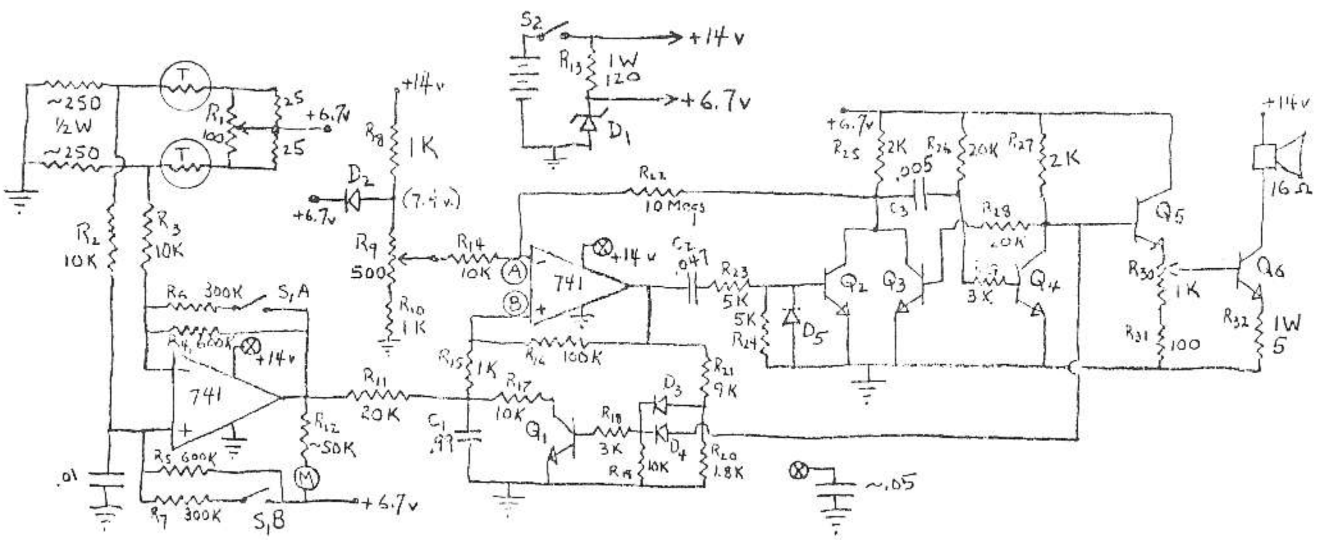
A TICKER AUDIO VARIO

Don Ott, John Larkins, and Kevin Ott
Los Alamos, New Mexico
U.S.A.

Having been without audible rate of climb information for awhile, and after having flown with it for some time, it is certainly a pleasure to be able again to thermal and cruise without so much visual attention to a needle. There are several fine audio variometers on the market, but if you like to spend time playing around with things like this, have some knowledge of electronics and shop practice, some helpful friends, and value your time at about zero, you should be able to come up with an instrument you'll really appreciate without much of a capital investment. This one contains about $25 worth of parts, if you buy them new.

Many criteria can be set for variometer performance. This variometer was designed for the purpose of getting audible rate of climb during thermaling and also getting an indication of lift above a threshold while cruising--not necessarily for indicating accurate or precise rate-of-climb numbers. It was for supplementing a conventional (silent) vario, such as a PZL, and not as the sole rate-of-climb instrument. However, experience so far indicates its long-term stability (hours), as well as short term, to be very good, and with a proper meter and calibration would most likely be an entirely satisfactory variometer. One concern, before actual flight testing, was response time (the thermistors used were larger and had a longer time constant than "usual"), but performance seemed to be "just right" (in our opinion)--somewhat faster than the PZL, but not so fast as to be distracted by turbulence (total-energy venturi). The output is a series of ticks, which at high rates sounds like a tone. Since the power in each tick is the same, the volume is as good at low frequencies as at high and more independent of speaker and ear characteristics (in contrast to a sine-wave output).

So, the basic requirements we started with were: a ticker, at least short-term stability (no noticeable drift during the time for a few turns), threshold capability, conservation of panel space, operation from power already available (14 volts dc), and, of course, satisfactory vario action. The electronic schematic is shown in Fig. 1. After buying the thermistors, the other bridge resistances were chosen to give reasonable balance and draw sufficient current (about 15 ma in each leg) to provide a high enough operating temperature (around 100°C) for the thermistors, considering the voltage and parts available (a 25 ohm zero balance pot would probably have been nice). There is the feeling that considerable luck was involved in mounting the thermistors in the air flow to and from



D_1 Zener diode, 400 mW, ~ 6.7 volts

D_2-D_5 Diodes (N914)

Q_1-Q_5 Low-power silicon NPN transistors (2N3567)

Q_6 Medium-power transistor (several watts) (2102)

M Zero-center microammeter; choose R_{12} to give full-scale deflection at about 6 volts

S_1 Range switch, DPST

S_2 On-off switch, SPST

C Capacitors are ceramic disc (~ 20 volts)

Audio variometer electronic schematic.

741 Integrated circuit differential amplifier

T Thermistors, ~ 2000 ohms at room temperature (Fenwall GB32J2)

R Fixed resistors are 1/4 or 1/10 watt unless otherwise indicated; resistors R_2 through R_7 need not be high precision, but should be fairly well matched so that R_2/R_5 = R_3/R_4, etc. Values depend on gain desired. R_1, R_9, and R_{30} are miniature pots: R_1 = bridge balance (zero set), R_9 = threshold, R_{30} = volume.

FIGURE 1

the flask--our way is shown in Fig. 2. The sensitivity turned out to be a little different for Up and Down--the more sensitive branch was chosen for Up. Very little difference in output was noted for a total bridge current of 30, 40, or 50 ma; however, with 20 ma, sensitivity was definitely less. Of course if you already have an electronic variometer, it should be a simple matter to get the necessary signal from its meter circuit and not worry about thermistor mounting at all.

At bridge balance (zero sink), the output of the first differential amplifier is around 6 volts. The ratio of the resistors R_4/R_3 (= R_5/R_2) is chosen to get this full-scale output. For our thermistor bridge and a one-pint flask the values shown gave full output (± 6 volts) at about ± 1500 (or ± 500) fpm. The gain of the differential amplifier is R_4/R_3 so the bridge can be checked out and the range and R_2 and R_7 determined by using a milliammeter or millivoltmeter across the bridge output. (For our bridge, 1500 fpm corresponds to about 1 ma or 300 mv.)

The output voltage of this first operational amplifier is a linear function of the bridge output. In circuits of this kind, the closed loop gain of an amplifier is a function of ratios of passive elements (resistors) and is unaffected by drift in open-loop gain, supply voltages, etc. The second op amp, in conjunction with Q_1, Q_2, Q_3, and Q_4 is a voltage-to-frequency converter. The action is as follows: The op amp acts as

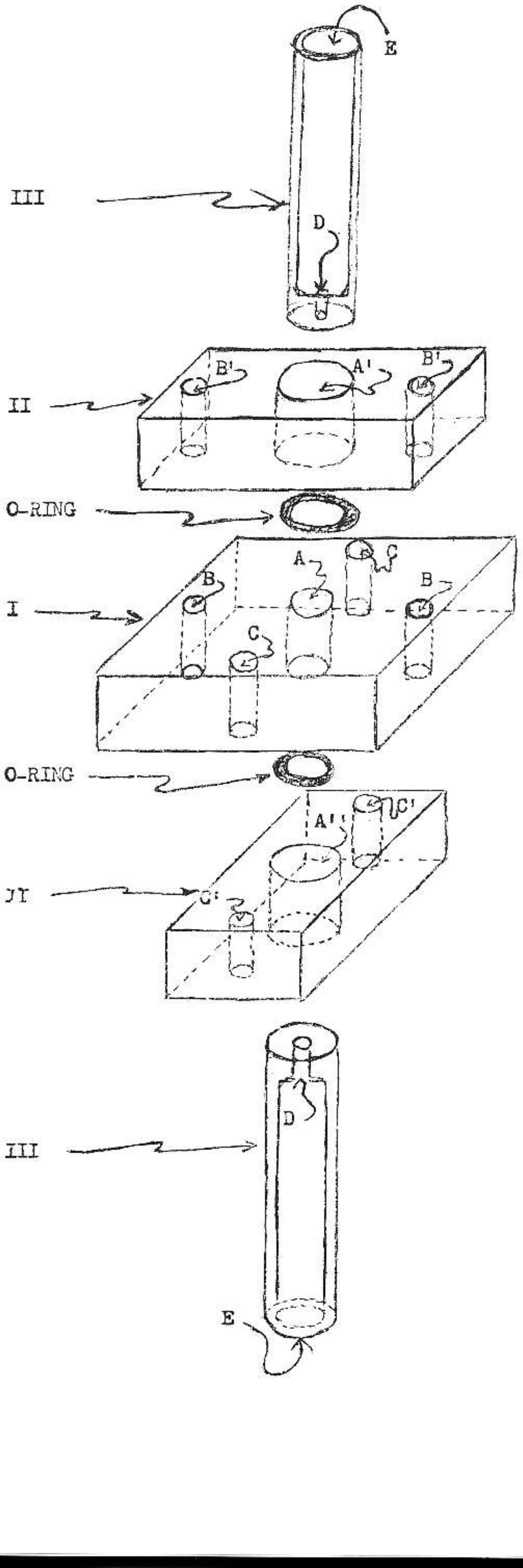


FIGURE 2

Sketch of thermistor mounting.

I. Lucite, ¼-in. thick x 1-in. square with hole A, 1/8-in diameter in center, concentric with holes A′ and A″, and nozzles D. II. Two ¼-in Lucite, ½ in. x 1 in. (assembled perpendicularly on opposite sides of I); holes A′ and A″ threaded (¼ in.-20) to accept tubes III; holes B′ and C′ line up with B and C, respectively; the three blocks held together with 4-40 screws (through holes B, B′ and C, C′); thermistor connections made to the 4-40 screws. III. Inlet/outlet tubes, ¼-in. diameter x 1-in. length, threaded (¼-20) to fit into A′ and A″; air-tight seal between parts I and III by the ¼-in. O-rings; nozzles D, 1/32-in. diameter x 1/8-in. long; opposite ends (holes E) connect to capacity and static. One thermistor has leads to screws through holes C/C′ of top side of I; other thermistor on bottom side of I with leads to screws through holes B/B′. Thermistors positioned, by leads, in Hole A, about 1/8 in. apart, centered under nozzles D; leads are pressed (sealed) between O-rings and part I; positioning of thermistors directly in line with nozzles D is important for fast and symmetric response; best to get them positioned properly before compressing O-rings (by tightening of screws through holes B and C); alignment can be checked somewhat by looking into hole E, through nozzle D--can see only black if aligned; should also be checked in the bridge circuit using a calibrated air flow (another vario or a 0-50 cc/min flow meter) which can be generated by siphoning water from a bottle.

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voltage comparator, comparing the output of the first op amp (point B on the schematic) with the reference voltage from R_9 (point A). Assume that V_B is less than V_A and Q_1 is cut off. Now, as climb is begun V_B will begin to increase as C_1 is charged through R_{11}. As soon as V_B exceeds V_A, the output of the comparator abruptly switches from low to high. This triggers the one shot (Q_2, Q_3, Q_4) which fires for a period determined by R_{26} and C_3. During this period Q_1 is turned on (saturated) and the voltage at its collector is very low. So C_1 begins to discharge through R_{17} and Q_1, and as soon as V_B falls below V_A, the comparator output goes low again. As soon as the one-shot period is over, Q_1 turns off again and C_1 begins to charge up again.

Since the average current into C_1 is proportional to rate of climb, and the average current out is proportional to the "on" time of the one shot (constant) times the repetition rate, the repetition rate is a function of rate of climb. (Incidently, the click rate is not quite linear below about 50 fpm.) When the duty cycle of the one shot tries to exceed about 60 percent, it will bog down and the apparent audio frequency will actually decrease. This consideration has some effect on the choice of R_{11} and C_1. These two components also pretty much determine the maximum pitch--with the values shown we get around 1000 Hz at 1000 fpm, but suit your own ear.

The voltage splitting, which allowed the use of the normal sailplane batteries, was accomplished with the zener diode circuit shown at the top-center of the figure. In addition to its providing the intermediate voltage required, it also dictates very stable operation; that is, response fairly independent of the batteries going from 15 volts down to less than 12 volts or so. Most of the current being drawn when there is no output signal (exclusive of the bridge current) is consumed in the zener diode circuit. Total current from the batteries is about 60 ma in sink to around 100 ma in a boomer with the volume all the way up (which is pretty loud). Several of the capacitors are obviously for the purpose of preventing interference when the mike button is pressed.

The unit can be packaged in various ways--our particular installation occupies 1 in. x 3½ in. of panel space. The electronics, assembled on a piece of perforated plastic circuit board, exclusive of the thermistor mount, would fit in a brown paper bag about 1-in. thick, 4-in. wide, and 6-in. long. The speaker--a 2-in. transistor radio type--was mounted in a typewriter-ribbon box behind the cockpit. The panel includes three ½-in. diameter pots (zero set, threshold, volume), two switches (on-off and range), and a 5/8-in. x 3/4-in. zero-center microammeter. About all the meter is used for is setting the zero before take off, and actually is not very useful; in-flight settings are made readily by sound, reference to the PZL, and little white dots on the control knobs.

The circuitry, number of electronic components, etc., could no doubt be varied and simplified. For example, the threshold pot could be eliminated and threshold set with the zero pot, probably; and the two ranges are also probably unnecessary. But this is the way we happened to put it together. It works and we like having it on the panel, and will probably keep flying it until the brown paper bag and scotch tape gives out.