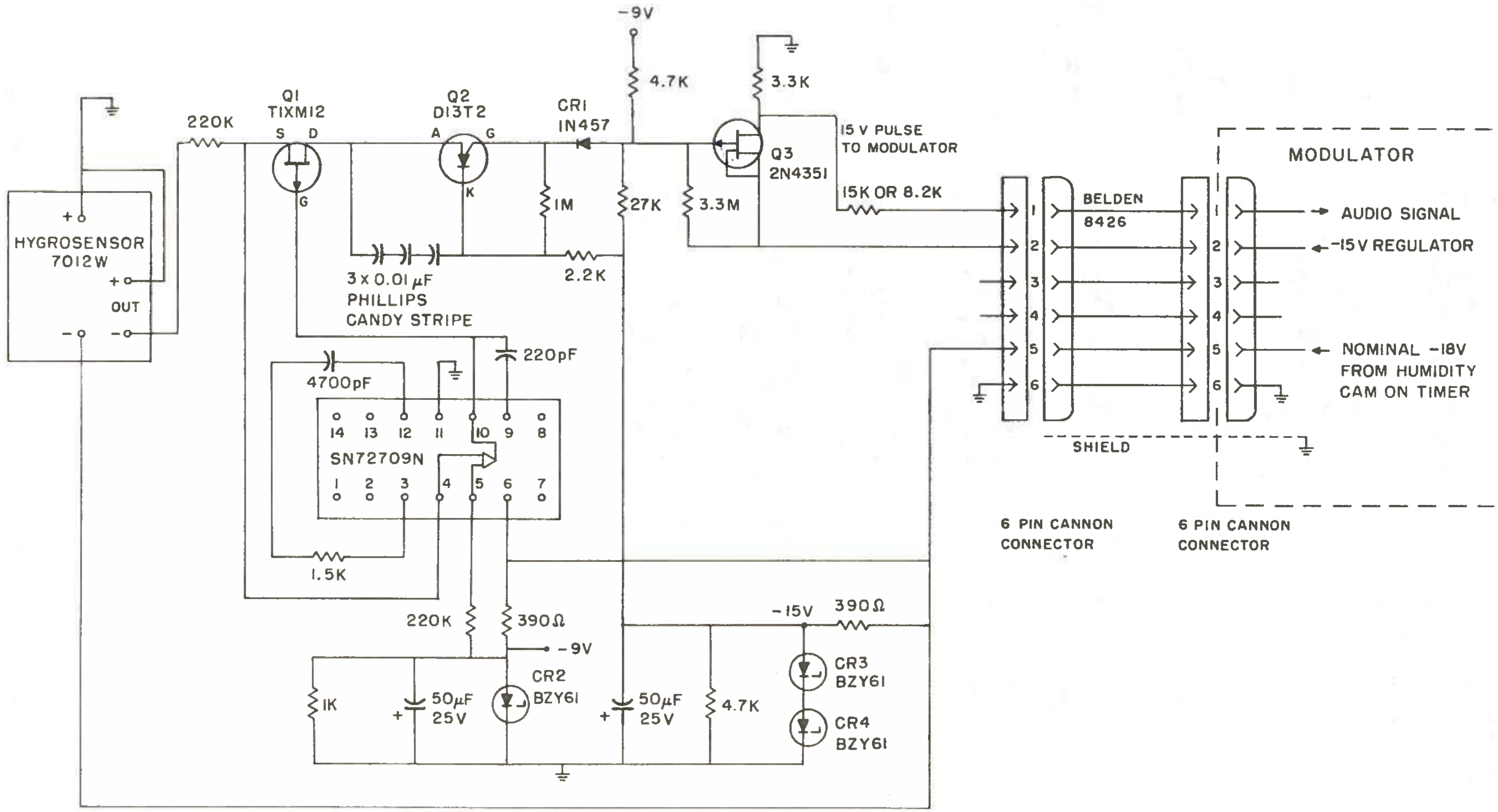


Fig. 3 - Humidity Sensing Circuit

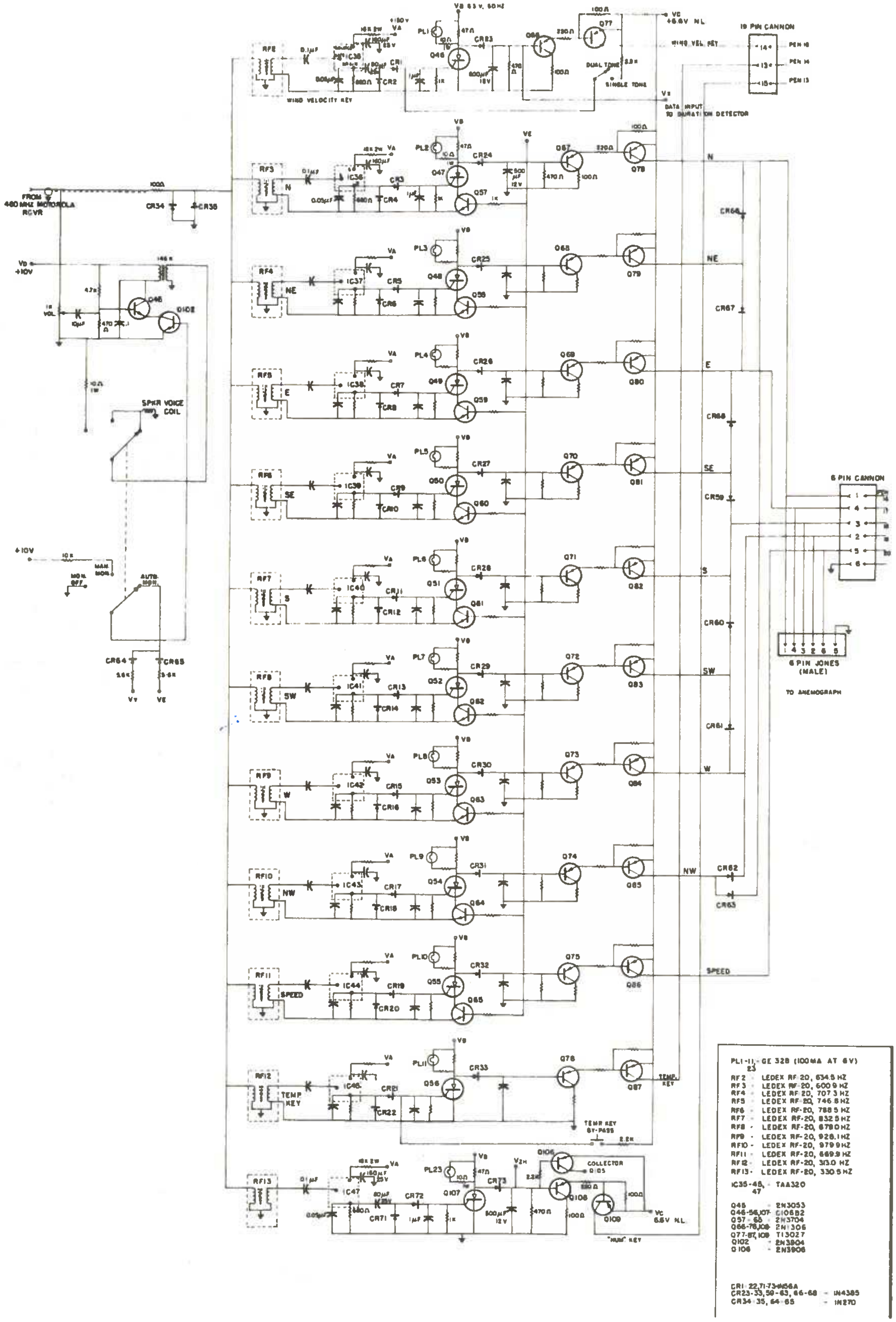


Fig. 4 - Wind Velocity Decoder and Pen Driver Circuits

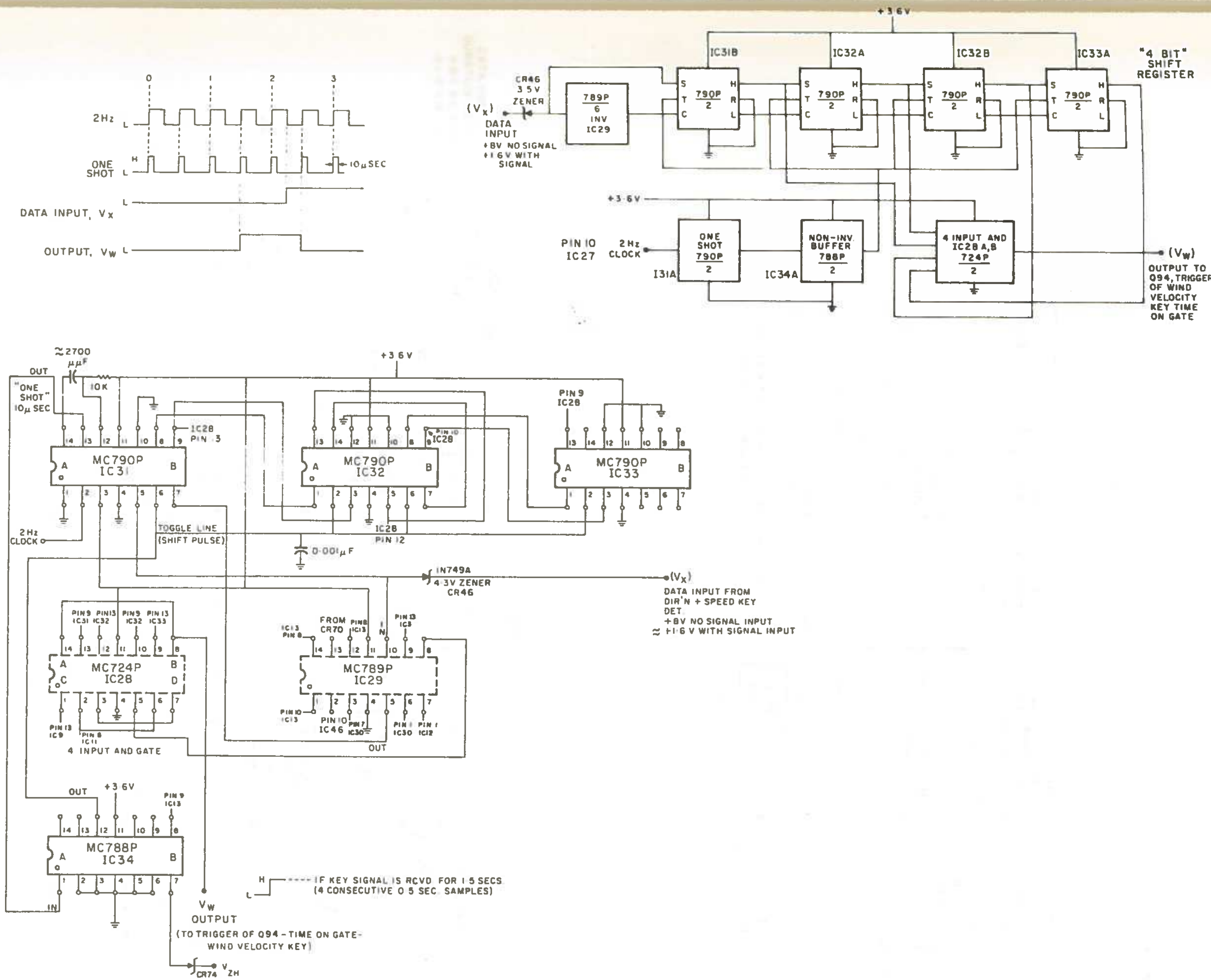
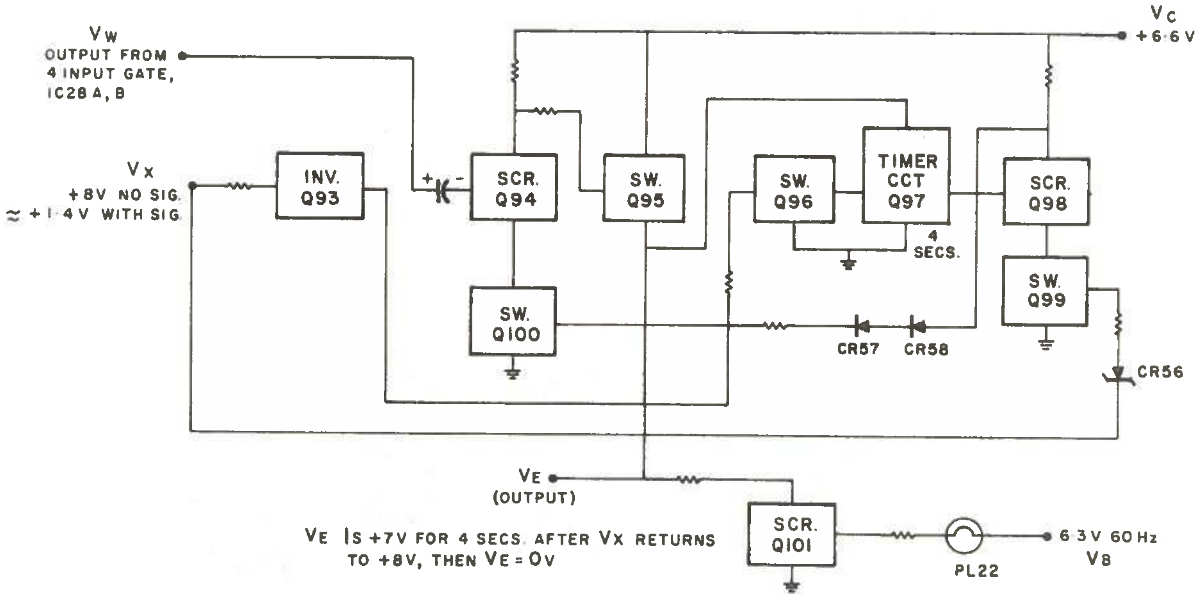


Fig. 5 - Wind Velocity Key Duration Detector



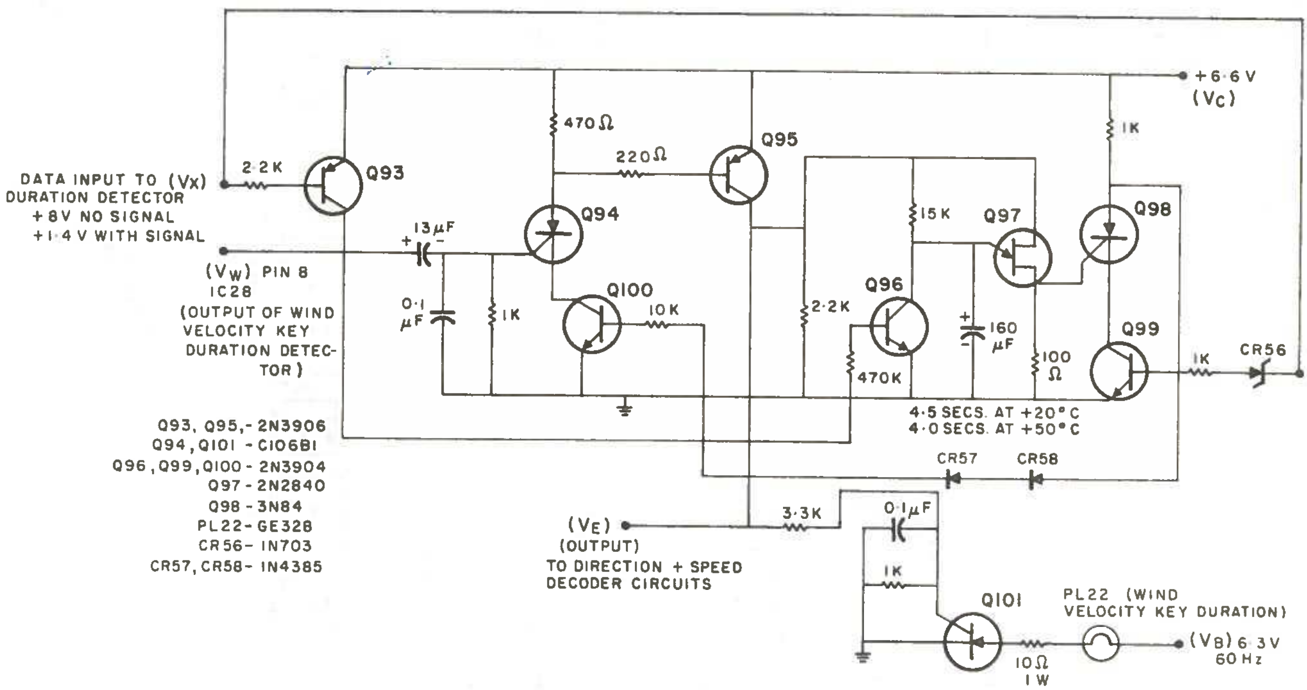


Fig. 6 - Wind Velocity Key Duration Circuit

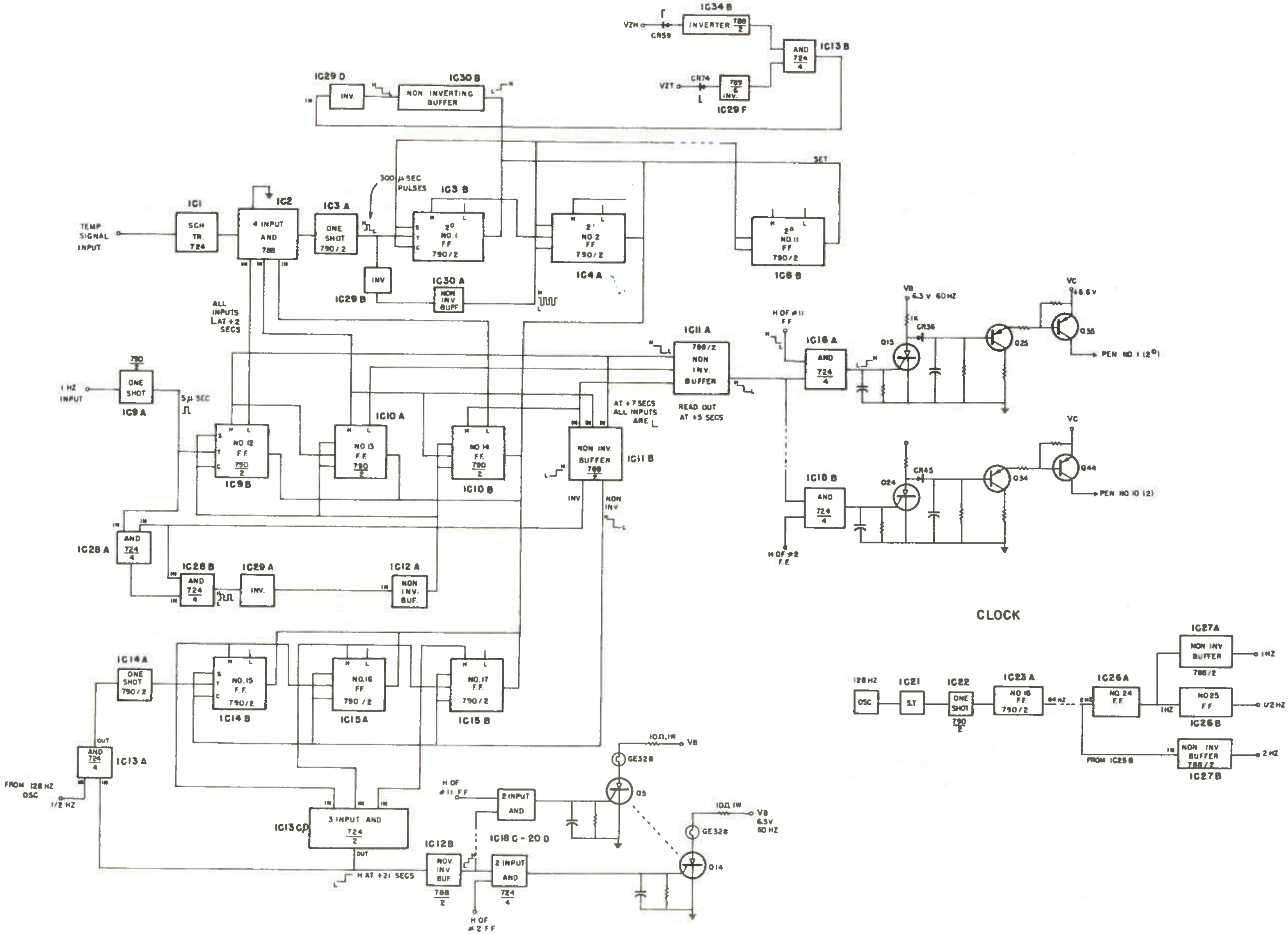


Fig. 7 - Block Diagram of Temperature Decoder

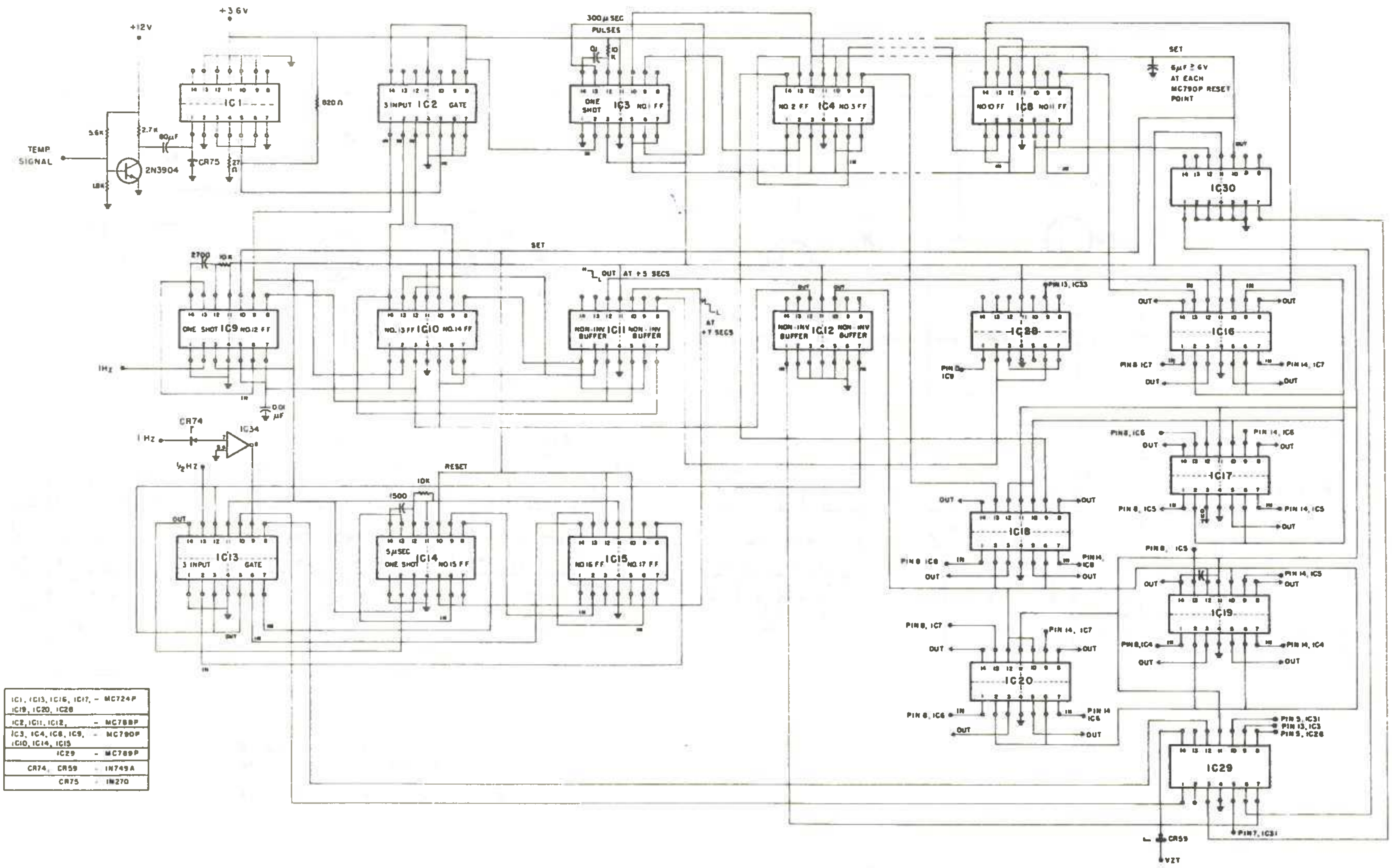
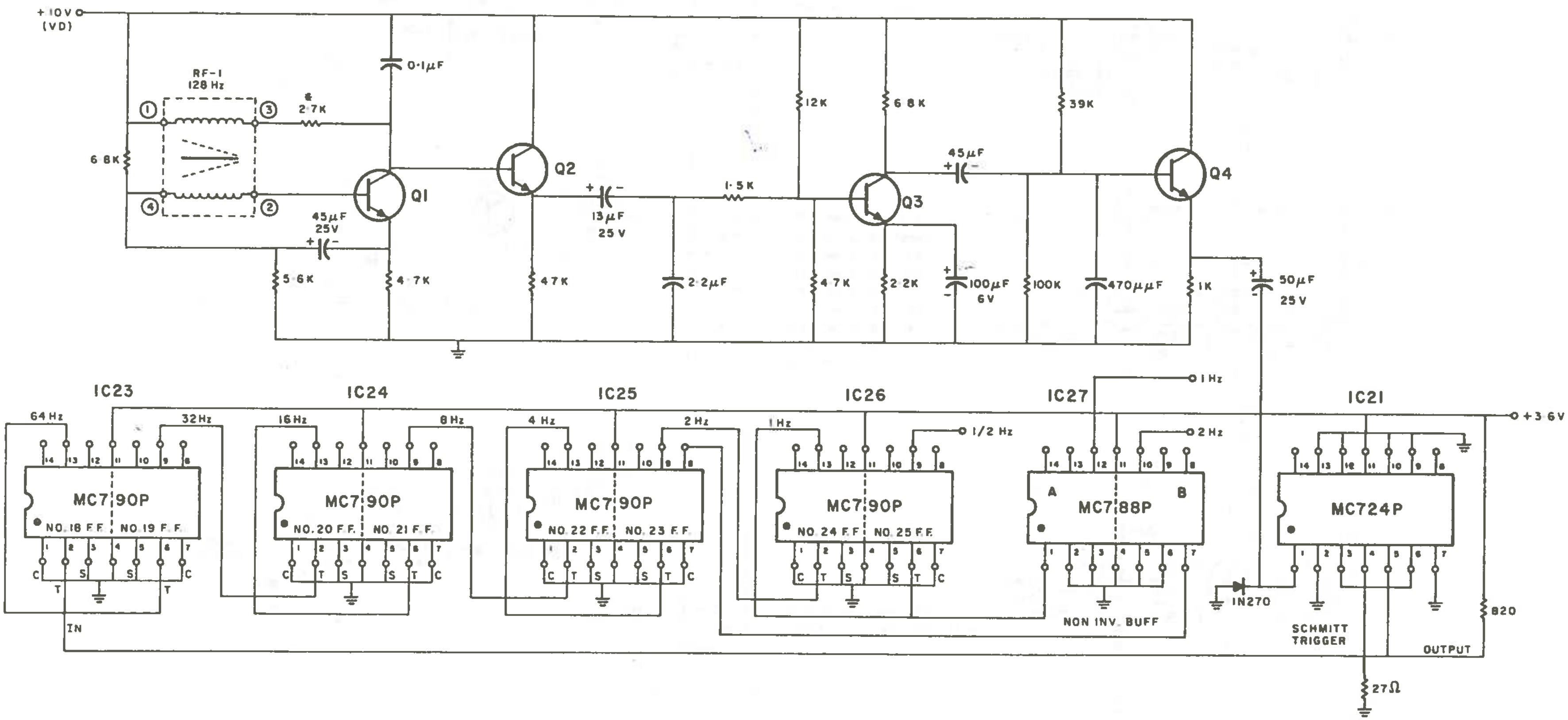


Fig. 8 - Temperature Decoder Circuit



Q1-Q4 - 2N3391A
RF-1 - LEDEX RF-20, 128 Hz
* ADJ. FOR 0.2 V RMS ACROSS ① & ③

Fig. 9 - Clock for Temperature Decoder

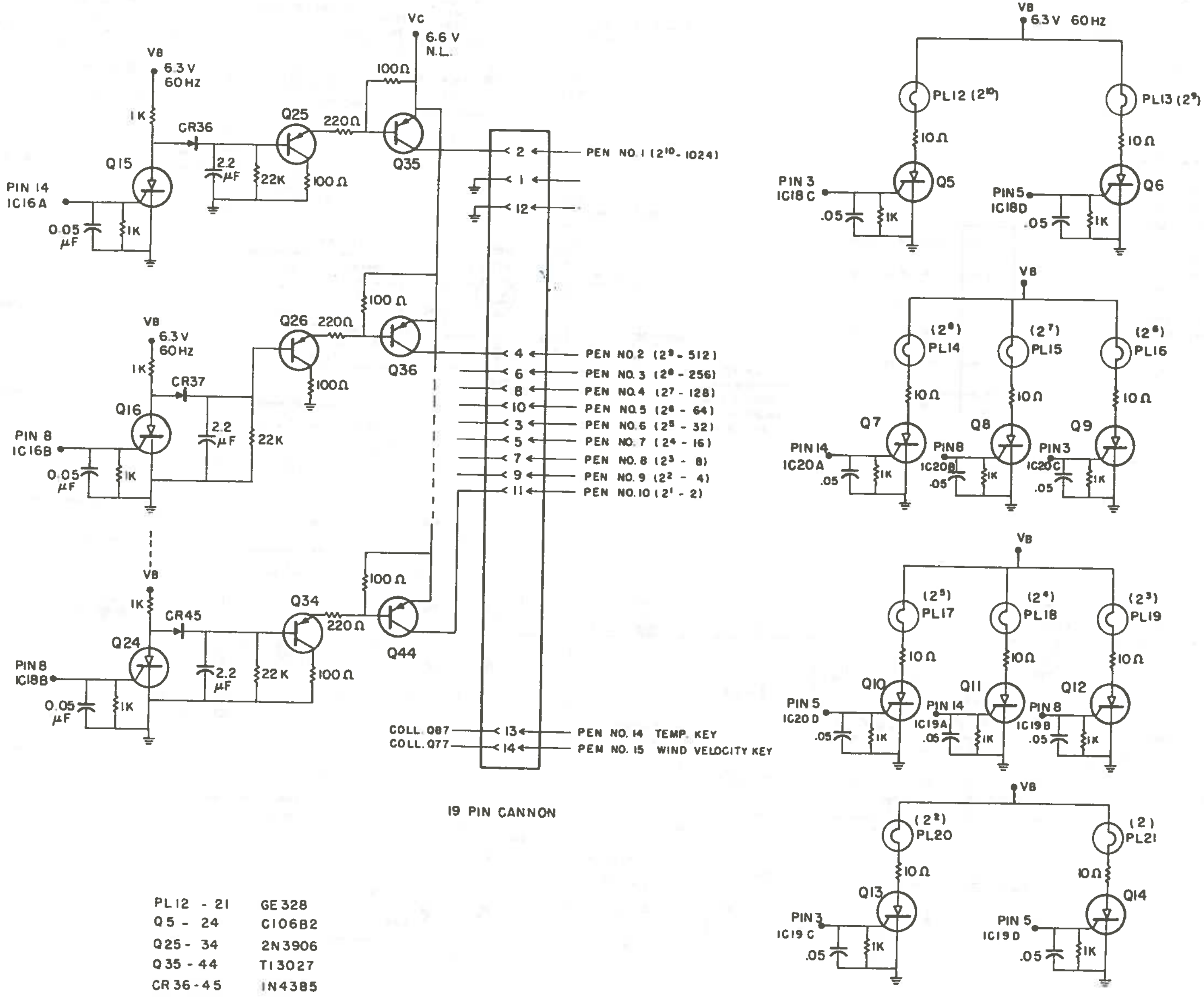


Fig. 10 - Pen and Lamp Driver Circuits

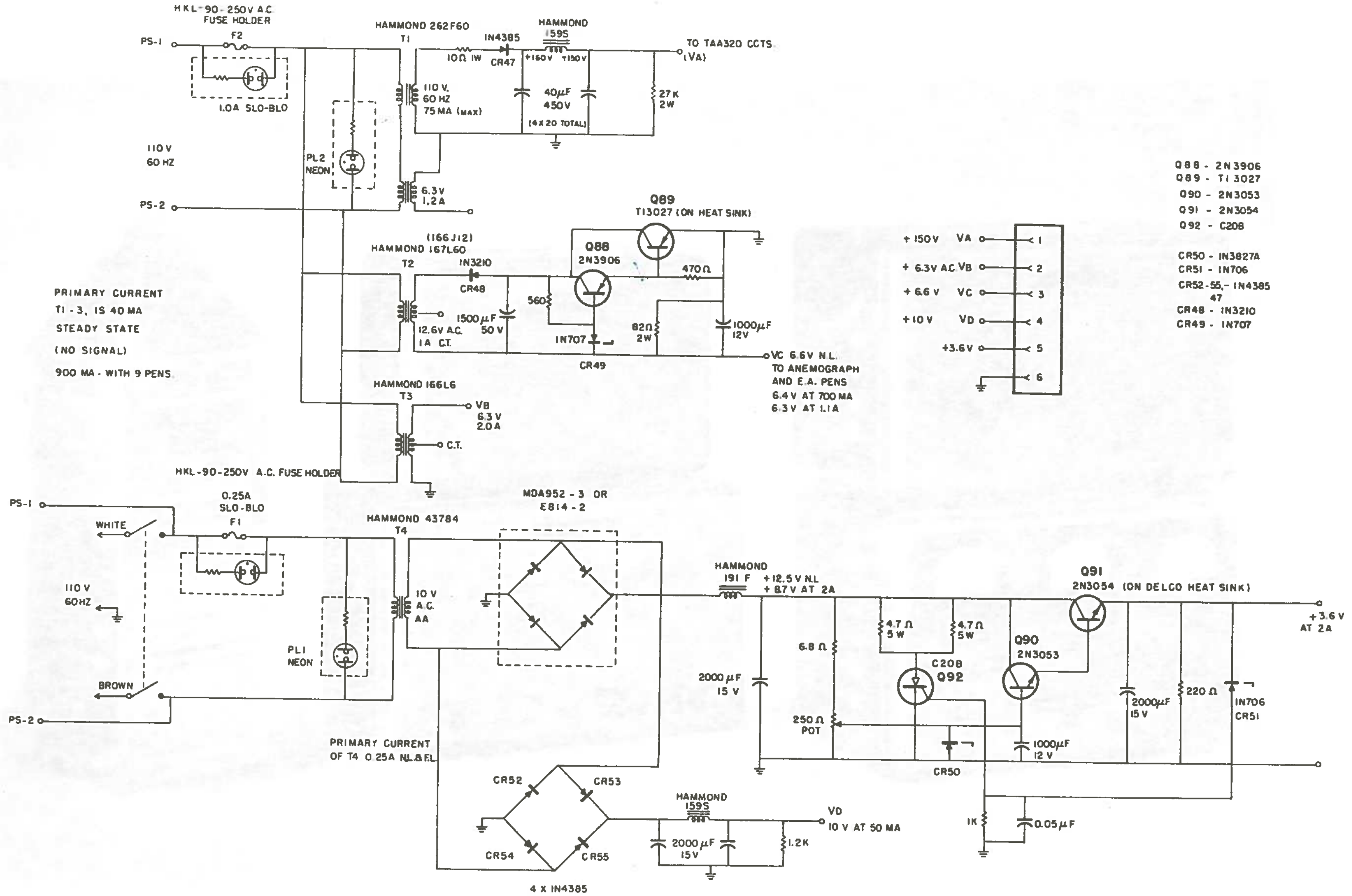


Fig. 11 - Power Supply for Temperature and Wind Velocity Decoders

Fig. 12 - Remote Transmitting Equipment used at Rogers Pass, B.C.

Fig. 13 - Rack of Receiving Equipment used at Rogers Pass, B.C.