NOAA Technical Memorandum ERL WPL-53

A CROSSWIND MEASUREMENT MODULE FOR THE MODEL II OPTICAL C_n^2 INSTRUMENT

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NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION / Environmental Research Laboratories

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NOTICE

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ABSTRACT

This instruction book describes a crosswind measurement module which attaches directly to the Model II Optical C_n^2 instrument. Operating instructions, alignment procedures, and circuit diagrams are included.

1. INTRODUCTION

The optical C_n^2 instrument Model II, described in reference (1), has been designed to accept a module that computes the average wind speed at right angles to the optical path used by the C_n^2 instrument. When this module is in place (Figure 1), the wind speed is continuously read out as a voltage (± 3 volts full scale) at the BNC output jack on the module, or it can be displayed on the C_n^2 instrument panel.

The circuit employed in the crosswind measurement module is almost identical to that used in the Optical System Model III wind measurement system, described in reference (2), except for the calibration frequencies, which must be changed due to the different size and spacing of the receiver, and some changes made so that the system can be used as a separate plug-in module. Reference (2) also contains a discussion of the wind measurement technique and the circuit that directly applies to the wind measurement module.

2. OPERATING PROCEDURE

The wind measurement module is attached by latches to the bottom of the C_n^2 instrument and the electrical connections are made through the front panel

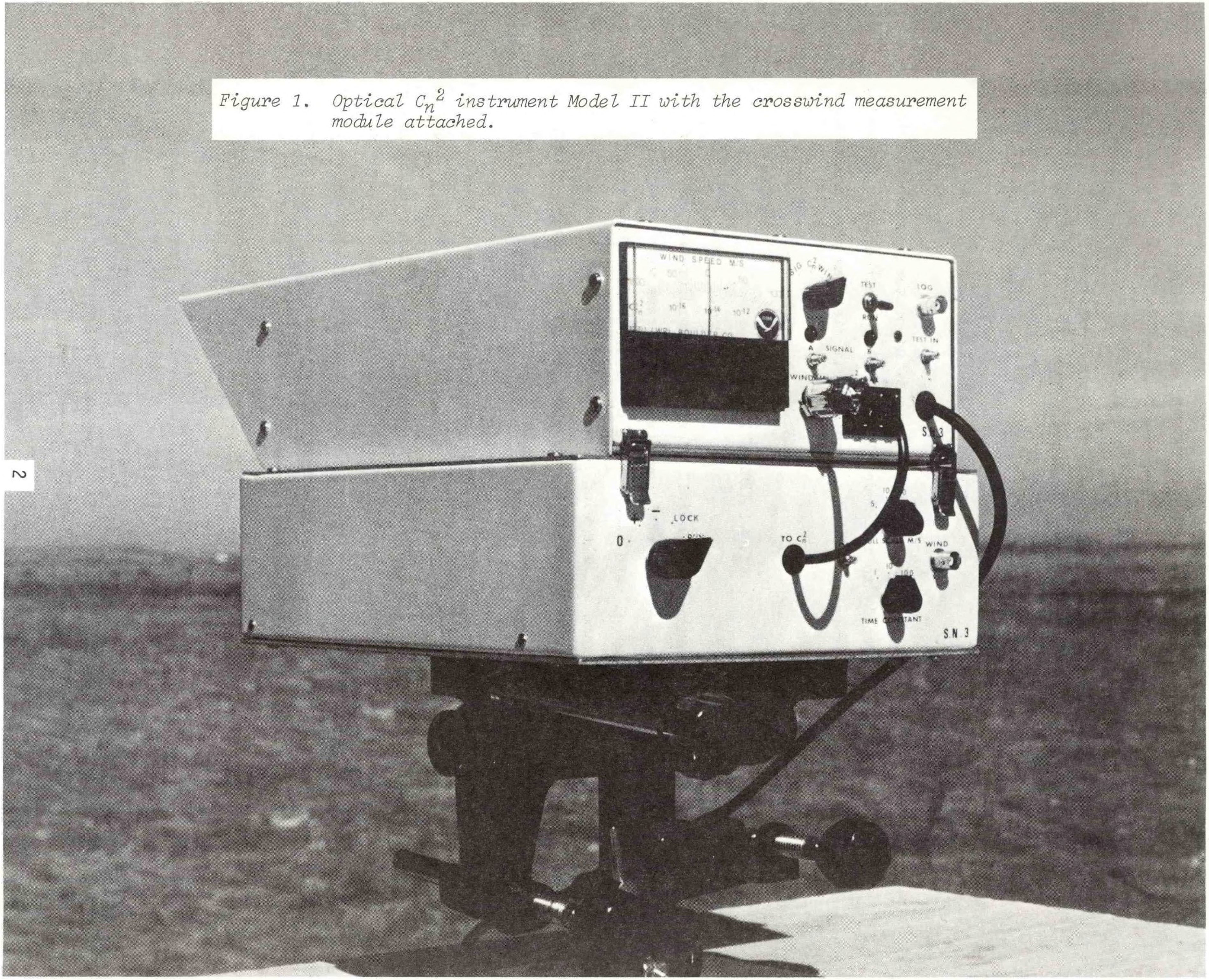


Figure 1. Optical C_n^2 instrument Model II with the crosswind measurement module attached.

connector. When attached, crosswind speed will appear on the meter when the meter selector switch is in the WIND position. The front panel controls on the wind measurement module function as follows:

FUNCTION SWITCH - This switch displays various functions on the panel meter when the meter selector switch on the C_n^2 instrument is in the wind position, and also controls other operation as indicated.

0,+,- - These positions (zero, +full scale, -full scale) serve as calibration points for circuit alignment and for wind signal recording convenience. At the WIND BNC the output for $\pm$ full scale is $\pm$ 3.0 volts.

LOCK - In this position, the meter reads a relative indication (0 to full scale) of the signal available for wind measurement. The polarity of the signal indicates the wind crossing direction. If the reading is zero or fluctuates + and - around zero, the wind is directly down the optical path, the servo system has not yet locked on, or there is insufficient signal-to-noise to operate.

RUN - The normal operating position with the panel meter indicating crosswind speed. When the meter is to the right of zero (or + output at the WIND BNC), the wind is crossing from left to right.

FULL SCALE M/S - This control sets the full scale reading for both the front panel meter and the WIND BNC output.

LOCK - The lock voltage is available on the panel for test purposes.

TIME CONSTANT - The wind measurement can be averaged over 1, 10, or 100 second periods. Generally, the 1 second position is used for testing, with 10 or 100 second averaging used in operation.

3. CIRCUITRY

A block diagram of the wind module is shown in Figure 2. The demodulated signals from the C_n^2 instrument are conditioned by a highpass filter, precision clipped, and then passed through a digital lowpass filter to the shift registers.

In operation, the shift registers delay the incoming signals so that one signal is delayed with both positive and negative time lags relative to the other signal. We use exclusive-or circuits to obtain the normalized covariance at 14 time lags on the covariance function. These 14 signals (a,b,c,d,e,f,g,h,i,j,k,l,m,n), biased as shown, are combined as (l+m+n)-(h+i+j+k)+(d+e+f+g)-(a+b+c). This summation will be positive if the time lags are short relative to the signal covariance and negative for time lags long compared to signal covariance. The signal is integrated, converted to a frequency proportional to the integrated signal, and used to clock the shift registers. If the polarity and time constants are properly arranged, the error voltage in this servo loop will change the shift register delay until the summation is zero. The shape of the covariance function will of course influence the delay for zero sum. This arrangement efficiently measures the mean frequency of the coherent portions of the signals, weighting most heavily the signals that are 90¼ out of phase. If the analog-to-frequency converter is linear, then its input voltage will be proportional to the mean frequency of the coherent portion of the signals. The circuit will very nearly obtain the frequency of the coherent portion of the signals at phase differences other than 90¼, tapering to zero weight for signals having a 0 or 180¼ phase relationship.

If the phase relationship of the input signals reverses sign, the sign of the servo voltage to the integrator must also be reversed. This information is obtained by summing (h+i+j+k+l+m+n)-(a+b+c+d+e+f+g). The sign of this sum is used to change the sign of the error voltage in the servo loop. It is also used to change the sign of the output. Thus the amplitude of the output voltage is proportional to the mean frequency of the coherent portion of the signals and its sign indicates whether input A or B is leading.

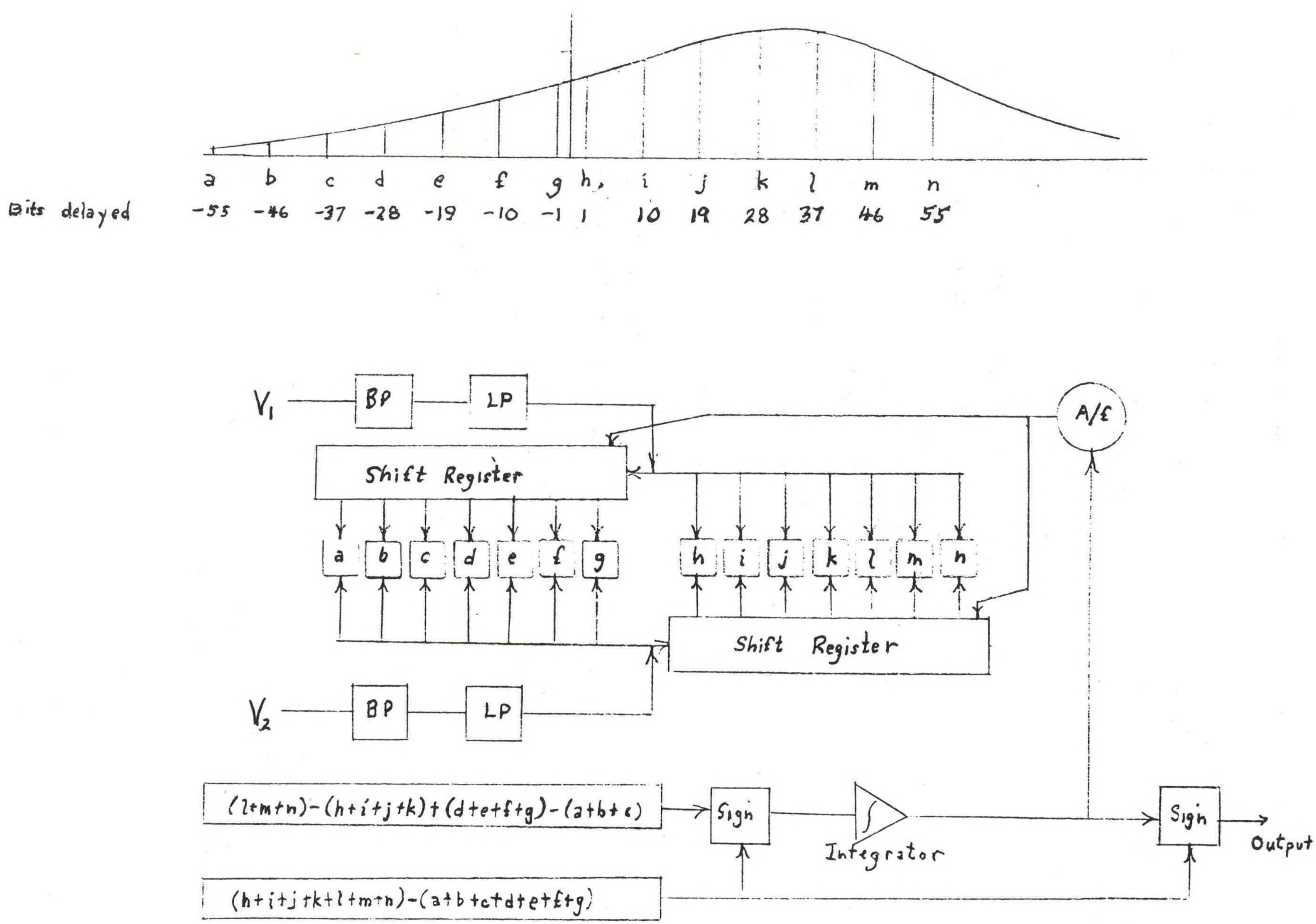


Figure 2. Block diagram of the crosswind measurement module.

Since the slope of the covariance function is proportional to the mean frequency, the measurement has characteristics similar to the slope technique. There are two important differences, however. A disadvantage is that for signals with zero average time delay, the answer is indeterminate; for the slope system it is definitely zero. An important advantage, however, is that incoherent noise present with the signals does not have a first order effect on the answer; for the slope system it certainly does.

The above discussion outlines the principles of operation, but of course the actual circuit design must consider such things as optimum servo time constants, servo capture problems, optimum shift-register frequency response, sign switching time constants, and also arrange for convenient calibration and scale switching. The circuit also incorporates various compromises dictated by experience. The resulting circuit is shown in Appendix A.

4. ALIGNMENT

This section discusses the procedures used for initial alignment of the circuit. They should not require adjustment in normal operation.

Refer to the Appendix for circuit diagrams and layout.

1. Remove the wind module from the C_n^2 instrument but leave the electrical connections plugged in.

2. Set panel controls as follows:
   - Function- RUN.
   - Time Constant- 1 second.
   - Full Scale- middle position.
   - Signal Input- grounded.

3. Remove the cover from the wind module.

4. Set pot L approximately to midscale. This step is necessary for the initial calibration only.

5. Adjust gain pot h and offset pot g for + and -3.00 volts at the wind output, with the function switch in CAL + and -, respectively. This can be done by adjusting gain pot h for a 6 volt difference between the CAL + and - positions, and then adjusting offset pot g to obtain +3.00 and -3.00 volts in the respective CAL + and - positions.

6. With the function switch in CAL + or -, adjust pot i for meter full scale.

7. With the function switch in CAL + or -, and the full scale switch set to each pot in turn, adjust pots j, k, l, and m for 4.92, 9.85, 19.7 and 39.4 kHz, respectively, at the clock TP.

8. Remove op amps A and G and apply a sine wave signal of about 2 kHz to pin 2 of both op amp sockets. This frequency will not get through the low pass digital filters so that nonchanging DC signal levels are applied to the following digital circuitry. Adjust pot e for full scale in the appropriate direction to keep the meter deflected right or left of zero during these adjustments. Set the full scale switch to the middle position. Turn the function switch momentarily to CAL and back to RUN so that the meter is neither zero nor full scale (right of center). Adjust pot d so that the meter drifts slowly toward zero (takes approximately 10 seconds to go from 50 to 40). It is very important that the drift tendency is toward zero, rather than full scale. Now adjust pot c in the same way for the left hand portion of the meter scale. Then repeat both adjustments as they may be slightly interactive.

9. Continue the 2 kHz sine wave to the inputs. With the function switch set to the 0 position, check for zero wind output and adjust pot g for zero if necessary.

10. Using the same inputs as used in 7, set the function switch to the zero position and adjust pot e for zero volts average at pin 6 of op amp EE.

11. Apply about 10 Hz sine wave signals, 90¼ out of phase, to the circuits. With the function switch set to LOCK, adjust pot f for full scale on the meter.

12. Replace op amps A and G. Cover the optical unit, and leave the unit on at least one minute. Adjust pots 2c and 2f so that the green panel LEDs are just flickering on and off. Then turn both pots 4 turns in the LED off direction.

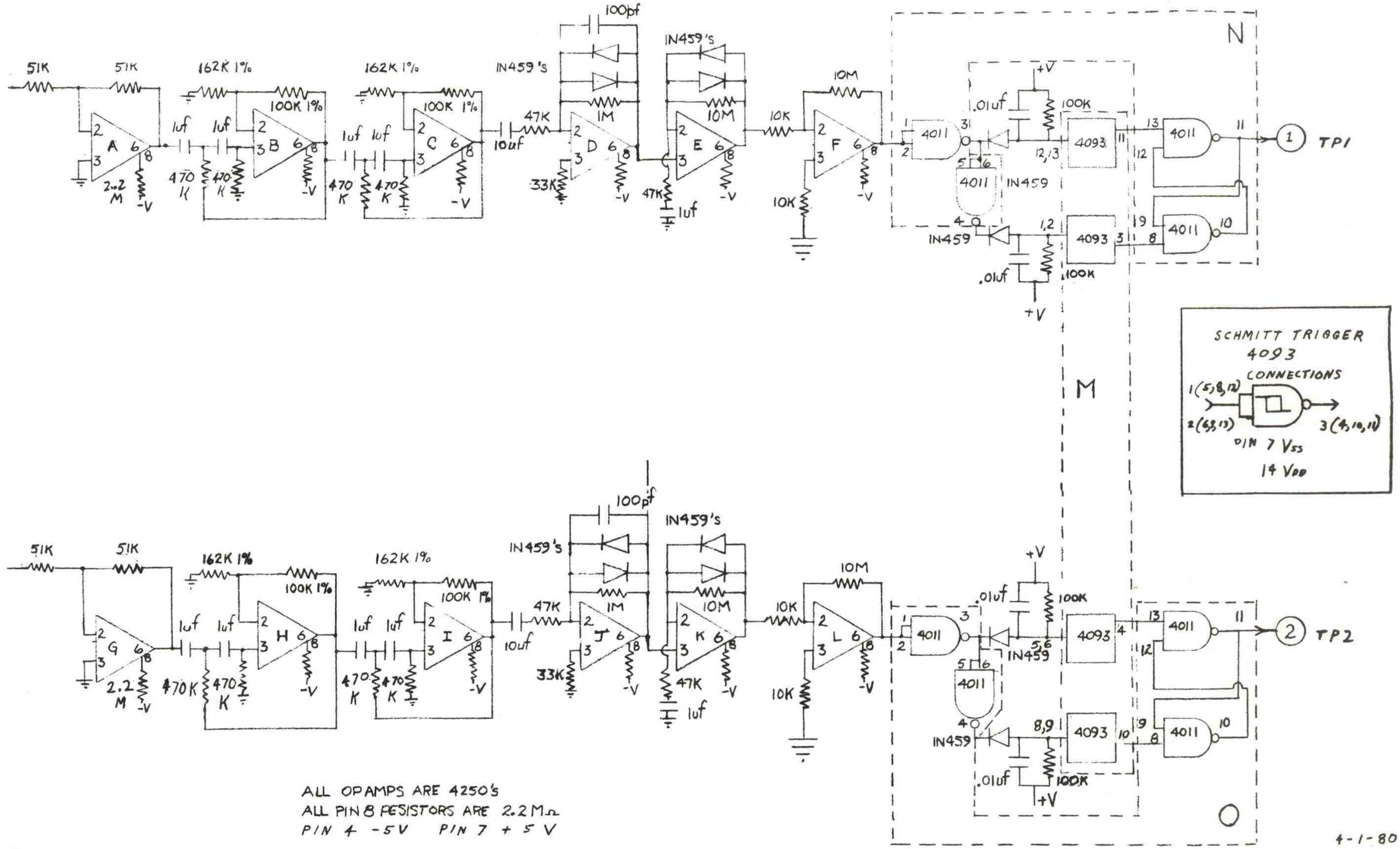
5. REFERENCES

1. Ochs, G. R., W. D. Cartwright, and D. D. Russell (1980): Optical C_n^2 instrument model II, NOAA Tech. Memo. ERL WPL-51.

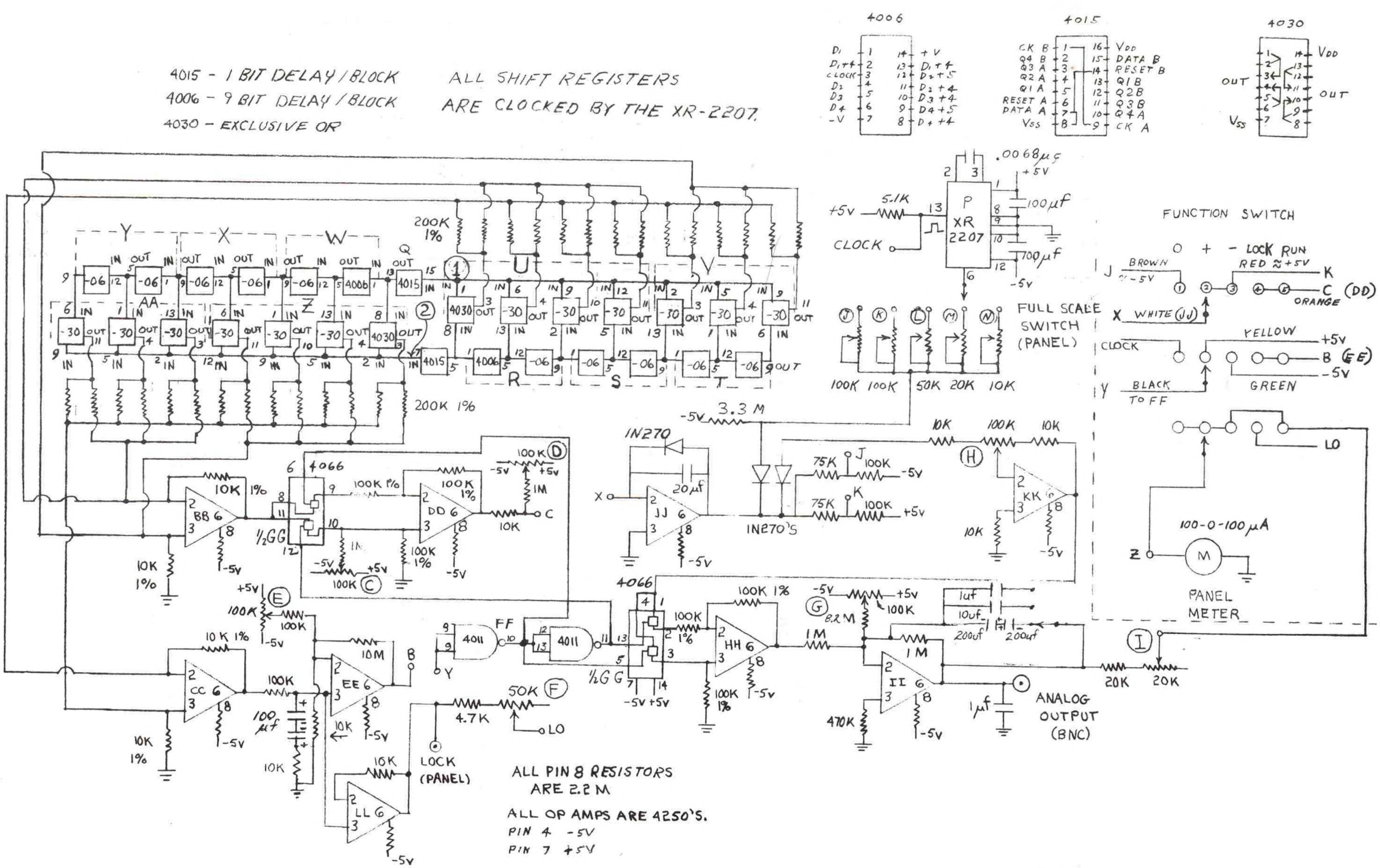
2. Ochs, G. R., W. D. Cartwright, and P. S. Endow (1979): Optical system model III for space-averaged wind measurements, NOAA Tech. Memo. ERL WPL-46.

APPENDIX A.

CIRCUIT DIAGRAMS AND LAYOUT



Crosswind measurement module circuit 1.



Crosswind measurement module circuit 2.

Covariance analyzer circuit board layout.