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U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
Environmental Research Laboratories

The NOAA Optical System for Measuring Average Wind

G.R. OCHS
G.F. MILLER

Wave
Propagation
Laboratory
BOULDER, COLORADO

July 1973

ENVIRONMENTAL RESEARCH LABORATORIES

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Wave Propagation Laboratory
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THE NOAA OPTICAL SYSTEM FOR MEASURING AVERAGE WIND

G. R. Ochs and G. F. Miller

The NOAA optical system for measuring average wind is described. Circuit diagrams and adjustment instructions for the instrument are included.

1. INTRODUCTION

The instrument, consisting of the optical receiver and wind computer shown in figure 1, is designed to measure the spatially averaged transverse component of the wind, averaged over an optical path to a laser transmitter. This is accomplished by analysis of the motion of various spatial wavelengths in the scintillating light pattern received from a helium-neon laser. The principle is discussed in detail by Lawrence et al. (1972). The instrument is a somewhat modified version from the one they described, since we correlate the difference of intensity fluctuations between two pairs of photodiode receivers, rather than correlate log-intensity fluctuations in two receivers. This modification has important advantages over the previous technique in that fluctuations in the light source have little effect upon the operation, and less error occurs when optical scintillation approaches the saturated condition. The use of intensity fluctuations results in a variation in the wind calibration with C_N, but this effect is almost entirely eliminated if the sensors are separated 0.3 of a Fresnel zone for the path length used. This separation also gives the most nearly uniform path averaging of the wind and is set up automatically when the path length adjustment is made at the receivers.

2. SPECIFICATIONS

Path length: 0.3 to 10 km with 4 mW helium-neon laser source.

Full scale: 0 to ±5, 10, or 20 m/sec (range may be extended).

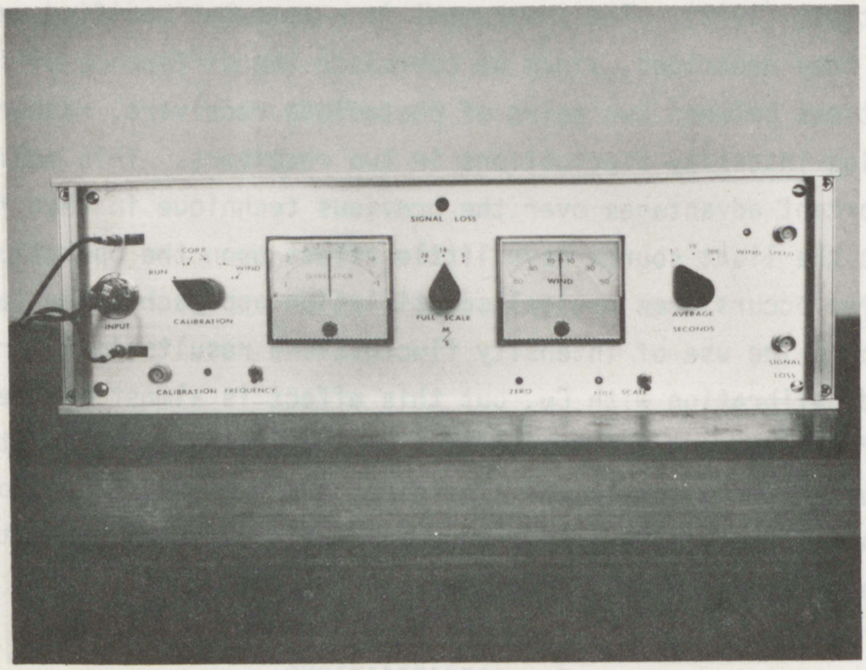


Figure 1. NOAA optical system for average wind measurement.

Accuracy: better than ±5% of full scale under average conditions on horizontal paths. Log-amplitude variance of the received signal not to exceed 0.3.

A helium-neon laser light source is required, arranged to simulate a point light source. A single-mode laser with no optics satisfies this condition. A beam with this little divergence may not stay pointed at the receiver, however, because of variations in the vertical temperature gradient of the atmosphere. A 2 to 3 diopter negative cylindrical lens placed in front of the laser will diverge the beam enough to eliminate this problem. Collimating optics may be used in front of the laser as long as a virtual point source is formed less than 0.2 of Fresnel zone in diameter for the path length used.

3. CALIBRATION AND USE OF THE INSTRUMENT

The calibration of the instrument is a function of optical path length and the two adjustments required may be made as follows. (1) To set the receiver unit for the desired path length, adjust the knurled knob at the back of the receiver. (2) To calibrate the wind computer unit, connect a counter to the output above cal freq. Set full scale for 10 m/sec. The calibrating frequency f_c equivalent to a 10 m/sec wind is

$$f_c = 322 L^{-\frac{1}{2}} , \qquad (1)$$

where L is the path length in kilometers. Adjust the cal freq to this value. By switching the cal knob between the two wind positions, and adjusting the zero and full-scale adjustment on the panel, set the wind meter to full scale + and -. Located next to this output is an independent gain adjustment for the wind signal output voltage. This completes the calibration for a given path length.

A different set of full-scale settings may be arranged by altering the constant in (1). For example if full-scale settings of 0.5, 1.0, and 2.0 m/sec are desired, rewrite (1) as

$$f_{c\ 1m} = 32.2 L^{-\frac{1}{2}}$$

and then calibrate as before.

The above calibration procedure is based upon the equations contained in Lawrence et al. (1972). The first adjustment changes the effective size and spacing of the receiver apertures and is calibrated to provide the most uniform path weighting function for the path length selected, i.e., $0.3\sqrt{\lambda L}$ spacing. The second adjustment uses calibrating signals, consisting of two square waves in phase quadrature, to provide the system with signals that have a known slope of covariance at zero delay. The required slope is based upon the slope-wind relationship, which holds for spherical wave propagation.

The time span over which the slope of the covariance function is measured has been chosen to minimize zero and full-scale errors. Near zero wind speed, one must measure a small difference in large signals; here a larger time delay would improve the accuracy. Near full scale, the signal difference is larger; however, if the time delay is too large, the slope will be measured over such a large portion of the covariance function that it will not be a good approximation of the slope at zero delay. In fact, if the actual wind speed exceeds the selected full-scale wind speed by a factor of two or so, the system may give false on-scale wind readings.

Thus, for unattended operation, it is important that the full-scale wind speed adjustment be set at least as high as the highest expected total wind (not just the cross-path component) or false readings may result.

4. CIRCUITRY

Figure 2 is a block diagram of the system. Essentially the normalized covariance of the two difference signals is measured by the exclusive or circuits at three time relationships: one signal lagging, zero lag, and the other signal lagging. The difference between the two time-lagged covariance measurements is used as a measure of the slope of the function at zero delay. For circuit stability, the difference between the two time-lagged covariance measurements is not taken directly.

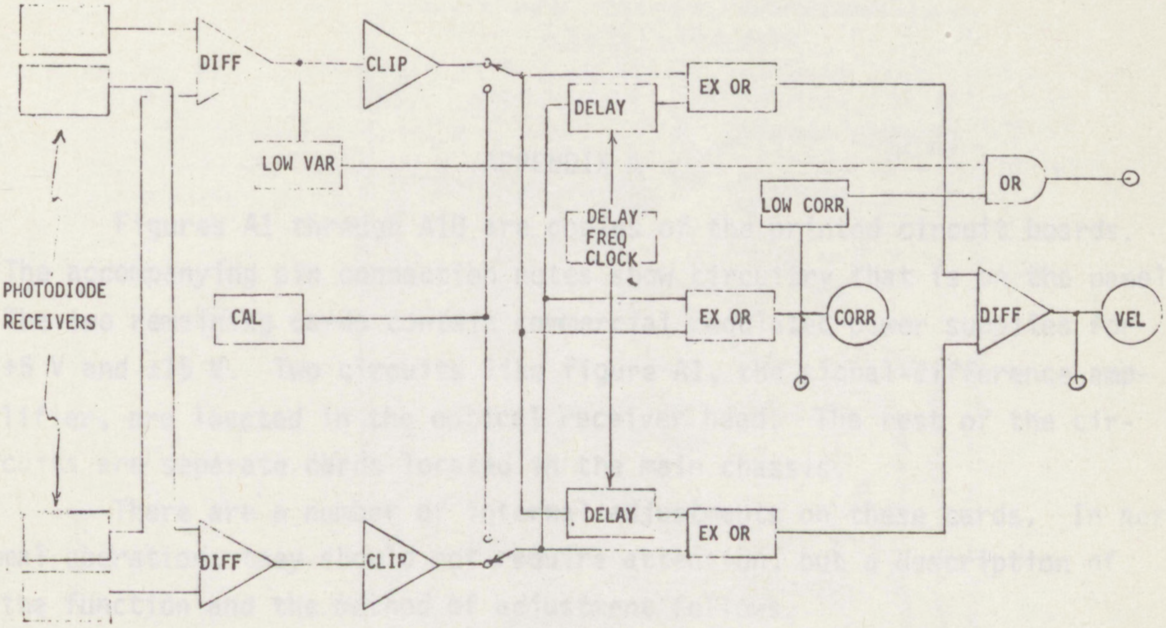


Figure 2. Block diagram of system.

Rather, an equivalent circuit is used in which the analog sum of one covariance and the digitally inverted second covariance are obtained.

Several features have been added to the circuit for operating convenience. A circuit may be switched in to provide signals with a known covariance slope at zero delay, so that the system can easily be calibrated. Two other circuits, low variance and low correlation detection, are provided so that the system can be operated unattended. If the laser fails or is obscured by weather, for example, the resulting low variance and/or low correlation will activate the signal loss output, indicating that the system is not operating.

5. REFERENCE

Lawrence, R. S., G. R. Ochs, and S. F. Clifford (1972): The use of scintillations to measure average wind across a light beam, *Appl. Opt.* 11(2):239-243.

APPENDIX A

Figures A1 through A10 are copies of the printed circuit boards. The accompanying pin connection notes show circuitry that is on the panel. The two remaining cards contain commercial regulated power supplies for +5 V and ±15 V. Two circuits like figure A1, the signal-difference amplifier, are located in the optical receiver head. The rest of the circuits are separate cards located in the main chassis.

There are a number of internal adjustments on these cards. In normal operation, they should not require attention, but a description of the function and the method of adjustment follows.

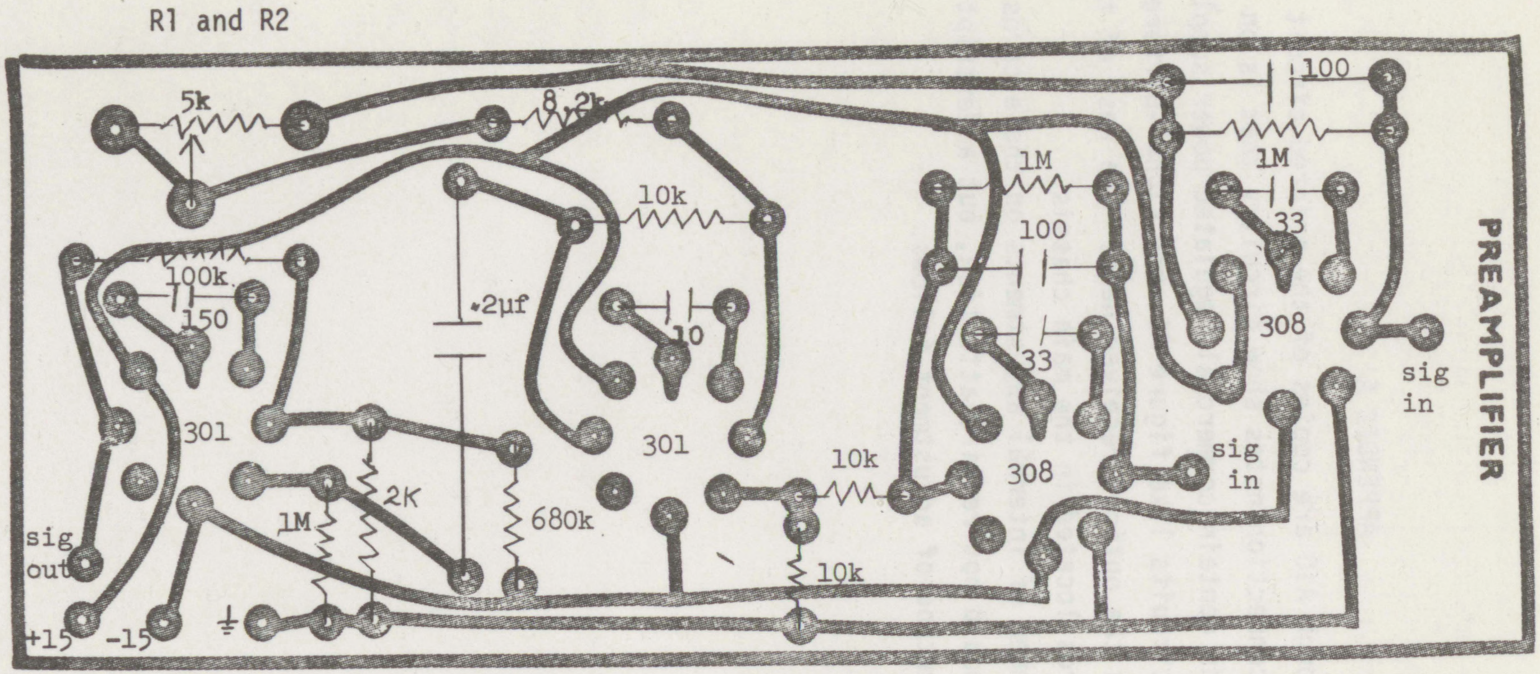


Figure A1. Signal difference amplifier. Two circuits required.

Adjustments for the signal difference amplifier (fig. A1):

R1 and R2--These equalize the amplifier gains to obtain zero difference for identical signal inputs. Disconnect the signal inputs to the wind computer, connect them to a scope, and adjust for minimum AC signal with the receivers pointed at a white card illuminated with a flourescent light.

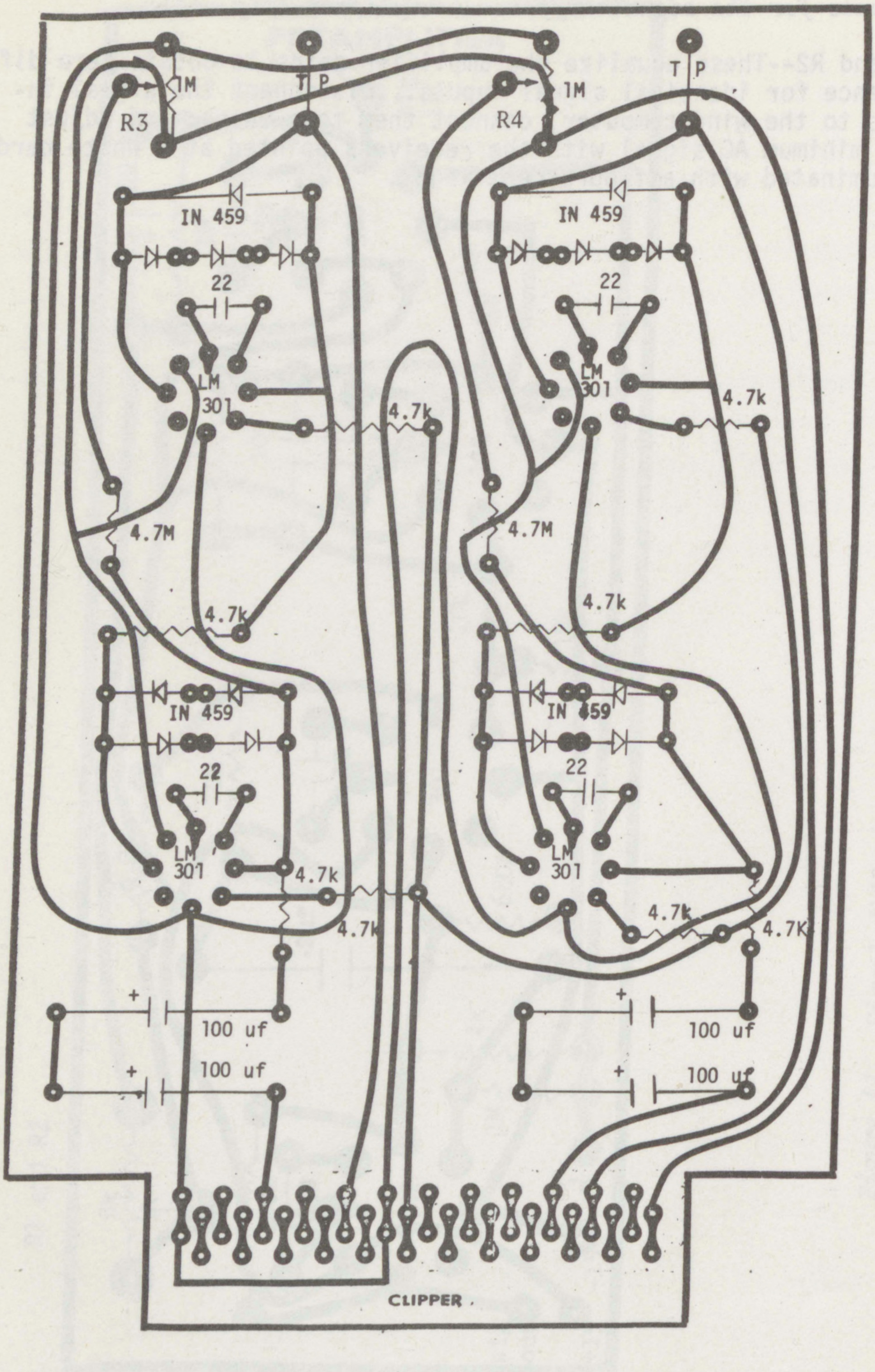


Figure A2. Clippers.

Pin notes for the clippers (fig. A2):

PIN 1	-15 V
PIN 5	input clipper 1
PIN 9	output clipper 1
PIN 12	ground
PIN 19	input clipper 2
PIN 21	output clipper 2
PIN 24	+15 V

Adjustments for the clippers (fig. A2):

R3 and R4--These set the zero clipper level. With receiver inputs unplugged, adjust until the test point voltage is just flipping between its two states.

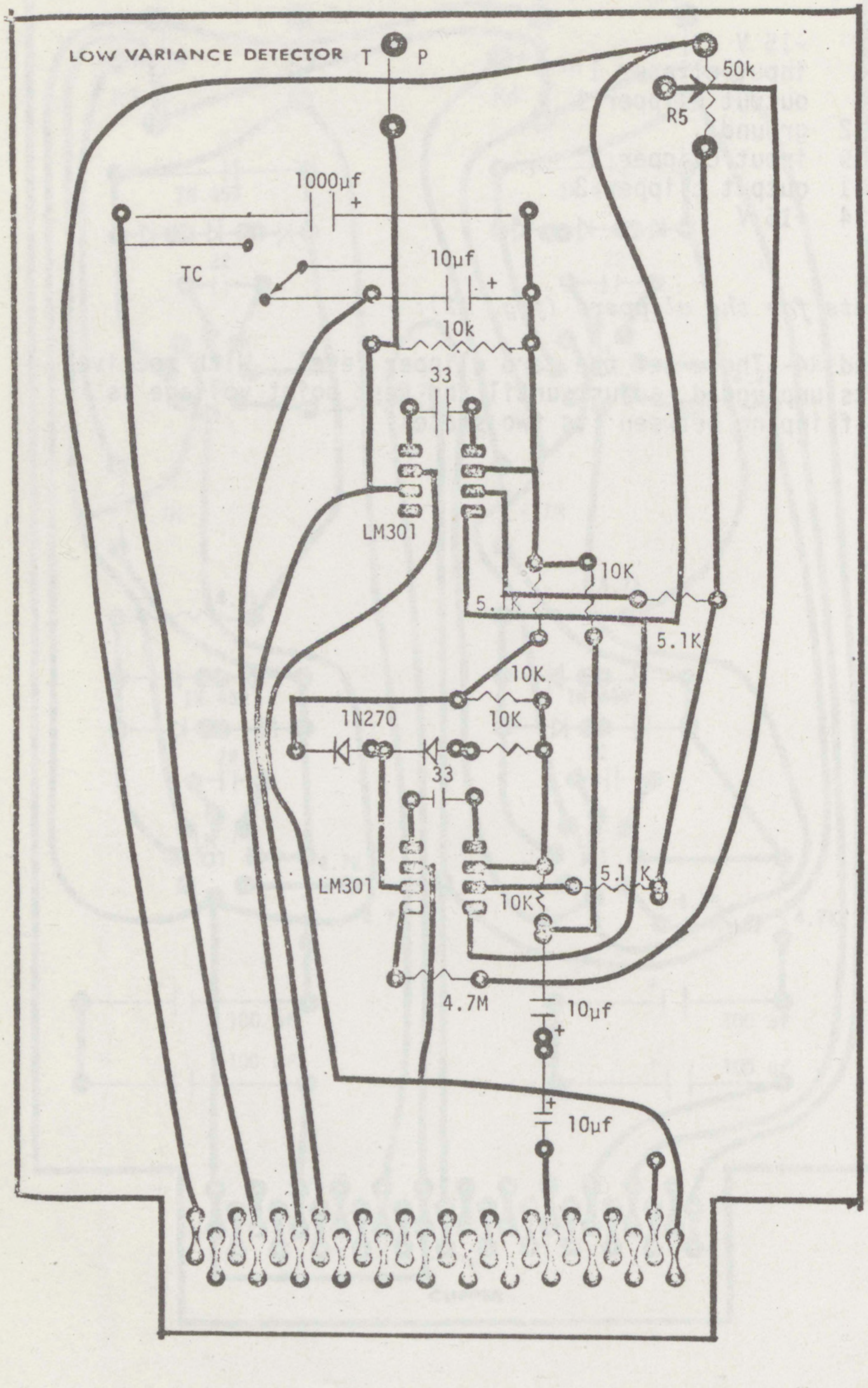


Figure A3. Low variance detector.

Pin notes for the low variance detector (fig. A3):

PIN 1	-15 V
PIN 4	to low variance toggle switch
PIN 6	to low variance toggle switch
PIN 7	output
PIN 18	input
PIN 23	ground
PIN 24	+15 V

Adjustments for the low variance detector (fig. A3):

R5--This is a zeroing adjustment for the associated operational amplifier and is not critical. Set by grounding pin 2 and adjusting for zero at pin 6. The switch on the card changes the time constant (100 or 1 sec of the low variance detector). For unattended operation on long paths, where precipitation may intermittently obscure the beam, chatter of the signal loss output will, of course, be less in the 100 sec position. Otherwise the short time constant should be used.

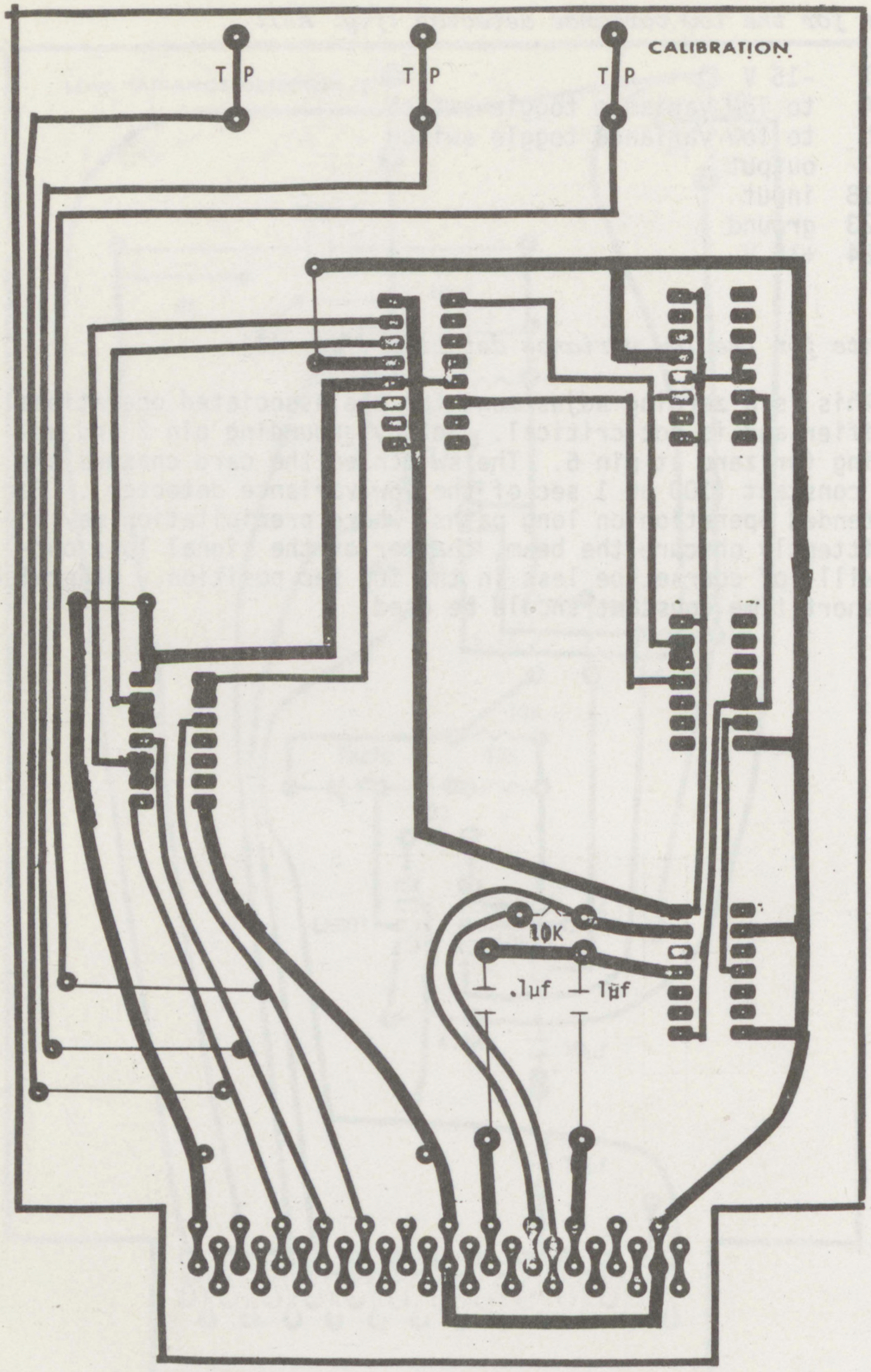
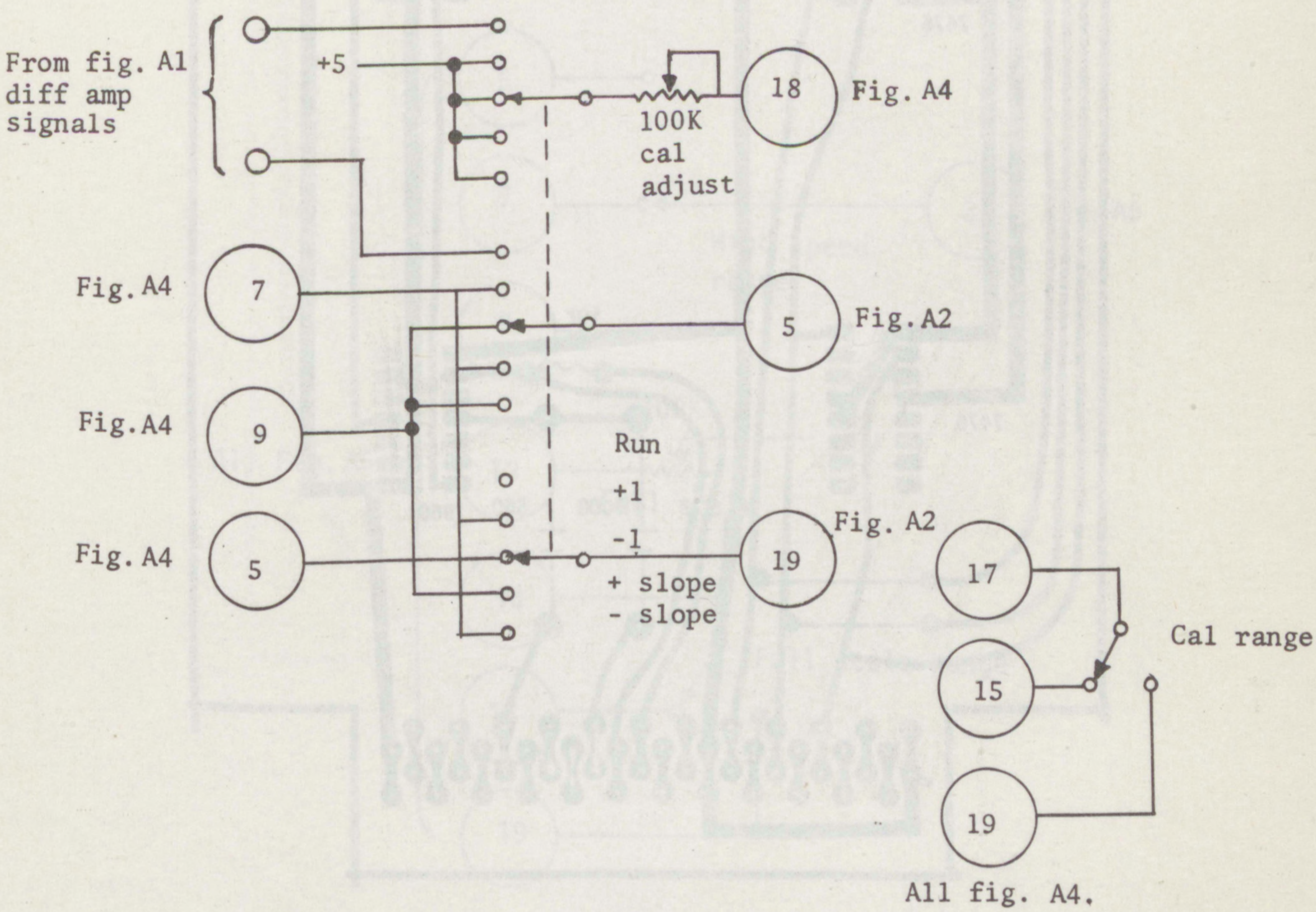


Figure A4. Calibration unit.

Pin notes for the calibration unit (fig. A4):

PIN 1	+5 V
PIN 5	calibration out
PIN 7	calibration out
PIN 9	calibration out
PIN 13	ground
PIN 15	to toggle switch
PIN 17	to toggle switch
PIN 18	to delay adjust pot
PIN 19	to toggle switch
PIN 23	ground



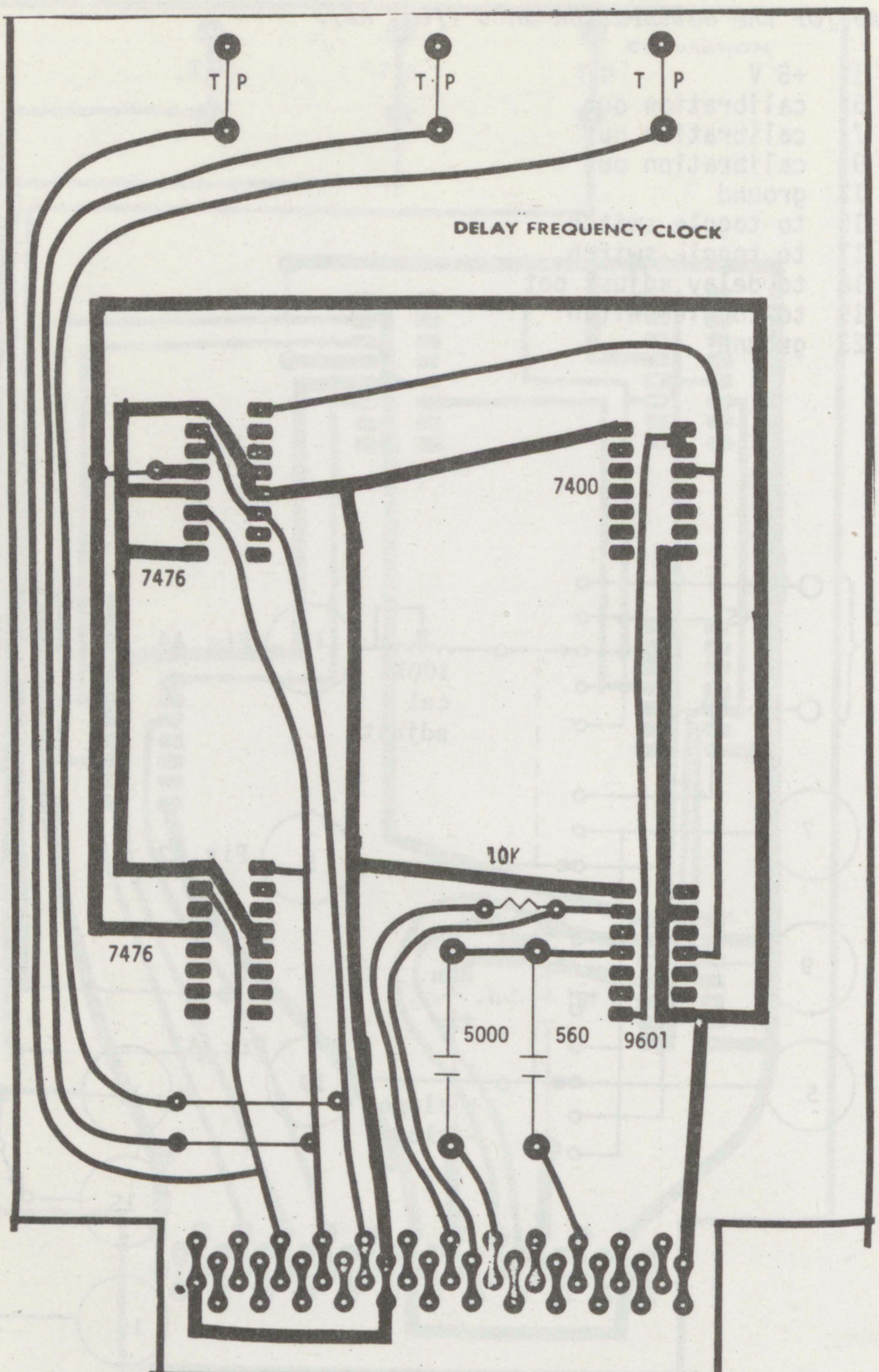
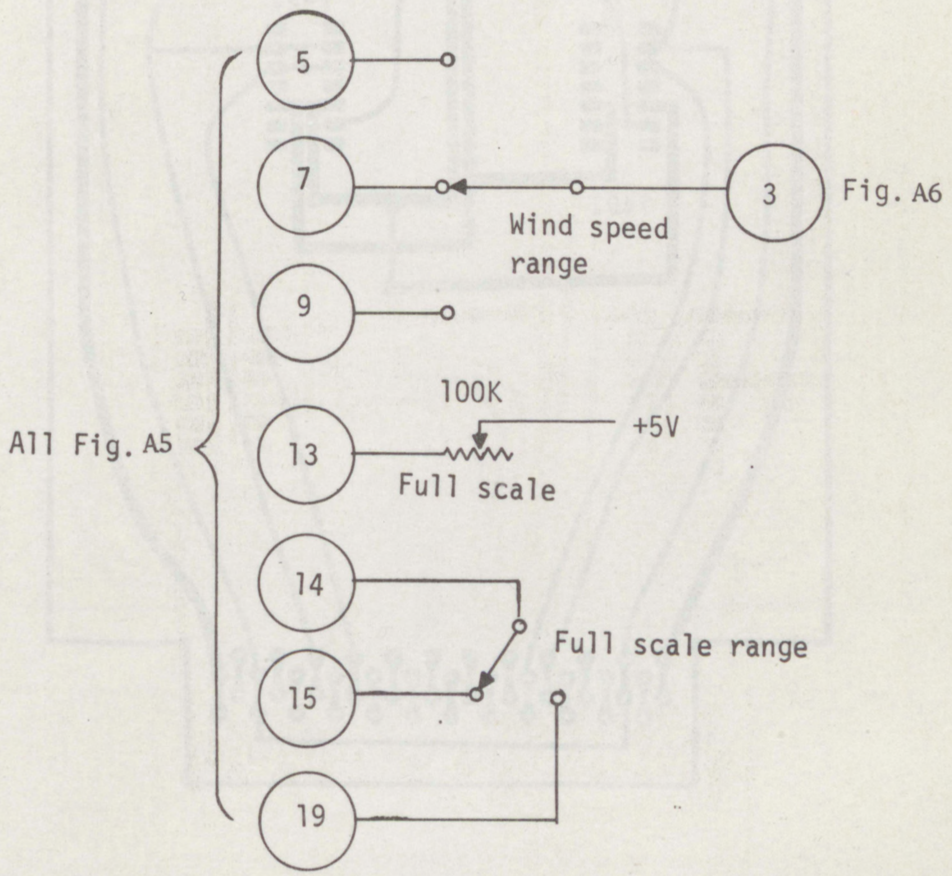


Figure A5. Delay frequency clock.

Pin notes for the delay frequency clock (fig. A5):

PIN 1	+5 V
PIN 5	× 4 output
PIN 7	× 2 output
PIN 9	× 1 output
PIN 10	+5 V
PIN 13	to frequency pot
PIN 14	to frequency switch
PIN 15	to frequency switch
PIN 19	to frequency switch
PIN 24	ground



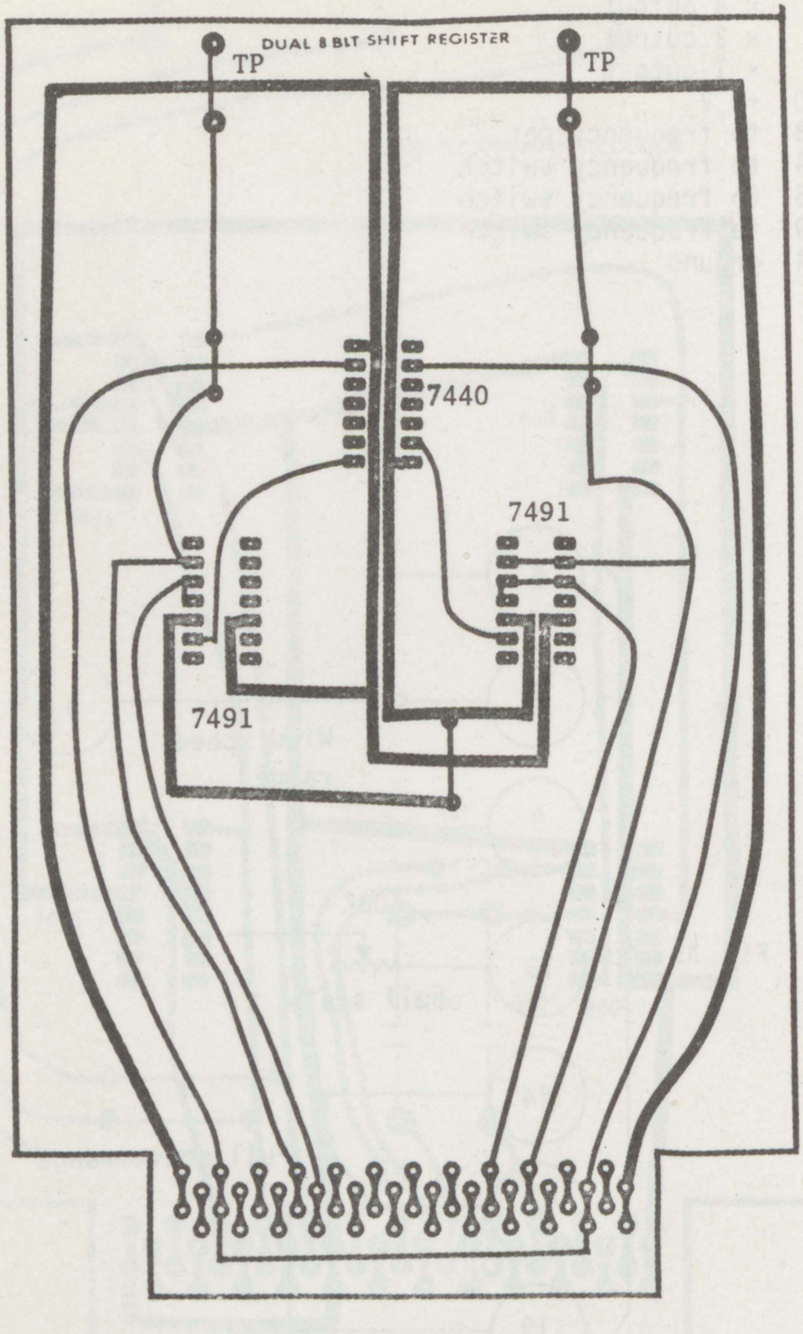


Figure A6. Dual eight-bit shift register.

Pin notes for the dual eight-bit shift register (fig. A6):

PIN 1	+5 V
PIN 3	clock input
PIN 7	shift register output
PIN 8	shift register input
PIN 17	shift register input
PIN 19	shift register output
PIN 20	clock input
PIN 24	ground

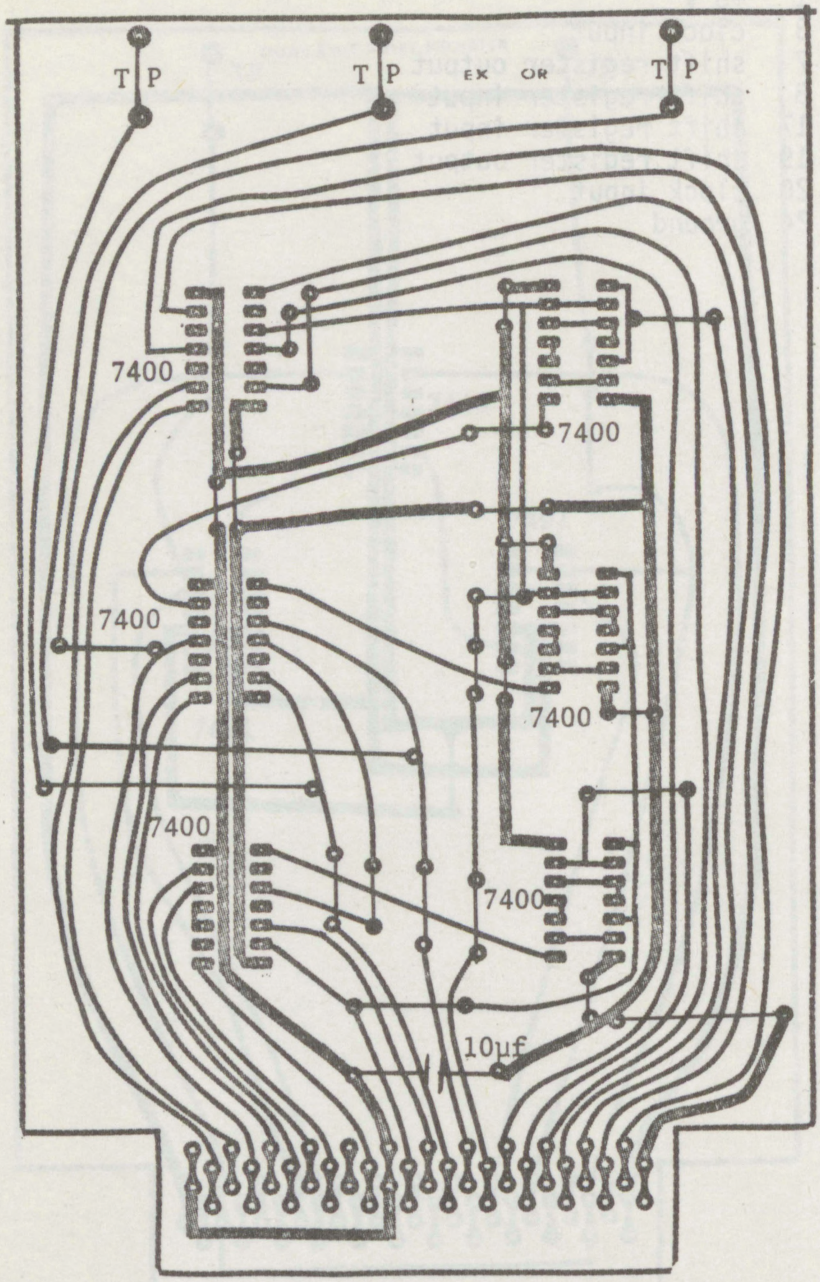


Figure A7. Exclusive or circuits.

Pin notes for the exclusive or circuits (fig. A7):

PIN 1	+5 V
PIN 2	Gate #5 input
PIN 3	Gate #5 output
PIN 4	exclusive or output
PIN 5	Gate #4 input
PIN 6	Gate #4 output
PIN 7	Gate #3 input
PIN 8	Gate #3 input
PIN 10	Gate #3 output
PIN 11	+5 V
PIN 12	output to shift register
PIN 13	exclusive or input
PIN 14	exclusive or output
PIN 15	exclusive or output
PIN 16	output to shift register
PIN 17	Gate #2 input
PIN 18	input from shift register
PIN 19	Gate #2 output
PIN 20	input from shift register
PIN 21	exclusive or input
PIN 22	Gate #1 input
PIN 23	Gate #1 output
PIN 24	ground

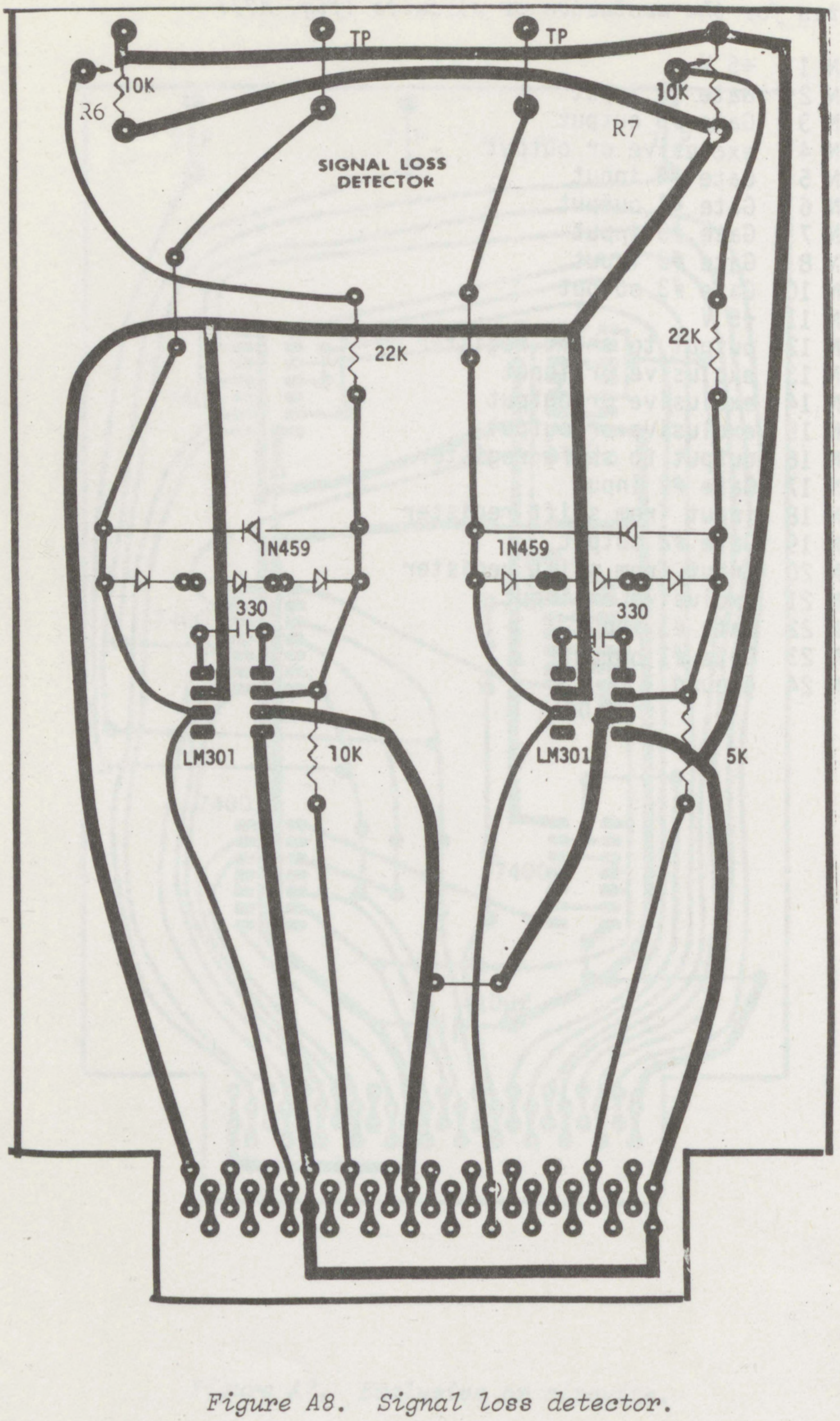


Figure A8. Signal loss detector.

Pin notes for the signal loss detector (fig. A8):

PIN 1	+15 V
PIN 6	output to Gate #3
PIN 7	-15 V
PIN 9	input from low variance detector
PIN 12	ground
PIN 16	output to Gate #3
PIN 20	input from zero delay amplifier
PIN 24	-15 V

Adjustments for the signal loss detector (fig. A8):

R6 and R7--These set the levels at which low variance and low correlation, respectively, signal the loss of the light source. The exact settings depend somewhat on how the system is operated but the following adjustments will suffice in most cases. Set the calibration switch on the front panel to corr +. Adjust R6 so that with the lens caps on the receiver, the signal loss light just comes on and remains on. To adjust R7, set calibration switch to run, remove one lens cap, and point the receiver at an AC light source to get an adequate AC signal so that the low variance signal is off. Then by setting the system average (front panel) at, say, 10 sec, and flipping the calibration knob (front panel) between + and - corr, you can sweep the correlation through any desired value. Set R7 so that the signal loss light comes on when the correlation meter reads 0.4 or less.

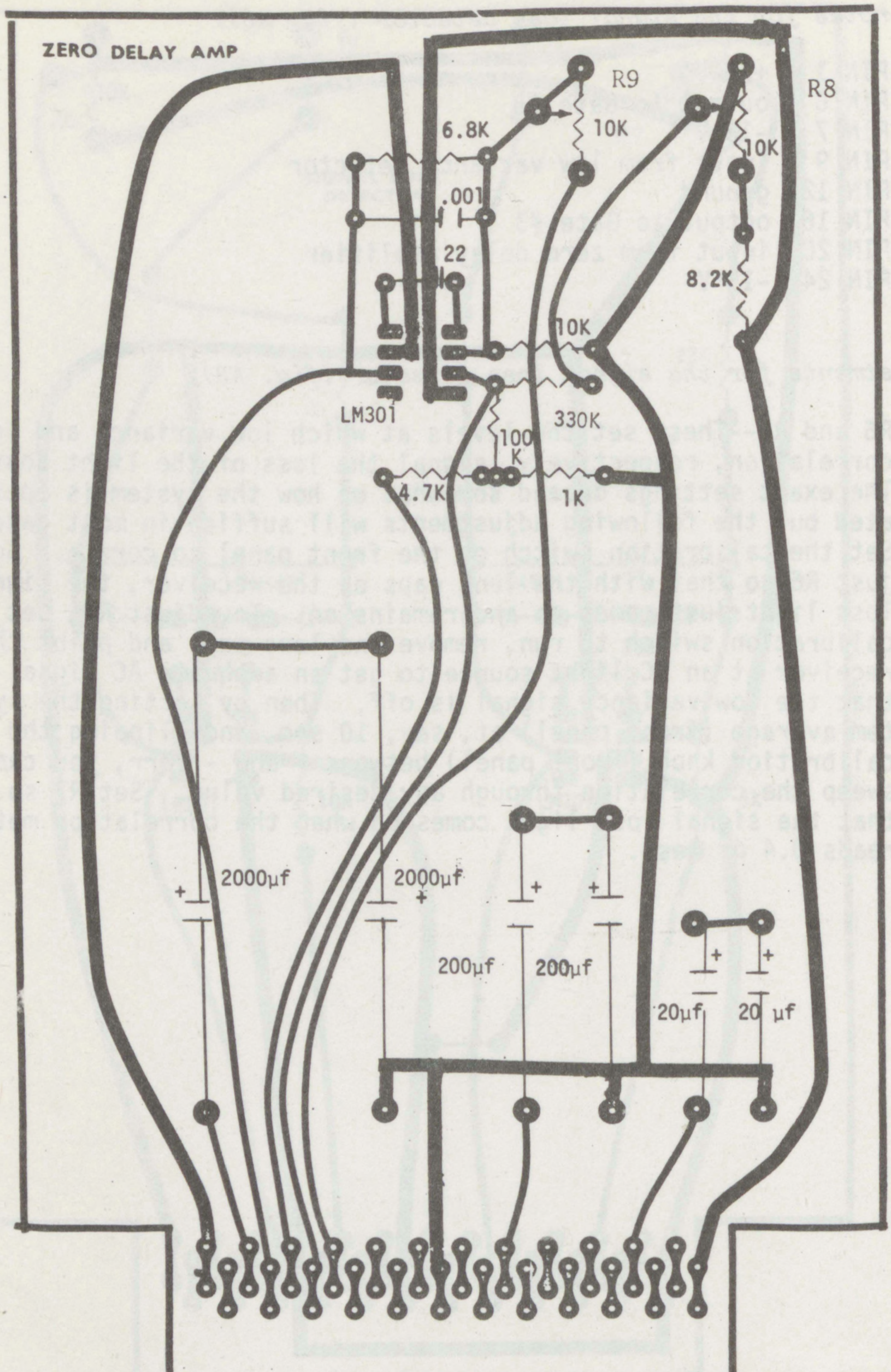


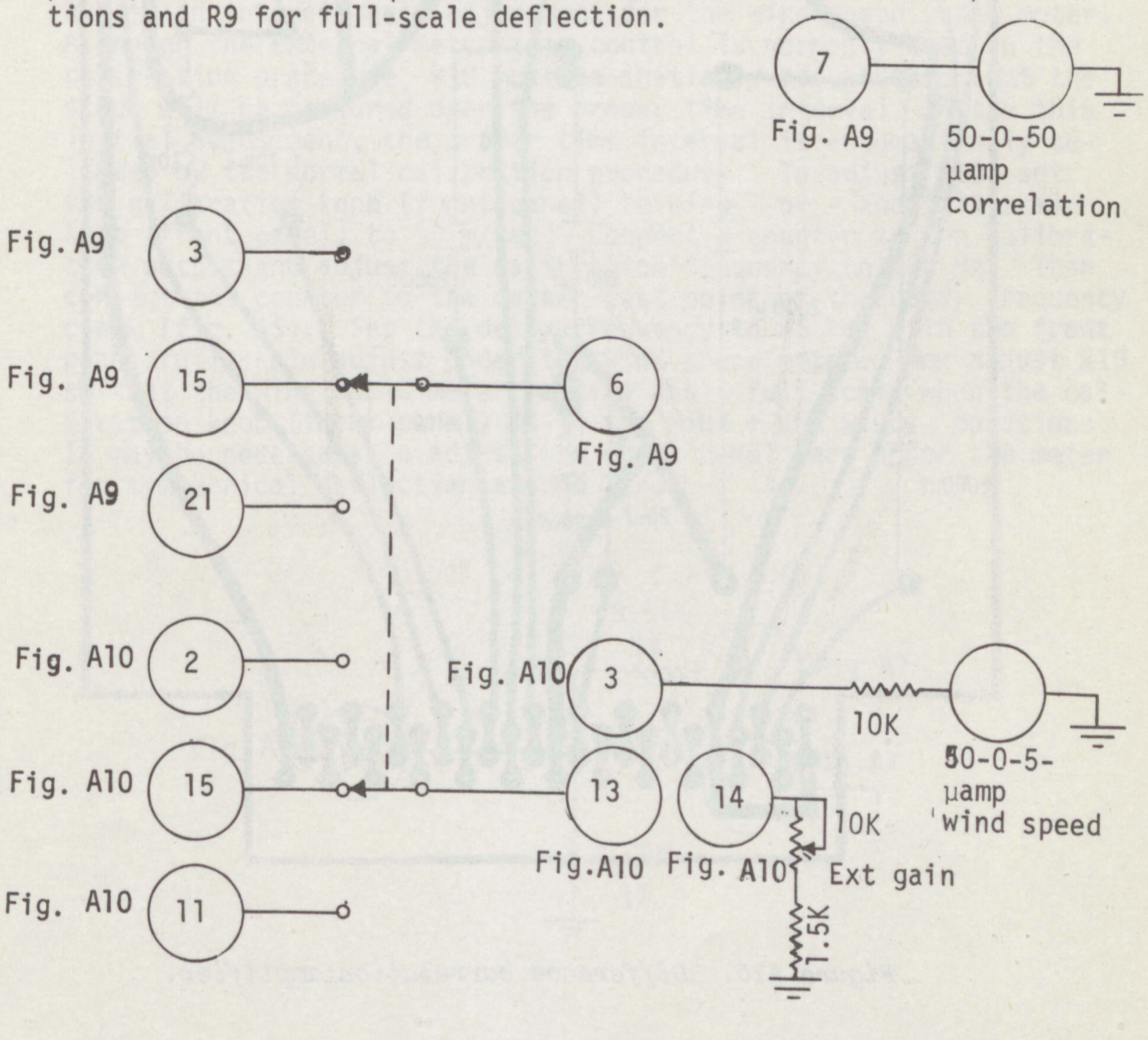
Figure A9. Zero delay correlation amplifier.

Pin notes for the zero delay correlation amplifier (fig. A9):

PIN 1	+15 V
PIN 3	to time constant switch
PIN 4	output
PIN 5	exclusive or input
PIN 6	to time constant switch
PIN 7	to meter
PIN 12	ground
PIN 15	to time constant switch
PIN 21	to time constant switch
PIN 24	-15 V

Adjustments for the zero delay correlation amplifier (fig. A9):

R8 and R9 are the zero and full-scale adjustments, respectively, for the correlation panel meter. They may be set by using the + and - correlation test positions of the calibration knob (front panel). Set R8 for equal meter deflection in the + and - positions and R9 for full-scale deflection.



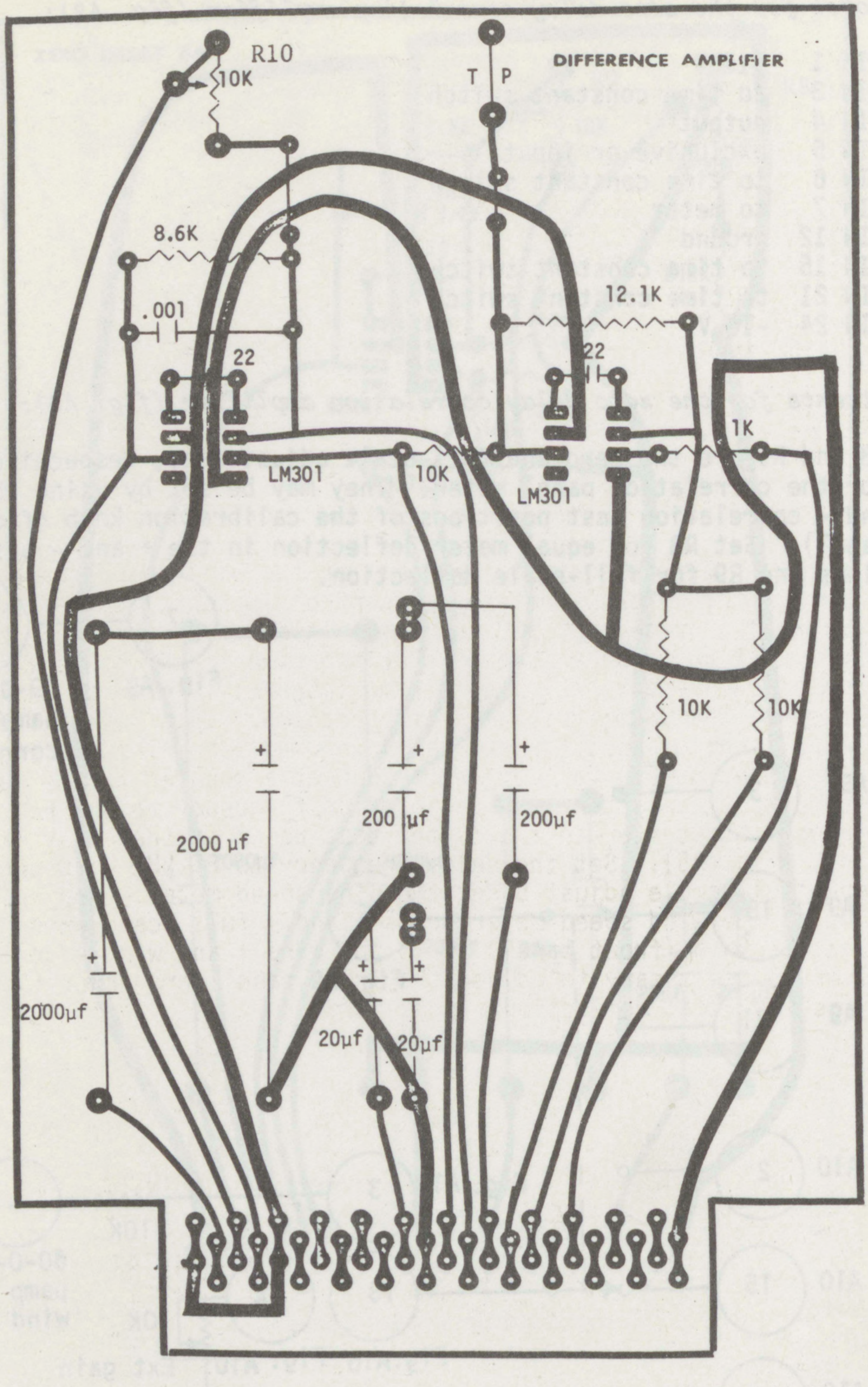


Figure A10. Difference correlation amplifier.

Pin notes for the difference correlation amplifier (fig. A10):

PIN 1	+15 V
PIN 2	to time constant switch
PIN 3	to meter
PIN 4	difference amp. output
PIN 5	+15 V
PIN 11	to time constant switch
PIN 12	ground
PIN 13	to time constant switch
PIN 14	to ext gain pot
PIN 15	to time constant switch
PIN 16	input
PIN 17	input
PIN 19	to 1K pot
PIN 24	-15 V

Adjustments for the difference correlation amplifier (fig. A10):

R10 is an internal gain adjustment for the wind speed panel meter. Although the external meter gain control is normally used in the calibration procedure, R10 must be initially adjusted so that the slope will be measured over the proper time interval. After this initial adjustment, the proper time interval is automatically selected by the normal calibration procedure. To adjust R10, set the calibration knob (front panel) to wind + or - and full-scale knob (front panel) to 10 m/sec. Connect a counter to the calibration output and adjust the calibration frequency to 300 Hz. Then connect the counter to the center test point of the delay frequency clock (fig. A5). Set the delay frequency to 65 kHz with the front panel full-scale adjust under the wind speed meter. Now adjust R10 so that the wind speed meter reads + and - full scale when the calibration knob (front panel) is in the wind + and wind - positions. It may be necessary to adjust the front panel zero under the meter for symmetrical deflection around zero.