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DATA ACQUISITION CONTROL MODULE:
AN INTERFACE FOR THE EXOTECH
MODEL 20-C SPECTRORADIOMETER

Designed and Constructed by

Robert D. Haselby

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Introduction

The Data Acquisition Control Module was designed to fulfill two basic needs concerning the interface of the Exotech Model 20-C Spectroradiometer with the data recording system. The data recording system in its present form consists of an Ampex SP-300 analog instrumentation tape recorder. Since the data is to be digitized later, some method was sought to control this digitization process in a repeatable manner. The programmable counter accomplishes this task by generating a train of sample command pulses which are synchronized with the beginning of the rotating CVF (Circular Variable Filter) of the spectroradiometer. In this mode of operation the programmable counter gates pulses from the CVF encoder until the desired number of sample command pulses (1000 pulses per CVF revolution) is reached. These sample command pulses are recorded on one track of the analog tape recorder and are later used to control the sample time of the analog to digital converter. Thus, since the sample command pulses are synchronized with the beginning of the CVF wheel rotation, each sample command pulse in the train corresponds to a definite position on the CVF. This position relation is independent of CVF rotation speed. Determination of the CVF optical bandpass, which corresponds to a given pulse in the sample command pulse train, is the remaining function which the programmable counter was designed to facilitate.

Wavelength calibration of the Exotech, in light of the data recording method described above, consists of assigning a bandpass wavelength for each pulse in the sample command pulse train. The DELAY TRIGGER mode was designed into the data acquisition control module with this end in mind. In the DELAY TRIGGER mode the controller will give a 1 microsecond pulse at the TRIG. output of the control module when the n^{th} encoder pulse is reached after the 1PPR (1 pulse per revolution) sync pulse occurs. This occurs every revolution of the CVF encoder and thus gives an "event mark" which can be used to determine where the n^{th} pulse (as set into thumb wheel switches) occurs in relation to the calibration spectra as displayed on an oscilloscope. This allows the pulse number of a known calibration peak or notch to be located by adjusting the count setting until the TRIG. output pulse occurs at the calibration point. By locating several points in each CVF, the remaining pulse numbers can be assigned their corresponding wavelength by fitting an interpolating polynomial to the calibration points. This method of wavelength calibration has been found to be repeatable and, as such, allows for orderly data reduction by a digital computer after digitization.

Other features designed into the control module are as follows. A precision square wave reference generator was included to enable absolute voltages to be recovered after recording on a non-discrete gain controlled tape recorder. This reference generator generates a

0.000 volt to approximately 5.000 volt square wave which is recorded on the data channels at the beginning of each data observation. An automatic event mark pen control was included to control the event mark pen of a Clevite Mark 260 strip chart recorder. This indicates on the field recorded "hard copy" which CVF scans were recorded on tape for later digitization. An "alternate" mode was included to allow synchronization of data observations to the incidence-reference mirror position signal of the short wavelength unit. For the long wavelength unit a "slave" mode was included which allows automatic initiation of the long wavelength controller by the short wavelength controller. The purpose of these added features will become more evident in the later sections of this paper.

Exotech Model 20-C Spectroradiometer Signal Characteristics

The Exotech Model 20-C Spectroradiometer consists of two main units, the long wavelength unit and the short wavelength unit, which operate completely independent of one another. Normally, however, if they are operated together they are operated in similar modes, and data are collected at the same time from each unit. Each unit also has similar output signals available. The output signals are listed in Table 1. Also, shown in Figure 2 are the wave shapes and timing relationships of the 1 pulse/revolution, the 1000 pulse/revolution, and the mirror position signals. This figure also defines the pulse number of the CVF wavelength scan. These defined count numbers will be the convention used to determine the wavelength to sample command pulse number relationship. With these signals and pulse relationships available the resulting Data Acquisition Control Module was designed to function as described in the following section.

Theory of Operation - Data Observations

Since the Exotech Model 20-C Spectroradiometer consists of two separate independent units, the Data Acquisition Control Module also contains two almost identical control sections. The differences in the controller for each of the spectroradiometer units will be discussed after the complete discussion of the control circuitry associated with the short wavelength unit.

Refering to Figure 3, pressing the RESET button will reset the AF/F through an OR gate (gates A1a and A1b). Also, the RESET button supplies a "1" to another OR gate (NOR gates A7c and A7d). The output (labeled R) of this OR gate resets the BF/F, the CF/F and all of the decade counters. This can be considered the "reset"condition of the controller.

With the Data Acquisition Control Module in the "reset" state and the Exotech Spectroradiometer CVF running, the following chain of events occur when taking a data observation. With the ALT-NORM switch in the NORM position the 1PPR signal is fed to the one-shot multivibrator A4. This one-shot is wired to trigger on the positive going edge of the 1PPR signal. The 1k/R signal is continuously fed into one-shot A6 which also triggers on the positive going edge of this signal. The Q output of A4 and the $\bar{Q}$ output of A6 are fed to AND gate a9d. Thus, the output of A9d can be a "1" only when the Q output of A6 is a "0". The function of A9d is to prevent setting the BF/F when the Q output of A6 is a "1".

To initiate a data run the GO button is pressed. Pressing the GO button places a "1" into AND gate A3b. The other input to this gate is from the $\bar{Q}$ output of the BF/F which is reset at this time. Thus, the output of A3b will "set" the A flip-flop. Occurrence of this setting is indicated by the LED display directly above the GO button. The "1" output of the AF/F is fed to AND gate A3a. In this state the controller is waiting for the next 1PPR sync pulse from the CVF position encoder.

When the next 1PPR pulse occurs it will trigger 1/S A4 and supply a 3 μsec pulse through gate A9d and gate A3a setting the BF/F. Setting the BF/F will enable pulses from 1/S A6 to appear at the output of gate A3d. Setting of the BF/F will also result in the disabling of the GO button through the action of gate A3b. The state of the BF/F is indicated by an LED labeled DATA on the front panel. This state of the controller can be called the "data" state.

The "data" state of the controller consists of two distinct phases. The first phase occurs during the first 120 pulses of the 1k/R input after the arrival of the 1PPR sync pulse. During this phase the controller generates a reference square wave which is switched to the analog data channels in place of the Exotech data signals. The reference square wave generation is controlled by the output of gate A9c. This gate buffers the "A" output of decade counter A14. The "A" output of A14 is a square wave with a frequency equal to the output of A3d divided by 20. Refering to Figure 4, the square wave from A9c is fed to a reference generator comprised of Q_1 and Q_2. The output of this reference generator is fed to a DPDT reed relay which is controlled by Q_3. With the switch in the OP position the state of the relay is controlled by the state of the AF/F. Thus, with the AF/F set and the controller counting (i.e., after receiving the 1PPR sync) the reference square wave is generated and switched into the data channels. Also, during this time sample command pulses are generated to control digitization of the reference square wave.

The generation of sample command pulses (refering to Figure 3) during this phase consists of gating pulses from A3d through B2c to one shot A10. The output pulse width of A10 is adjustable and is set for 0.2 msec to meet bandwidth requirements of the recording instrument. The gating at B2c is controlled by the AF/F. Thus, to obtain only 120 sample pulses the AF/F must be reset after 120 pulses have occurred. This is accomplished by gates A1c, A1d, and A3c which are wired at the thumb wheel switches to a count of 0120. This results in a "1" at the output of A3c when a count of 0120 is reached. With the NORM-DELAY TRIGGER switch in the NORM position the "1" at A3c resets the AF/F. Reseting the AF/F results in switching the Exotech signals back into the data channels and blocking generation of any further sample command pulses by disabling B2c. During the remaining portion of this Exotech CVF scan the Data Acquisition Control Module continues counting and initiates the second phase.

The second phase of the data recording cycle commences upon the arrival of the 1000th pulse after the initial 1PPR sync. Immediately after the arrival of the 1000th pulse the counter's decoded output is 1000; and thus, gates B1a, B1b, B2a, and B2d set the C F/F. Setting this flip-flop allows the next pulse (the 1001st pulse) to begin another sample command pulse chain. The 1001st pulse occurs at the defined pulse number 1 on the CVF (since there are 1000 pulse/revolution of the CVF). Following the 1001st pulse the Exotech Spectroradiometer data have 1000 sample command pulses generated for each CVF scan. The total number of scans that are to be digitized in a given observation are thus controlled by the total number of sample command pulses generated. To allow flexibility in the field experiments this total count was made adjustable through a set of four thumb wheel switches. The total number of CVF encoder pulses set into the thumb wheel switches control the termination of the data observation.

The thumb wheel switches are single pole 10 position switches. The output of these switches are all "0" when the desired count is reached. Gates A7a, A7b, and A9b supply a "1" to A9a only when the desired count is reached. One shot A8 is wired to trigger on the falling ("1" to "0") edge of the output of A3d. The Q output of A8 is used to "strobe" A9a (also B2d). This allows the counters 1 μsec to reach their final state before checking to see if the final count has been reached. When the final count has been reached an output pulse of 1 μsec duration, delayed by 1 μsec from the output of A6, will appear at the output of A9a. This pulse is fed to the TRIG output on the front panel and to OR gate A7b and A7c. This supplies a "1" at the R line and resets the BF/F, the CF/F, and the decade counter stages. Reseting the CF/F and the BF/F prohibits further sample command pulses from being generated. Resetting the BF/F also extinguishes the DATA LED on the front panel signifying termination of the data observation. At this time the counter is in the "reset" state and pressing the GO button will result in a repeat of the entire cycle just described.

Alternate Mode

The alternate mode is another data taking mode. This mode is enabled by placing the ALT-NORM switch to the ALT position (See Figure 3). In this mode the beginning of the reference phase is initialized to the "0" to "1" edge of the mirror position signal. The mirror position is controlled by the 1PPR signal when the spectroradiometer (SW only) is in the "alternate" mode of operation. In this mode the spectroradiometer observes the target for two scans, the solar port for two scans, and repeats the cycle. By synchronizing the reference phase of the Data Acquisition Control Module to the mirror position signal, the beginning of the data observation will always coincide with the first target scan of the spectroradiometer scanning sequence. It must be remembered, however, that the first scan is reserved for the reference square wave. Thus the actual data recording sequence in the alternate mode will consist of 120 samples of reference square wave, 1000 samples of target, 2000 samples of incident, 2000 samples of target, etc., until the total set count is reached.

The Delay Trigger Mode

The main function of the Data Acquisition Control Module in the delay trigger mode is to generate a trigger pulse at a predetermined position of the rotating CVF in the spectroradiometer. To accomplish this the DELAY TRIGGER-NORM switch is placed in the DELAY TRIGGER position. With the ALT.-NORM switch in the NORM position and the CVF running, pressing the GO button will initialize this mode.

In this mode, pressing the GO button sets the AF/F and allows the BF/F to be set as before at the occurrence of the 1PPR sync. If the count is set to some count between 0001 and 1000 a trigger pulse (at the TRIG. output) will be generated at the set count prior to the next 1PPR sync pulse. This trigger pulse from A9a also resets the BF/F and the decade counter stages. In the delay-trigger mode the AF/F can only be reset by pressing the RESET button. Thus, the BF/F will be set at the beginning of each CVF scan until the RESET button is pressed.

Since in this mode data are not recorded, generation of sample command pulses due to the AF/F being set is of no consequence. However, to observe Exotech data instead of the reference square wave the OP switch (Figure 2) must be placed in the center position. This is necessary since the reed relay is controlled by the state of the AF/F. Operating procedures for the delay-trigger mode are in the Wavelength Calibration Technique section of this paper.

Event Mark Control

The only remaining feature to be described for the system of the Data Acquisition Control Module associated with the short wavelength unit of the Exotech spectroradiometer is the event mark pen control for the Clevite Mark 260 strip chart recorder. Refering to Figure 7, the event mark pen is controlled by placing an effective switch closure at two terminals on the rear of the recorder. Since it is desired to mark the "hard" copy during the recorded observation, the BF/F of the counter is used to control the event mark pen.

When the BF/F is in the reset state the $\overline{B}$ or "0" output is at a logic "1" level. This keeps Q_1 in the cutoff state and allows the 2K resistor between base and collector of Q_2 to keep Q_2 approximately cutoff. When the BF/F is set during the observation the $\overline{B}$ output is at a logic "0" and thus causes Q_1 to conduct. Conduction of Q_1 saturates Q_2 and thus marks the event of the BF/F being in the set state.

Long Wavelength Controller Differences

There are only two differences between the controller used with the long wavelength unit and the controller used with the short wavelength unit. The first difference results from the fact that the long wavelength unit of the spectroradiometer does not have an alternate mode. Thus, the only input to the one-shot A4 is the 1PPR sync pulse. This is shown in Figure 4. The other difference between the two counter sections is the addition of a SLAVE-MAN. switch in the long wavelength counter.

As seen in Figure 5, the SLAVE-MAN switch is in the GO button circuitry. In the MAN position the counter functions as described previously. In the SLAVE position the AF/F is set when the BF/F of the short wavelength controller is set. Thus, by pushing the GO button for the short wavelength counter the long wavelength counter is initialized at the time the short wavelength section starts counting. This results in the beginning of the long wavelength data always appearing after the beginning of the short wavelength data in any given observation.

Operational Considerations

There are several things to consider in using the data acquisition control module. First, the system patching for data observations is as shown in Figure 12. In this setup the sample command pulses are recorded on the Ampex SP 300 in the direct mode. The .2 msec pulse width of the sample of command pulses is sufficient for the FM mode of the Ampex SP 300, however, in reproduction any tape liftoff will cause erroneous sample command pulses. For this reason the FM mode is to be avoided.

A second consideration concerns measurement of the reference square wave voltage levels (0.000 and 5.000 volts). This can be accomplished for each controller by placing the toggle switch on the signal switching panel of the Data Acquisition Control Module to the REF. READ position. This switches the relay so that the reference generator is loaded with the recording devices. With the counter "reset" the +5.000 V (approx.) reference voltage can be read with a digital voltmeter at the yellow banana jack on the signal switching panel. To read the 0.000 V level stop the CVF and then press the GO button on the controller. With the

CVF in its slowest speed it is possible to start and stop the CVF until the output of the reference generator is low (0.000 V) as measured before (i.e., when pressing the toggle switch down).

In the A to D conversion equipment at LARS it is necessary to adjust analog channel gains and offsets so that the maximum dynamic range can be utilized. To aid the operator in setting these gains, the reference square wave is recorded for about the first 50 to 75 feet of each analog tape. This is a complished by setting a count of 9999 in the thumb-wheel switches for each counter and pressing the GO button with the controllers in the delay trigger mode.

The last operational consideration concerns the correct setting for the thumb-wheel switches. In the normal mode the count set into these switches determine the total number of 1k/R pulse that are counted before termination of the control cycle. When determining the total number of scans to be digitized it must be remembered that the first CVF revolution of the total sequence is dedicated to the reference phase and is not digitized (except for 120 samples of reference). Thus, for example, to digitize four CVF scans a count of 5000 could be set into the counters. The total number of sample command pulses recorded in this case would be 4120.

For the A to D system at LARS the total number of sample command pulses for each observation must be divisable by 3. Thus, to digitize four scans completely, a count of 5002 would be set into the counters. This would result in 4122 sample commands pulses which is divisible by 3.

Wavelength Calibration Technique

Wavelength registration is accomplished by recording both the analog data from each channel of the spectroradiometer and a synchronized pulse chain for each unit of the spectroradiometer. These pulses (1000 per CVF revolution) are used as sample command pulses in the analog to digital conversion process. Thus, wavelength calibration consists of assigning each pulse in the chain to a corresponding wavelength.

This assignment is normally accomplished by locating the pulse number for several wavelengths within the range of each CVF and interpolating the wavelengths for the remaining pulses in the sample command pulse chain. Location of the pulse number for the calibration points of each CVF is accomplished through the use of the delay-trigger mode of the Data Acquisition Control Module (DACM).

As described in a previous section, the delay-trigger mode of the Data Acquisition Control Module supplies a trigger pulse at the n^{th} pulse (as set into the thumb-wheel switches) of each CVF wheel rotation. This trigger pulse is used to generate a discontinuity in the horizontal sweep of the oscilloscope presentation of the calibration spectrum. The equipment patching used in this calibration technique is shown in Figure 13.

The discontinuity in the horizontal axis of the displayed calibration spectrum is introduced through the use of a Tektronix type 564 oscilloscope. This type of oscilloscope allows a dual trace plug-in amplifier with an "added algebraic" mode to be used for the horizontal sweep. A horizontal sweep generator is not needed in the oscilloscope since the spectroradiometer generates a CVF position ramp that is used as one input to the horizontal amplifier of the oscilloscope. The other input to the dual input horizontal amplifier is furnished by a General Radio 1217-C pulse generator. This pulse generator is operated in the "external drive" mode which allows a pulse to be generated which is synchronized to the delayed trigger (TRIG.) output of the DACM. By adding the ramp and the pulse inputs to the horizontal amplifier of the tektronix 564 oscilloscope, the discontinuity of the horizontal waveform is generated. The effective waveform used as the horizontal sweep signal is shown in Figure 14 . The effect of this discontinuity is to split the calibration spectrum presentation at the occurrence of the discontinuity. The position of this discontinuity with respect to the ramp and thus the position of the CVF (or wavelength) is determined by the count set into the thumb-wheel switches of the DACM. Figure 14 also shows the effect of the discontinuity on the displayed spectrum and the graphical verification of this technique.

Location of an "event" in the calibration spectrum, such as an emission peak or an absorption notch whose wavelength is known, is accomplished by adjusting the count of the DACM until the discontinuity in the horizontal waveform splits the peak or notch symmetrically. As shown in Figure 15 this is accomplished by adjusting the count until a hook is not visible on either side of the split. Due to gear lash and drive belt imperfections the "event" position will vary from CVF revolution to revolution. This variance is usually on the order of one or two pulses. Thus, the pulse number of an "event" is determined after observing the oscilloscope presentation for several CVF rotations at each setting of the DACM in the neighborhood of the event. The final choice for the pulse number of the event is the count that best satisfies the "no hook" condition on the average. This technique allows determination of the event position to within a pulse on sharp peaks or notches.

As seen in Figure 14 there is also a retrace discontinuity in the oscilloscope presentation. This is due to the pulse nature of the introduced discontinuity in the horizontal sweep. The retrace portion of the presentation can be moved away from the region of interest by adjusting the pulse width of the General Radio pulse generator.

Another aid in locating an event is the use of the storage mode of the oscilloscope. This is helpful because calibration should be carried out at the slower CVF speeds which allow maximum response of the spectroradiometer electronics. It is also possible to "magnify" the presentation in the region of interest by increasing the gain in the horizontal and vertical amplifiers of the oscilloscope.

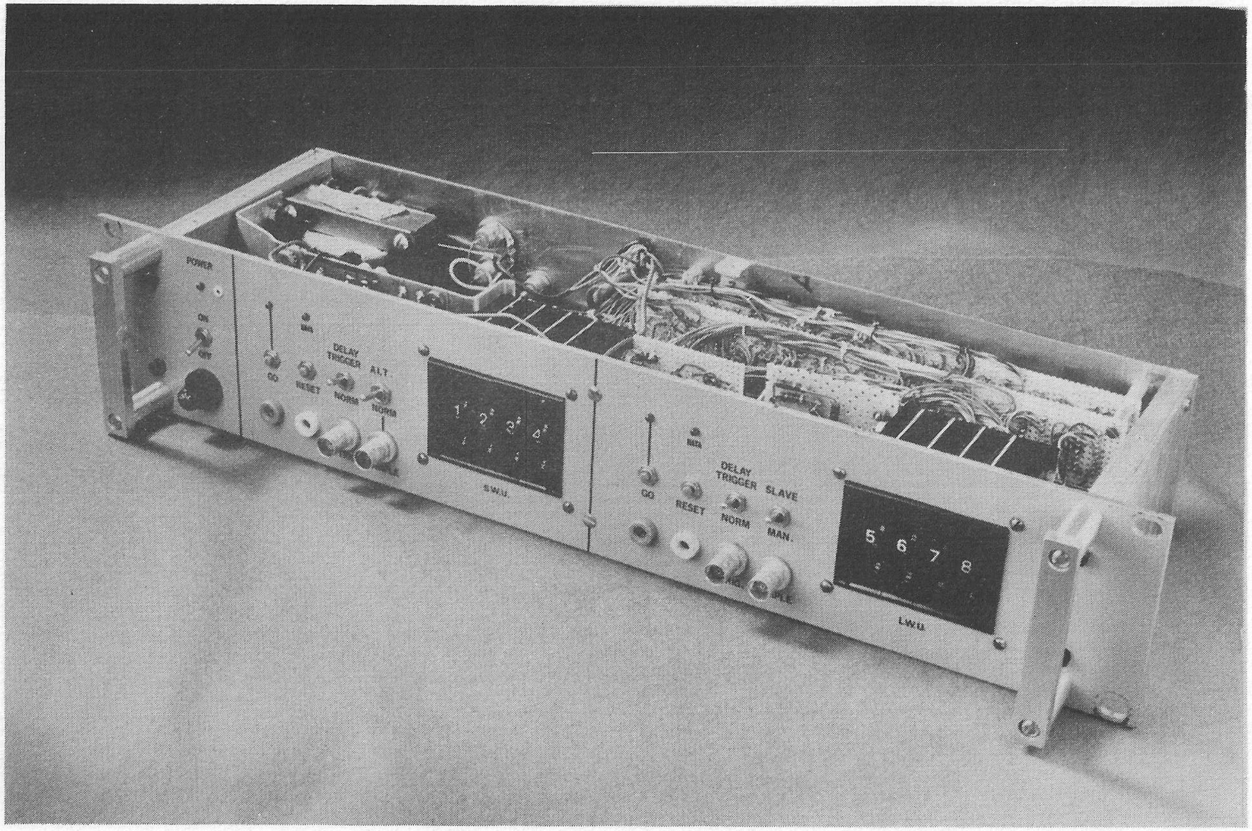


Figure 1. Data Acquisition Control Module

TABLE 1 Exotech Model 20-C Outputs

Short Wavelength Unit

Si Channel Output

Si Gain Setting

CVF Position Ramp

PbS Channel Output

PbS Gain Setting

CVF Scan Rate Setting

Incident Reference Control Setting

Incident Reference Status

Incident Reference Position

1 Pulse Per Revolution Signal (1 PPR)

1000 Pulse Per Revolution Signal (1K/R)

Long Wavelength Unit

InSb Channel Output

InSb Gain Setting

CVF Position Ramp

HgCdTe Channel Output

HgCdTe Gain Setting

CVF Scan Rate Setting

Black Body Control Setting

1Pulse Per Revolution Signal (1 PPR)

1000 Pulse Per Revolution Signal (1K/R)

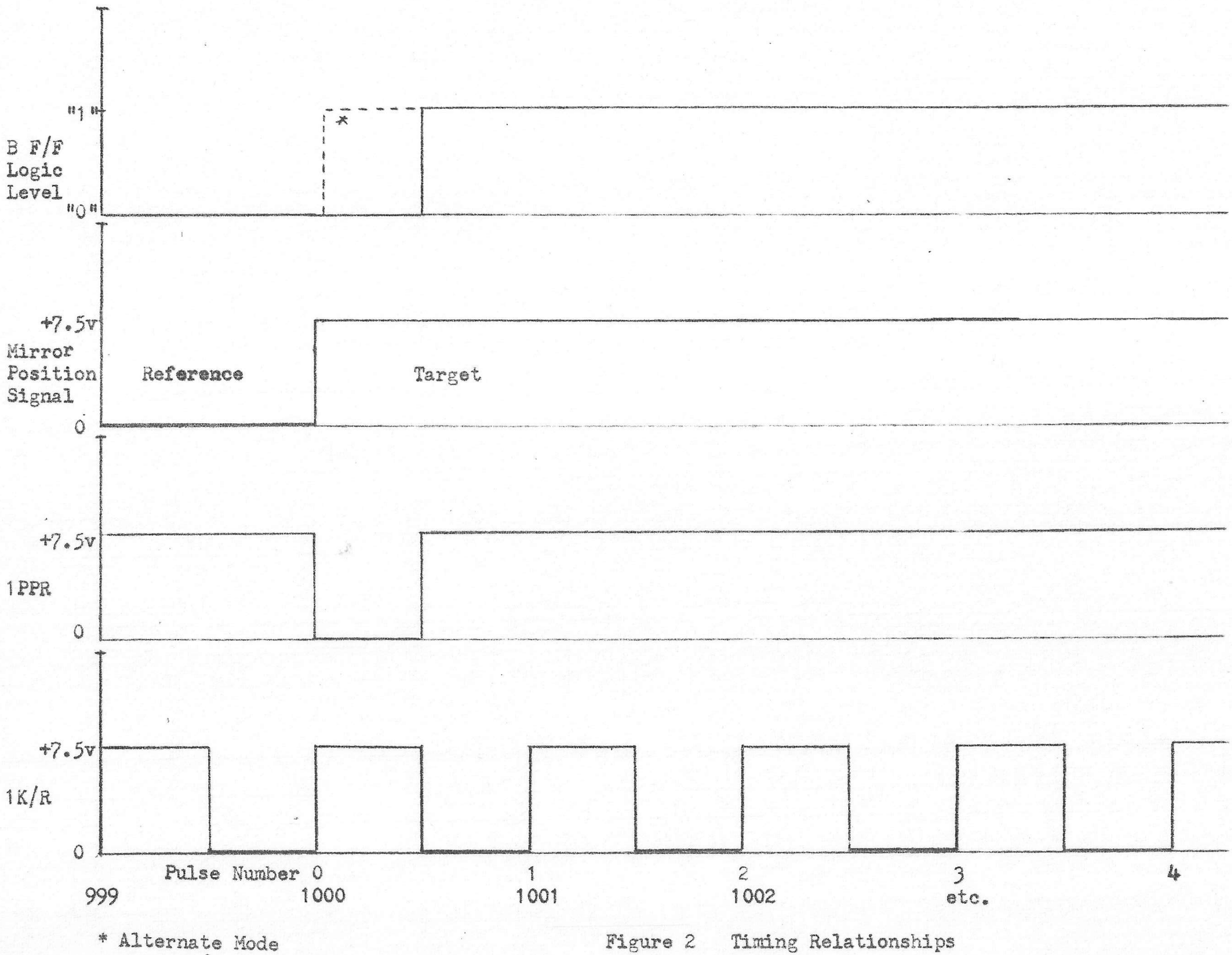


Figure 2 Timing Relationships

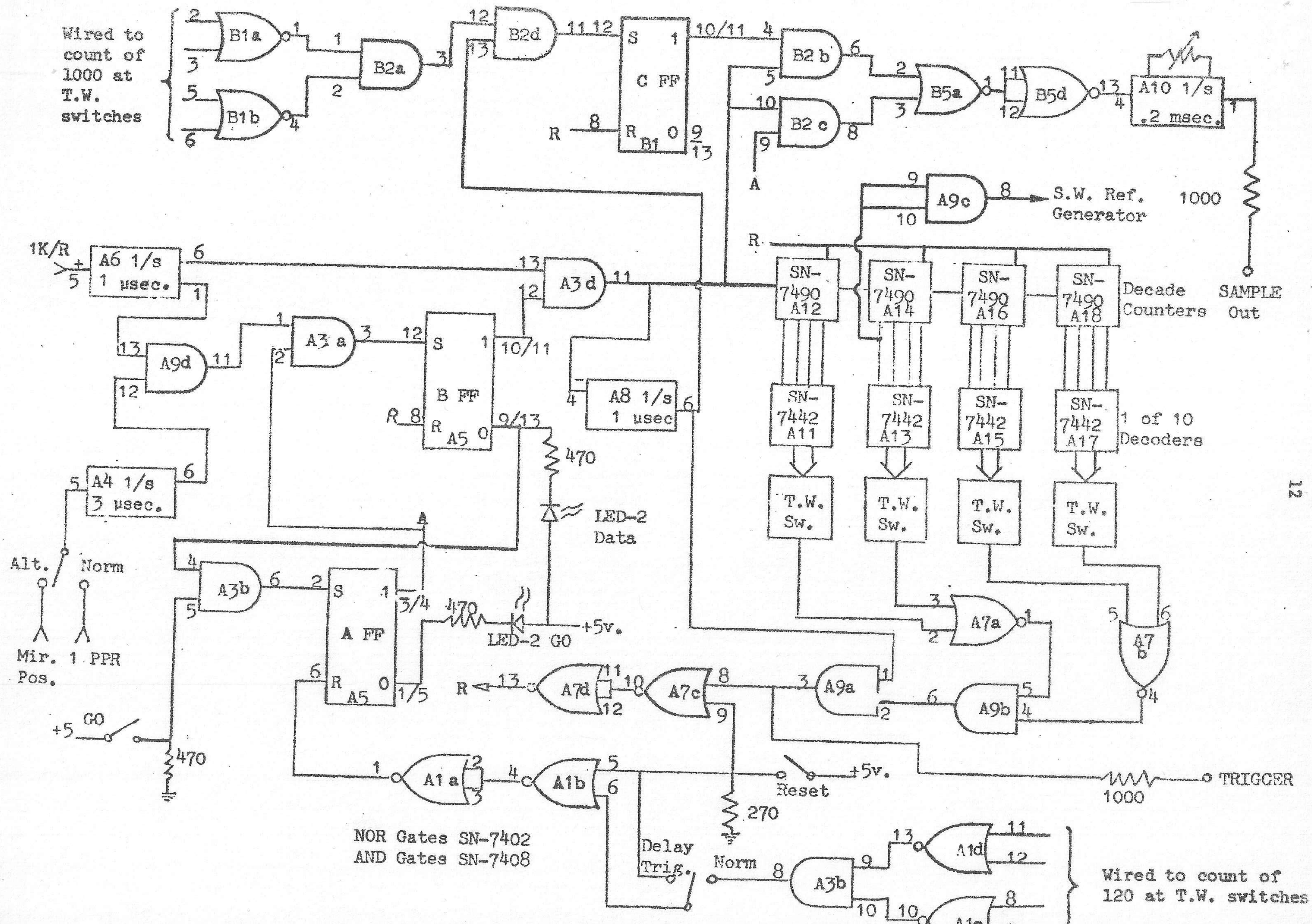
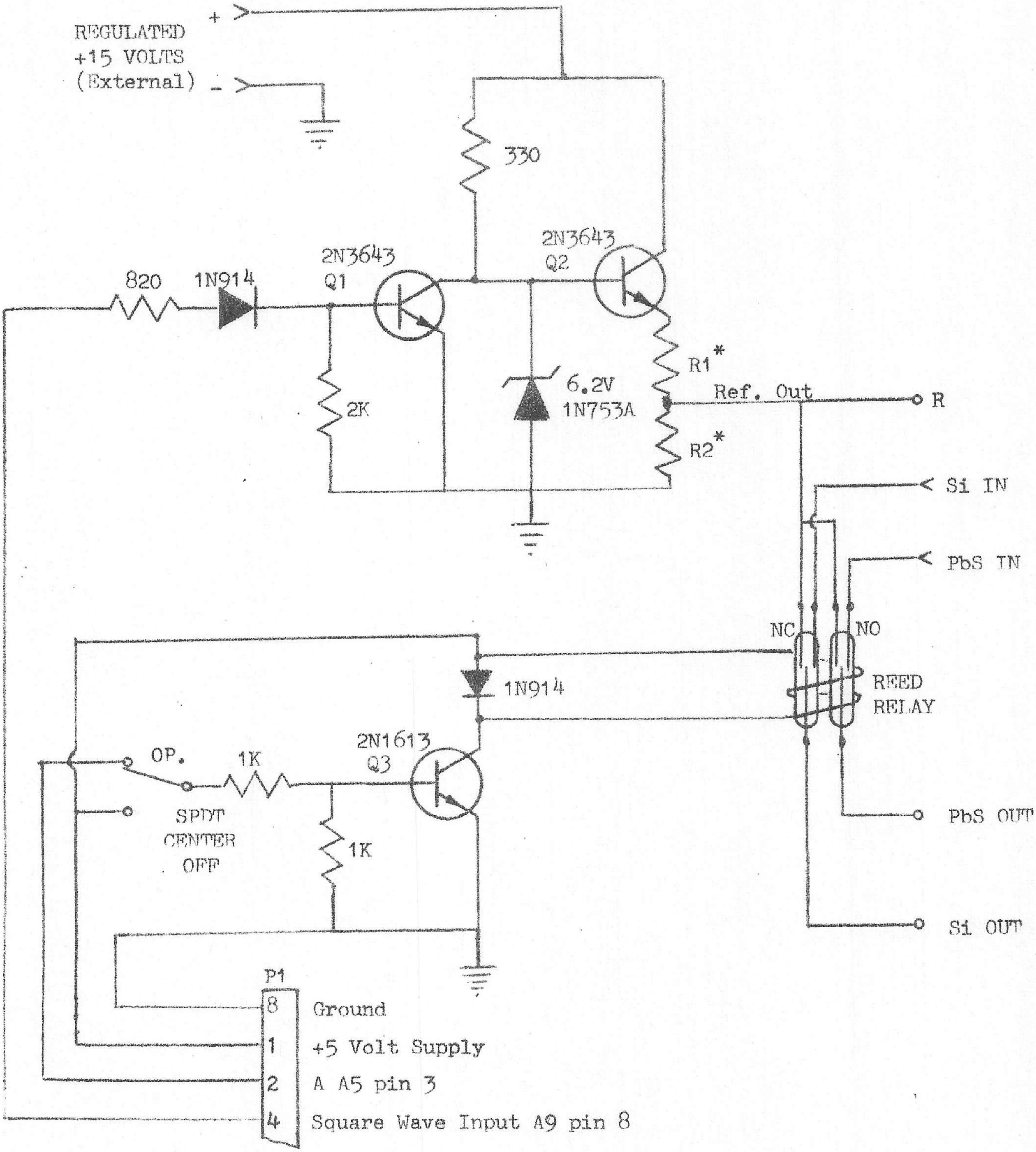


Figure 3 Short Wavelength Controller



*Note: R1 and R2 are hand selected such that Ref. Out is approximately 5.000 volts and the parallel combination of R1 and R2 is 1K ohm.

Figure 4 Short Wavelength Reference Generator

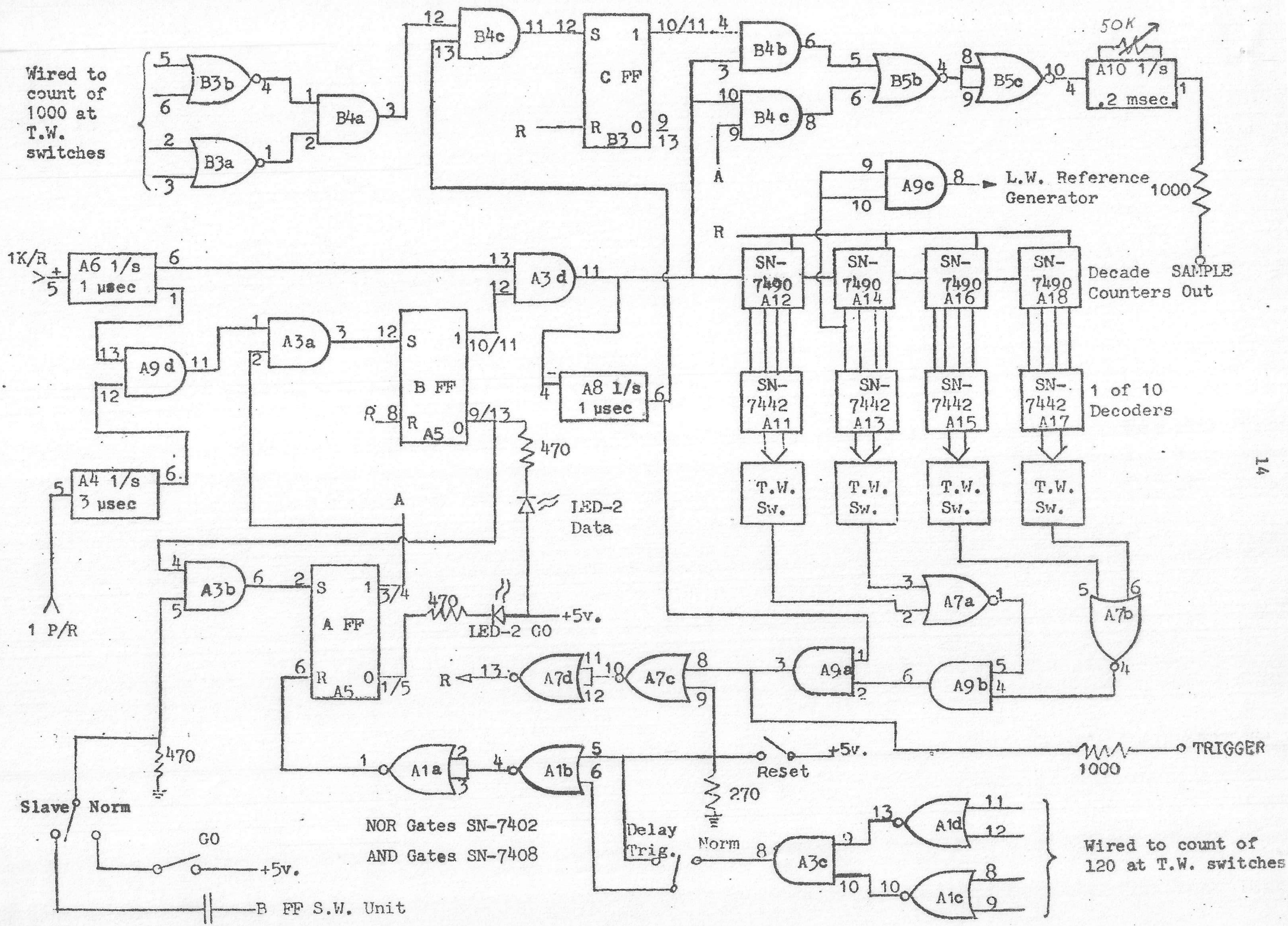
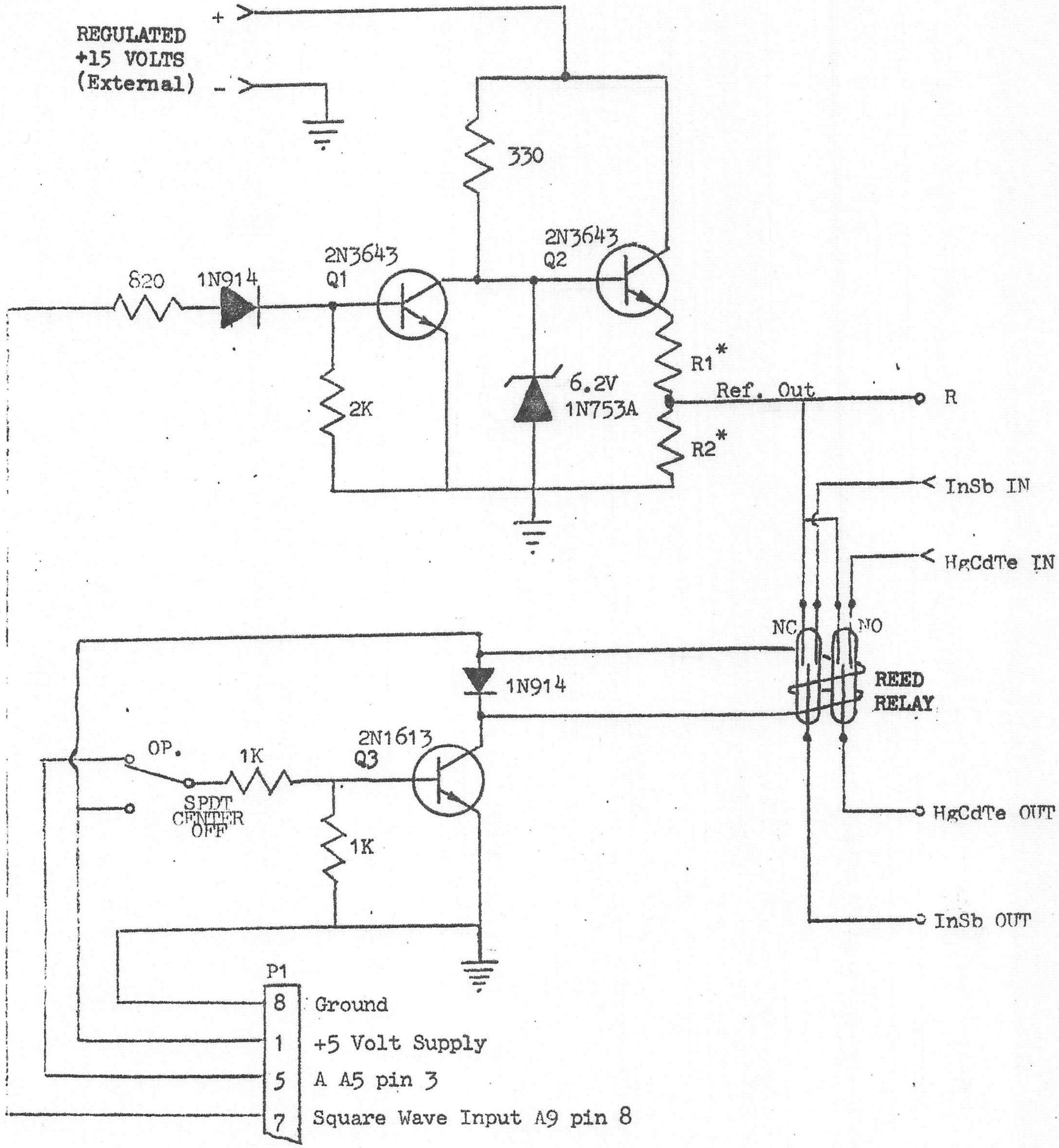
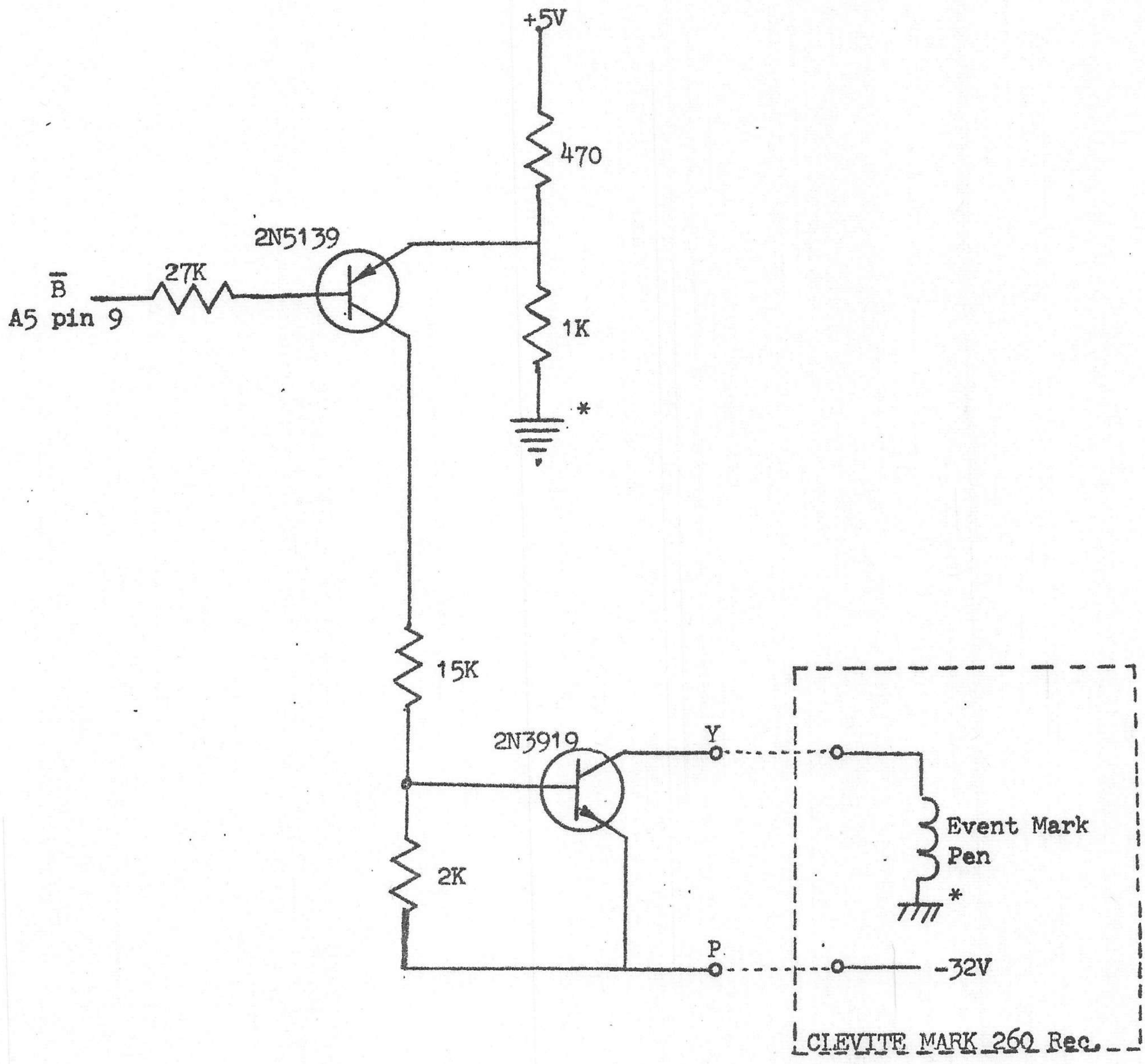


Figure 5 Long Wavelength Controller



*Note: R1 and R2 are hand selected such that Ref. Out is approximately 5.000 volts and the parallel combination of R1 and R2 is 1K ohm.

Figure 6 Long Wavelength Reference Generator



*Note: The grounds of the counter and the Mark 260 strip chart recorder must be connected (line cord ground is sufficient).

Figure 7 Event Mark Pen Control

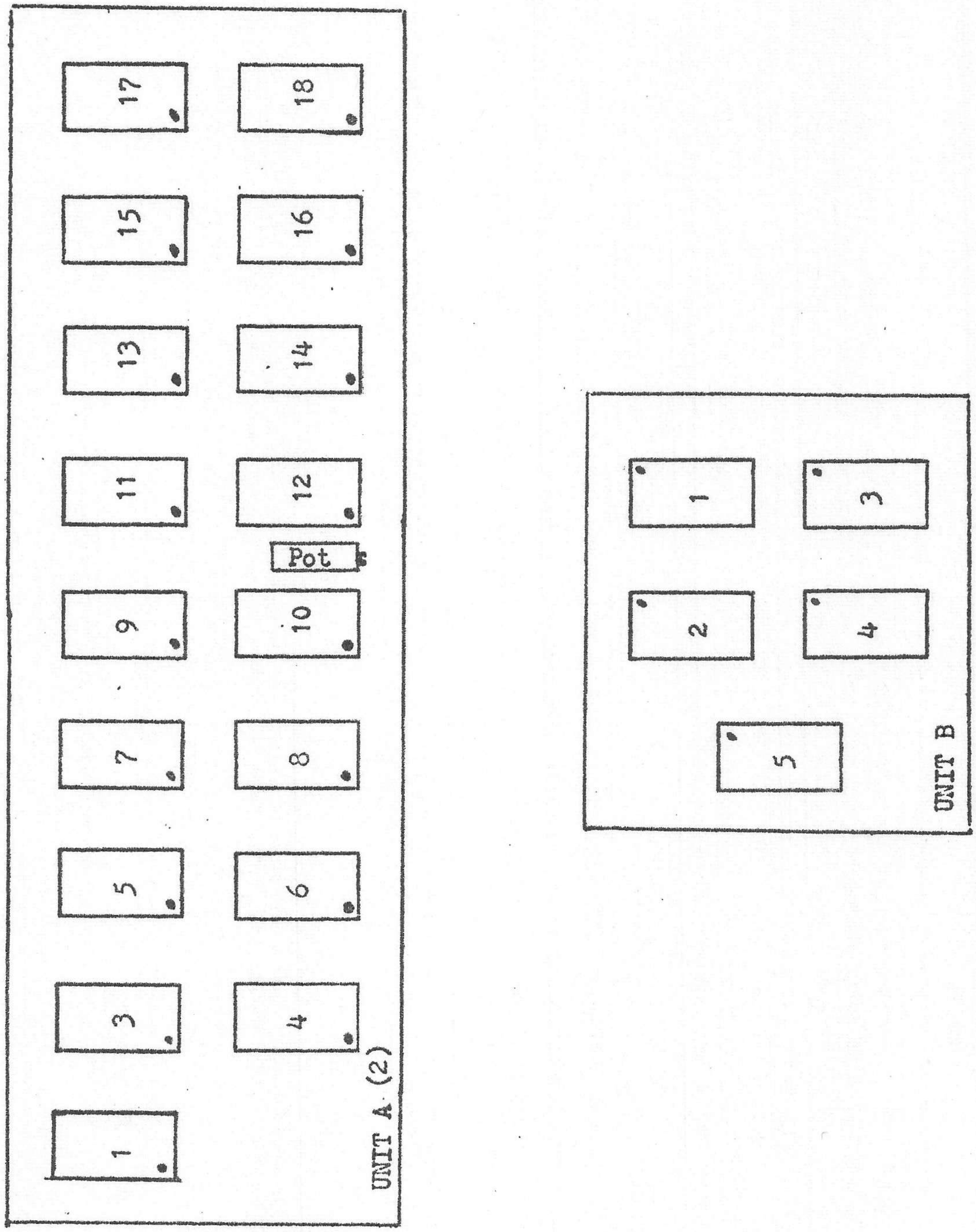


Figure 8 IC Layout

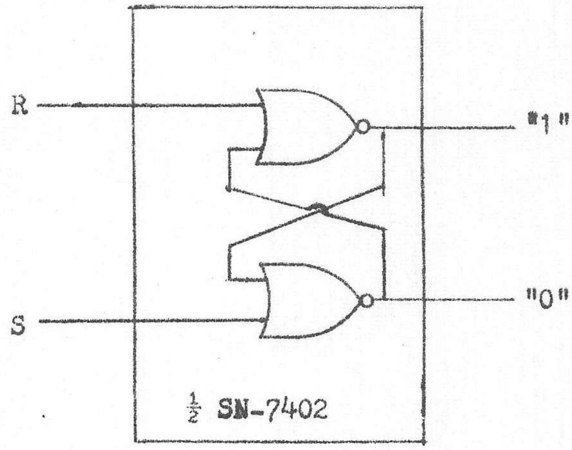
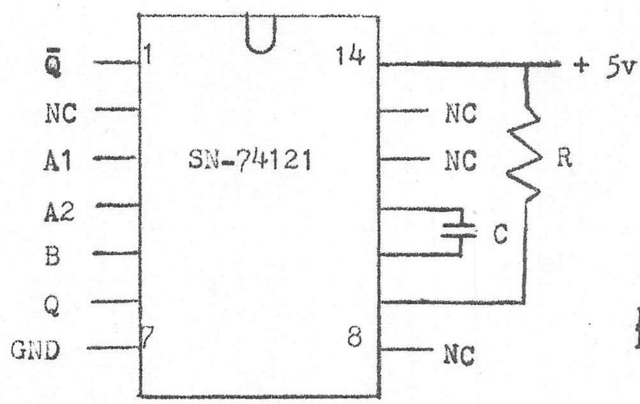
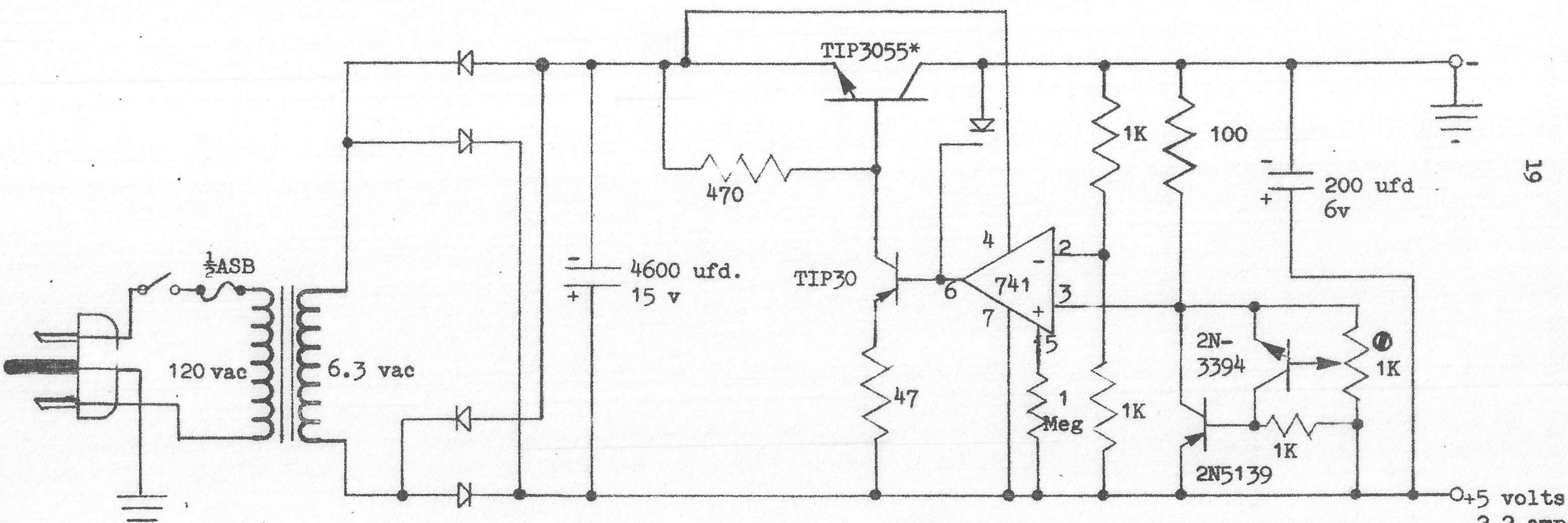


Figure 9 Flip-Flop Logic Wiring



One-shot Wiring				
Unit	A4	A6	A8	A10
A1	GND	GND	+5v	GND
A2	GND	GND	IN	GND
B	IN	IN	+5v	IN
R	56K	15K	15K	Pot 50K
C	100pf	100pf	100pf	.04µf
Pulse Length	3µsec	1µsec	1µsec	.2msec

Figure 10 One-shot Wiring



* Note: Heat sinked to side panel of instrument.

Modified Environmental Products DPS-2A Power Supply

Figure 11 +5 Volt Power Supply

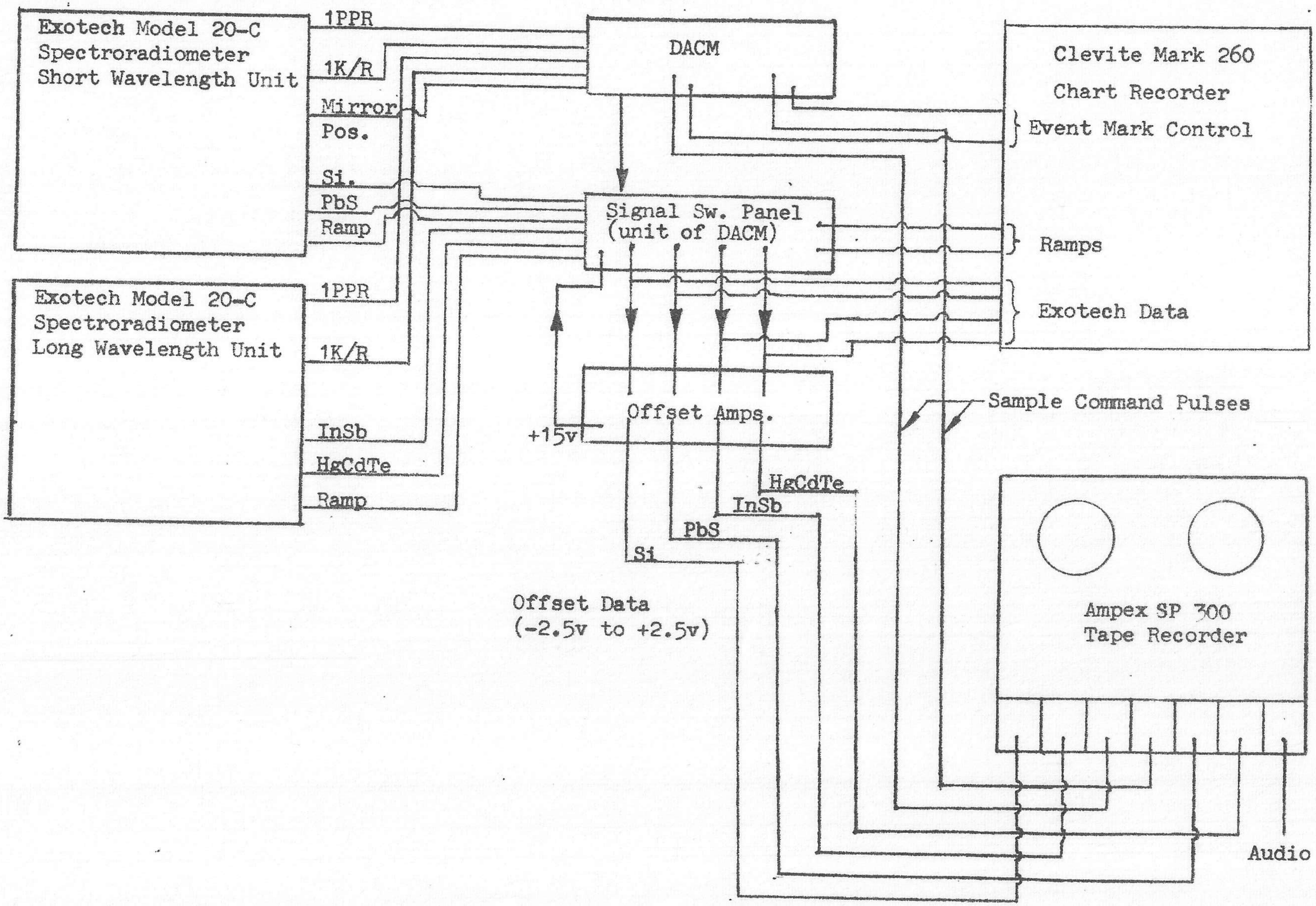


Figure 12 Patching Diagram

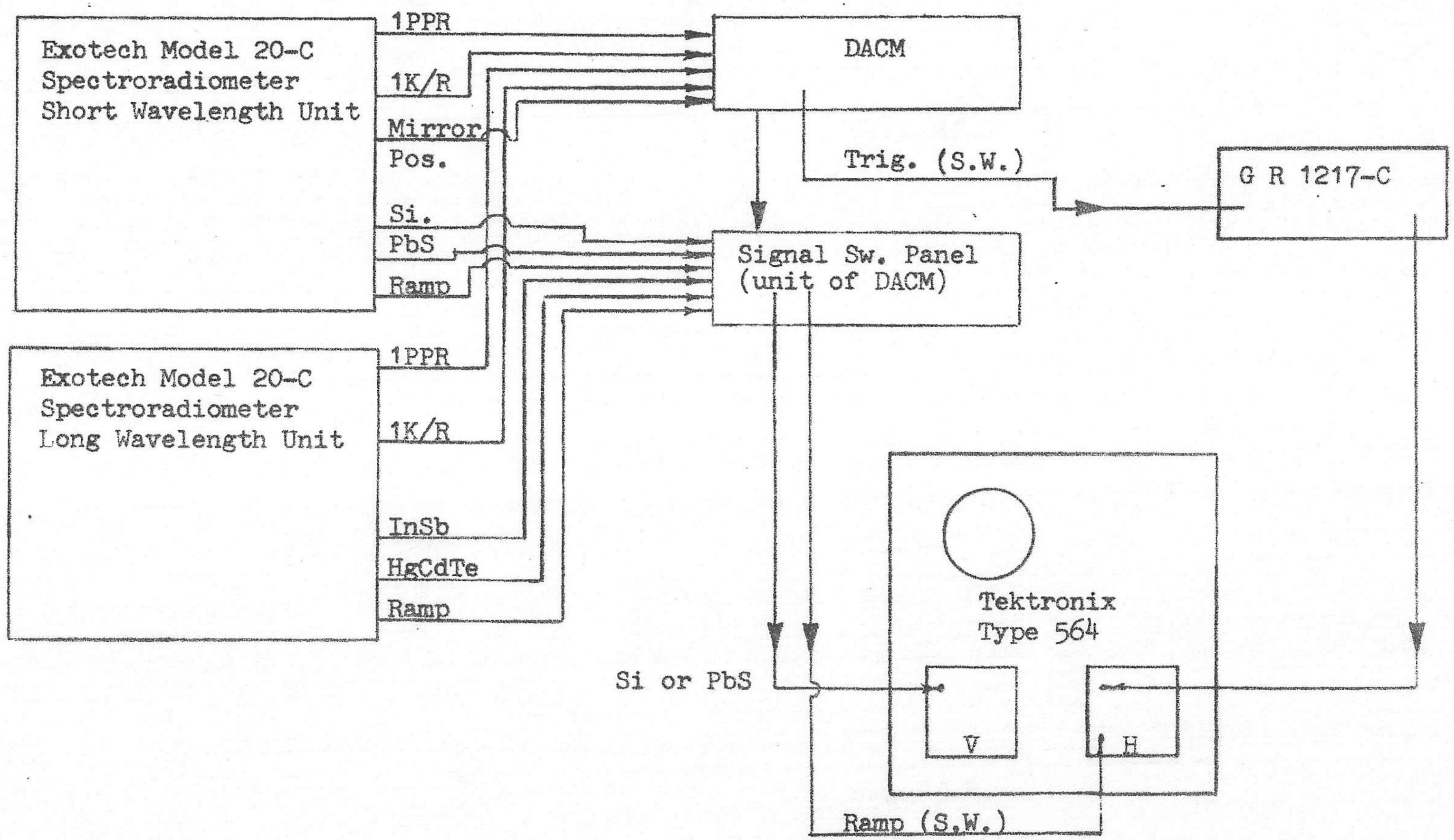


Figure 13 Patching Diagram for Calibration of Wavelength (S.W.U.)

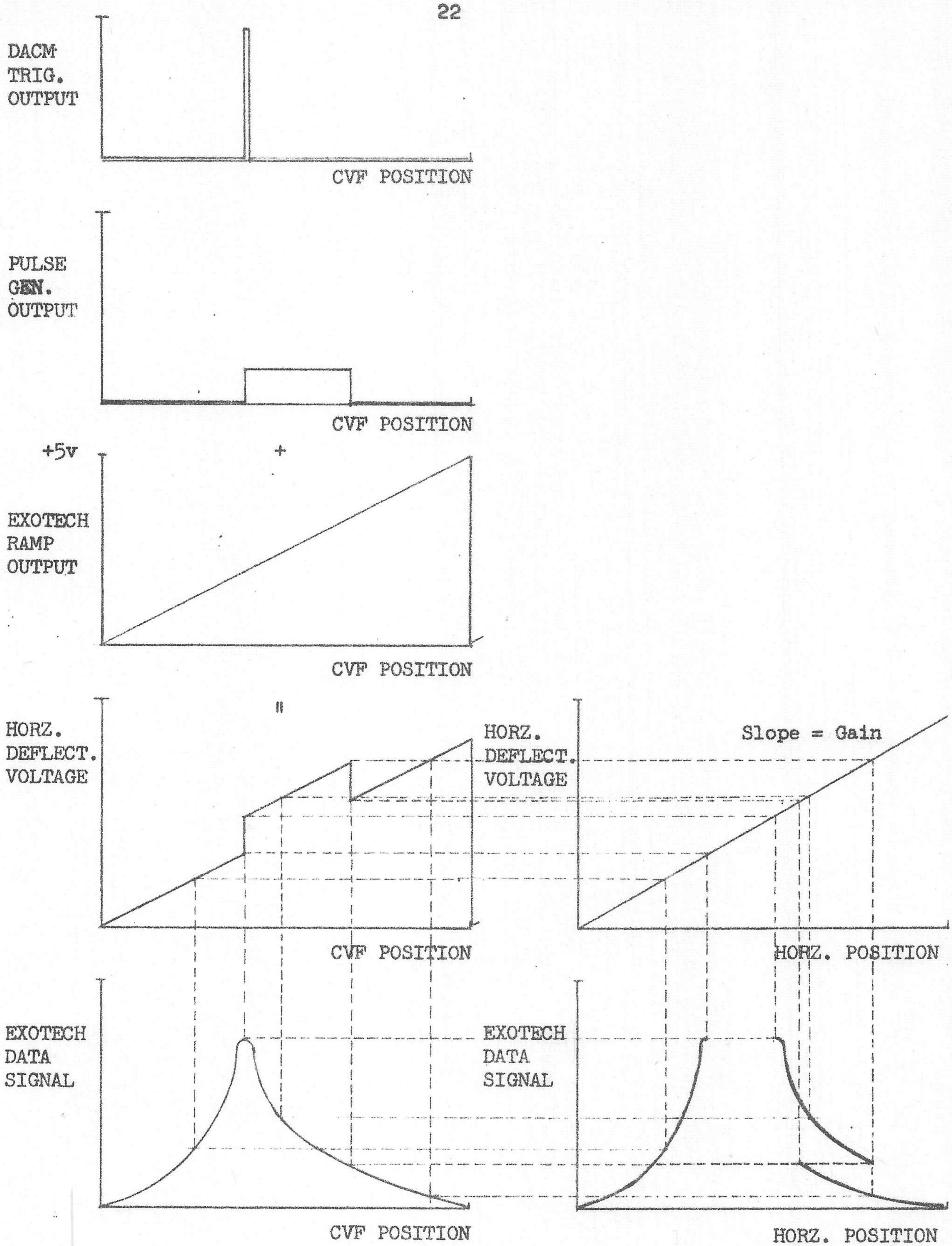


Figure 14 Analysis of Oscilloscope Presentation for Wavelength Calibration Technique

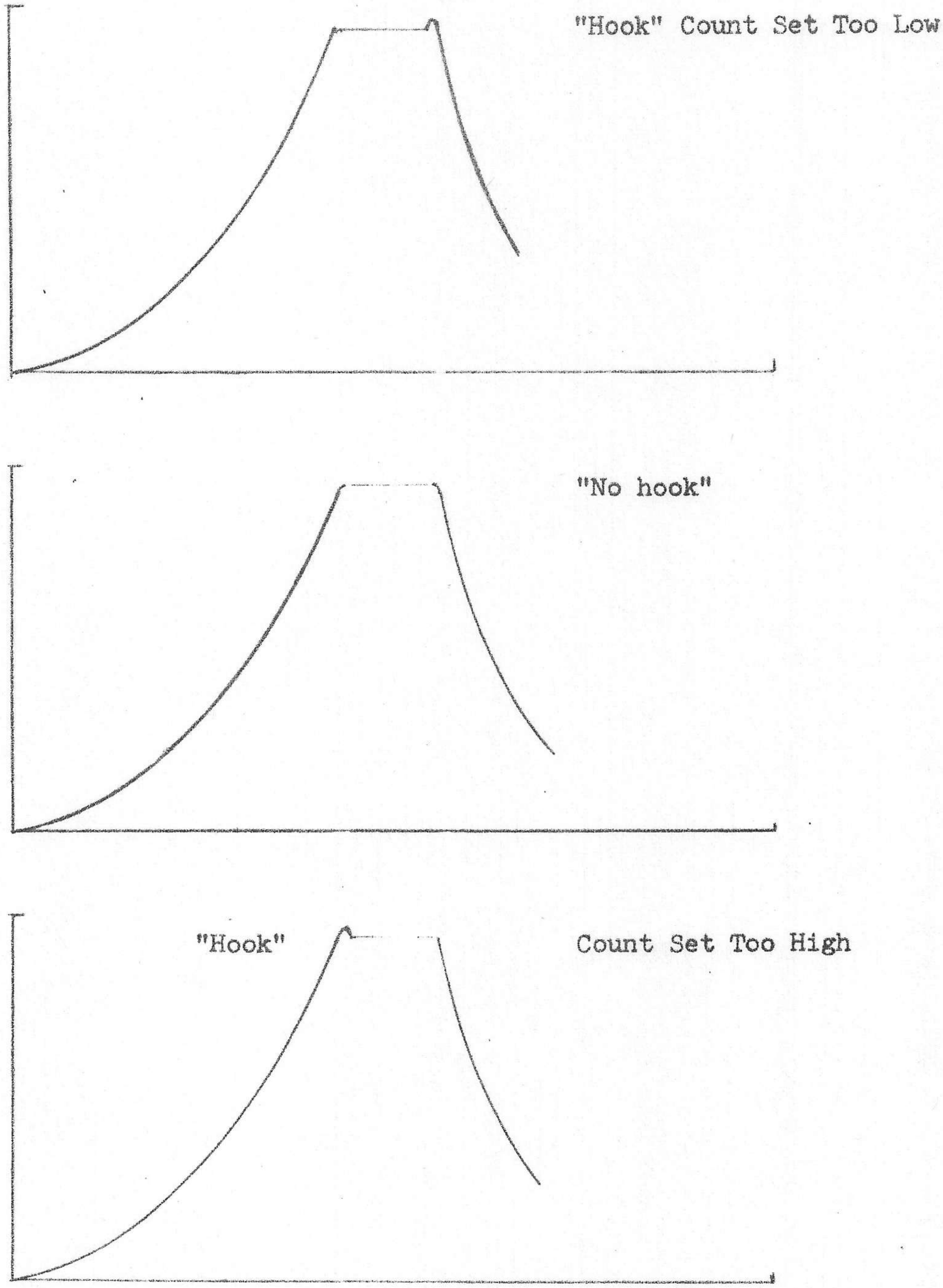


Figure 15 Adjusting for "No Hook"

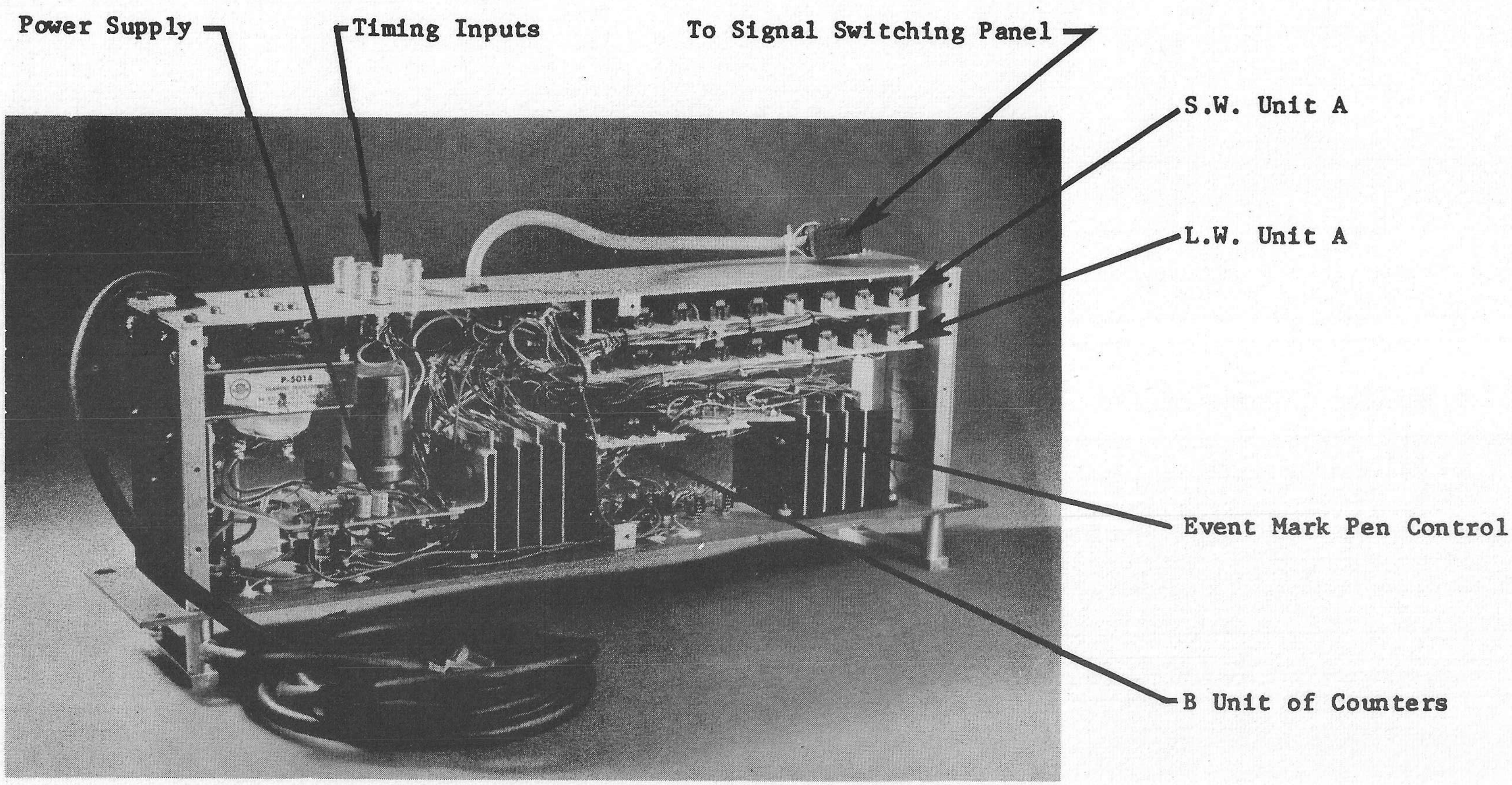


Figure 16 Unit Locations of Main Frame

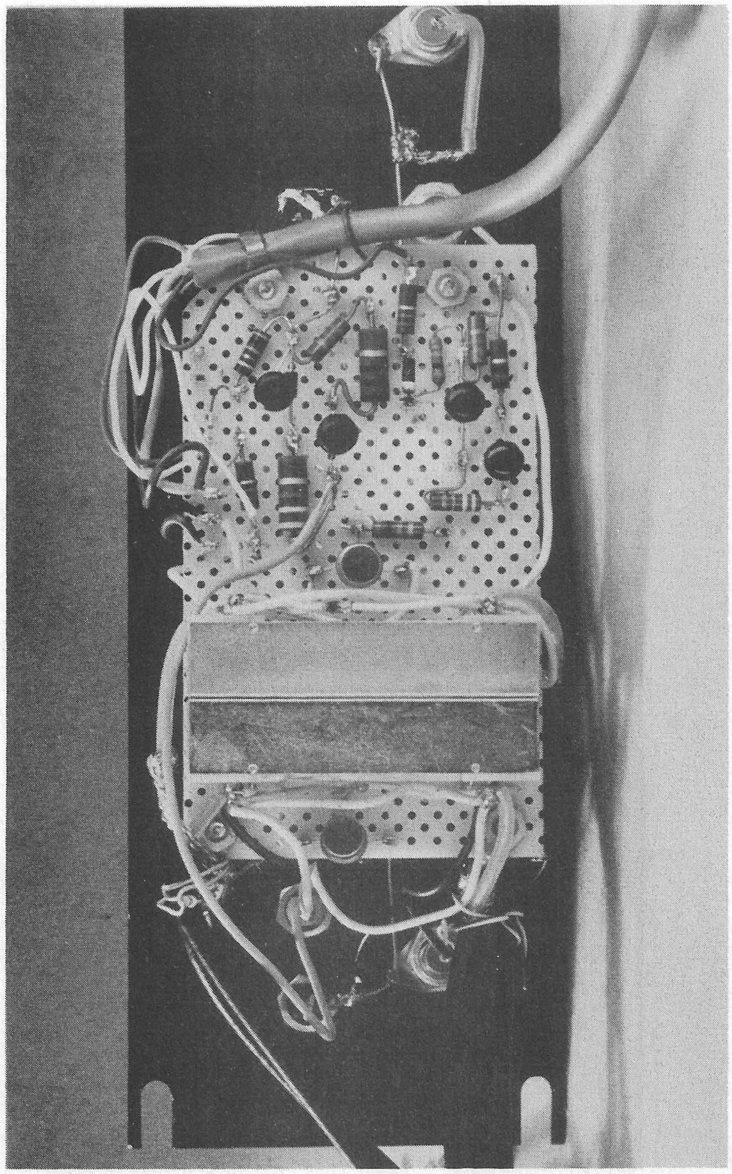


Figure 17 Signal Switching Panel (Rear View)

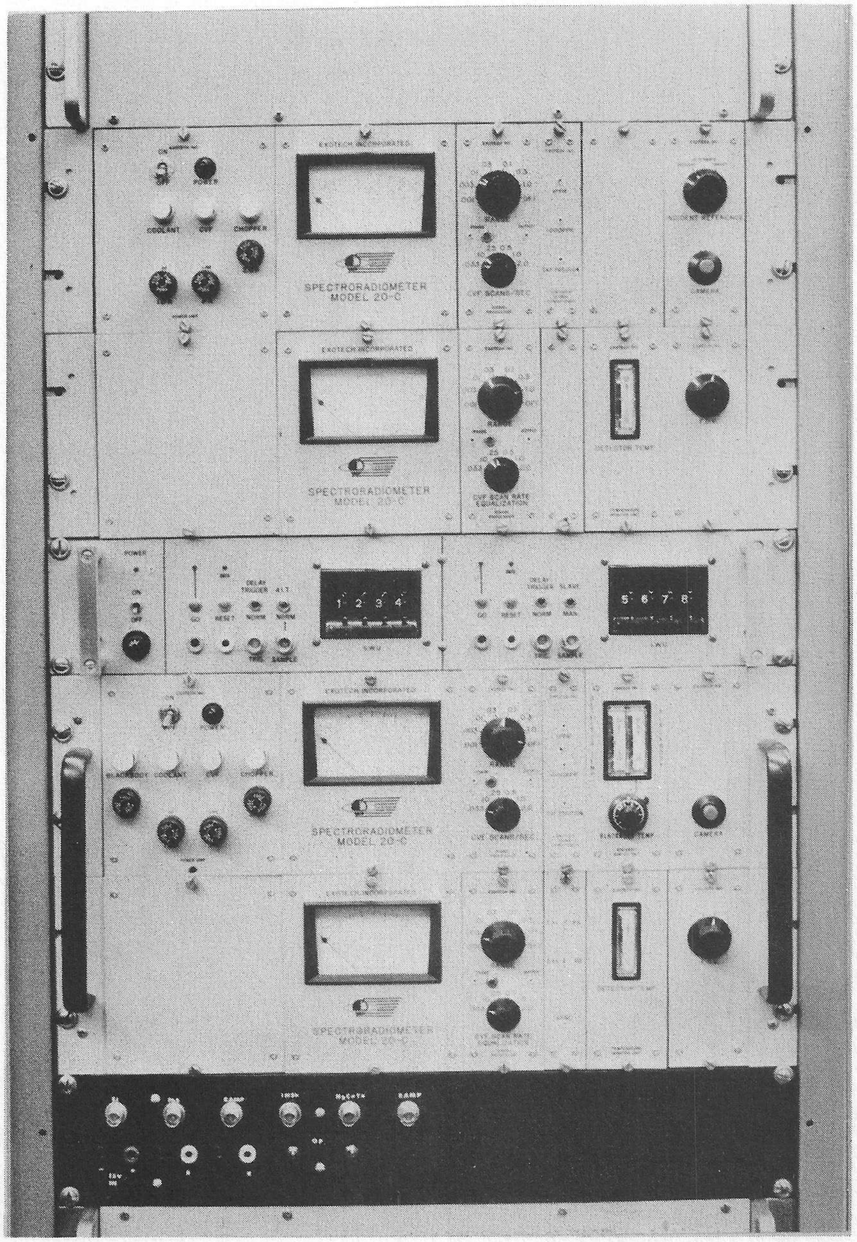


Figure 18 Exotech Model 20-C Spectroradiometer