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CIRCUIT MODIFICATIONS FOR COMPLEX MODULATED PULSE DEMODULATOR

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ABSTRACT

The need for a general system for the demodulation of complex pulse modulations has been felt for some time. Such a system has been developed (NRL Report 4463). Since the publication of this report, a considerable amount of circuit modification has been effected in the equipment therein described. Improved circuit techniques have been tested over a period of several months and have resulted in greater over-all reliability. The new design for the pulse frequency demodulator circuit was considered more practical for field use; an improved frequency demodulator has been added to the existing equipment and is currently under test.

PROBLEM STATUS

This is an interim report on the instrumentation connected with certain phases of the general complex modulated pulse demodulation problem; work on other phases of the problem is continuing.

AUTHORIZATION

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CIRCUIT MODIFICATIONS FOR COMPLEX MODULATED PULSE DEMODULATOR

GENERAL DESCRIPTION OF MODIFICATIONS

Over a period of several months after the completion of the Complex Modulated Pulse Demodulator (CMPD)[1] two problems arose in connection with circuit instability. It was found that the Schmitt clipping-circuit (V9, Fig. 6, Ref. 1) which coupled the two halves of the delay-gate multivibrators needed frequent adjustment of the threshold-level voltage control. The same trouble occurred in the Schmitt circuit (V12) connecting the delay-gate multivibrator to the inclusion gate multivibrator. These adjustments were undesirably critical; the improper setting resulted in trigger pulses of insufficient amplitude to trigger the following multivibrators.

The second problem encountered was instability in the modified Schmitt circuit (V20, Fig. 13, Ref. 1) whose function was to convert position-modulated pulses to width-modulated ones. Incorrect setting of the threshold voltage in this circuit led to an occasional failure of the circuit to trigger at all. The random missing pulses produced a noisy output signal.

These two problems were alleviated by the installation of different circuits which required no adjustments whatsoever and which used the same number of vacuum tubes as did the original.

A solution to the frequency-demodulator voltage-inversion problem has been offered in the form of new circuits, the stability of which is determined by passive electrical components and crystal switches rather than by the nonlinear characteristics of a vacuum tube. The new circuit has been permanently installed in the CMPD, and present tests indicate that with respect to stability it is a much more practical solution to the problem than was the original circuit.

Several other minor circuit changes were effected, all of which are outlined in the complete circuit diagram (plate 1). References will be made to the circuits of the original equipment, detailed diagrams for which are found in NRL Report 4463.[1]

SCHMITT CLIPPING CIRCUITS

Figure 1 shows the redesigned coupling circuit that is placed between the first and second halves of the delay multivibrator. The new circuit utilizes the same tubes formerly employed in the Schmitt clipping-circuit, V9 and its associated differentiating amplifier V8B. The output plate load resistor of multivibrator V7B is replaced by a damped ringing circuit which produces negative-polarity pulses from the trailing edge of the multivibrator gate. This pulse is coupled to the grid of V8B, which has been altered to function as a cathode follower. The output pulse from the cathode of V8B is fed through a crystal clipping-network that clips off positive-polarity overshoots and prevents them from getting to the grid of V9A, which now operates as a voltage amplifier and inverter. The positive-polarity output pulse from this amplifier is sent to a one-tube slicer (described in detail in the previous report, p. 27) where the top and bottom are sliced from the pulse, producing a negative-polarity, constant-amplitude pulse at the plate of V9B. It is this signal that triggers the second half of the delay multivibrator.

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[1] Holmes, J. C., "A Demodulator for Complex Modulated Pulses," NRL Report 4463 (Confidential), January 28, 1955.

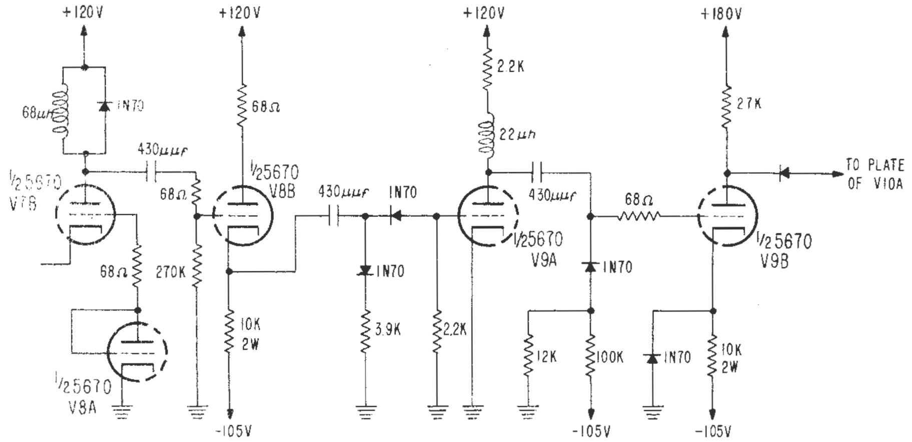

Fig. 1 - Clipping circuits

This improved circuit functions perfectly over the entire range of multivibrator gate widths, no adjustments being necessary. One of the disadvantages of the dc-coupled Schmitt clipper was that a variation in supply voltage of two or three percent required readjustment of the threshold-voltage control for proper operation. The new circuits are ac-coupled and are not affected by such supply-voltage variations. A circuit identical to the above described is installed between the output plate of multivibrator V10 (Fig. 6, Ref. 1) and the input plate of the inclusion-gate multivibrator, V13. Tubes V11B and V12 are utilized for this conversion.

PULSE POSITION-TO-WIDTH CONVERTER

The heart of the pulse position-to-width converter was originally a Schmitt circuit (V20, Fig. 13, Ref. 1), the grid of which was normally biased at a voltage half way between the upper and lower threshold voltage levels. The incoming sync pulse drove the Schmitt threshold grid negative, thereby producing a negative-polarity step voltage at the output plate terminal. The position-modulated information pulse was applied with a negative polarity to the cathode of the input Schmitt triode, thus effectively driving the grid above the upper threshold level. For proper operation, the effective bias voltage on the input Schmitt grid had to be held within about a volt of the optimum value. This limitation was not tolerable, so an Eccles-Jordan circuit (Fig. 2) was substituted, the negative-polarity sync pulse being applied to one plate and the information pulse to the other. Thus a pulse whose width is equal to the time between sync and information pulse is produced at the plates of the Eccles-Jordan circuit. The negative-polarity pulse is taken from the plate of V20A and sent on to the output Schmitt-circuit grid as was done in the original model. The Eccles-Jordan circuit is, like the Schmitt circuit, a dc-coupled multivibrator; but, with the compensating cathode feedback and the symmetrical plate-grid coupling networks, the circuit is much less susceptible to plate voltage/supply variations than was the Schmitt circuit. No voltage adjustment potentiometers are necessary.

PULSE FREQUENCY MODULATION VOLTAGE INVERTER

Purpose

The function of the PFM voltage inverter was to free the demodulated FM signal of the hyperbolic distortion introduced by the time-demodulation techniques. The voltage inverter accomplishes this end

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by producing from its output a voltage that, when subtracted from a suitable reference voltage, is inversely proportional to the input voltage. The original inverter was considered somewhat unsatisfactory for use except in the laboratory. It required the use of an arbitrary-function generator for proper alignment, a procedure which was necessitated each time the multiplying tube was replaced. Multiplying-tube characteristics were found to vary considerably from tube to tube.

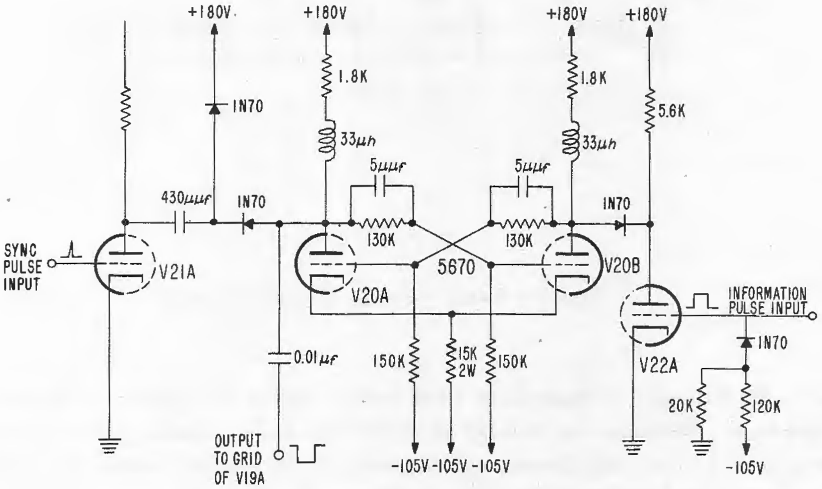

Fig. 2 - Eccles-Jordan circuit

The alternative was to attempt to duplicate the nonlinear inverter transfer function by the use of a multislope approximation curve. The circuit would utilize diodes as switches to successively switch into the output, passive voltage-divider networks each having a different attenuation constant, so that the gain of the network was a function of the input voltage. Several such networks were tried using germanium, vacuum, and silicon junction diodes for switches. The type of circuit that was finally used, because of its inherent simplicity, is shown in Fig. 3. The transfer function of the circuit is defined as the gain vs. input-voltage curve required to transform a hyperbolic input-voltage vs. time waveform into a linear voltage vs. time waveform.

Description

The operation of the circuit (Fig. 3) is as follows. Assume that there is a negative-going hyperbolic signal at the input to the network; the positive peak of this signal is at ground potential. As soon as the input terminal starts moving negative, crystal 1 starts conducting. The gain of the network at this point is determined by the ratio of the combined parallel impedance of R1 and R3 to the total impedance. Meanwhile the voltage at point B is also falling, and it falls faster than the voltage at point A because the resistance ratio between R4 and R5 is less than that between R2 and R3. But R5 is returned to a positive voltage, so that crystal 2 does not conduct until the input voltage reaches a predetermined value at which the potential at point B is equal to that at point A. Then crystal 2

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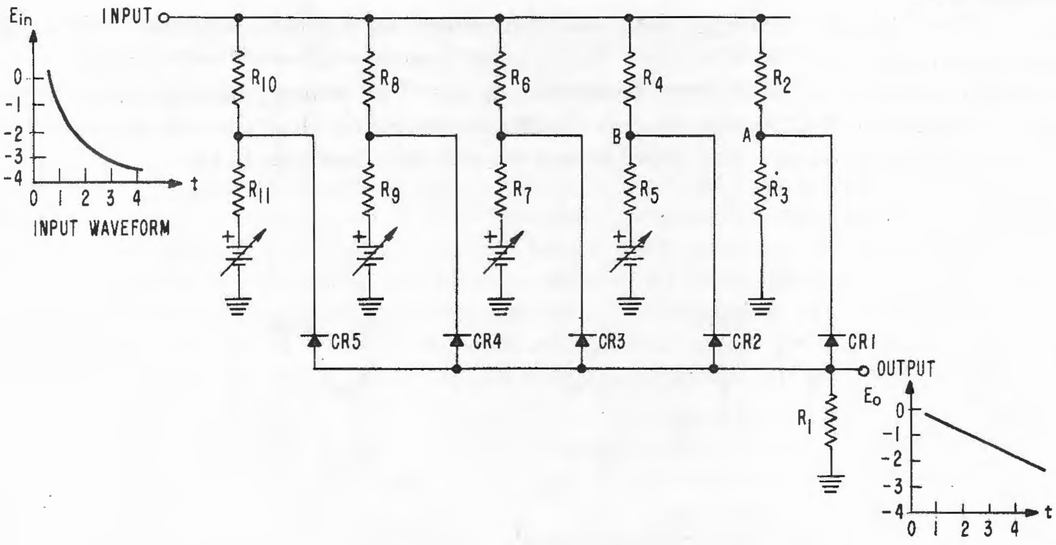

Fig. 3 - Basic voltage inverter circuit

starts to conduct. As the input voltage falls even lower, crystal 2 conducts more and more while crystal 1 conducts less. Because the voltage at point B is falling faster than that at point A, crystal 2 soon relieves crystal 1 of all its current, and the gain of the circuit is now determined by resistors R4, R5, and R1. Careful selection of the values of these divider resistors and their respective return voltages results in a network, the gain of which increases with the amplitude of the negative-polarity input signal to produce a linear voltage output from a hyperbolic input.

The gain of each resistive divider must be inversely proportional to the average slope of the hyperbola throughout that portion of the hyperbola where the crystal diode conducts. If the hyperbolic input signal has a maximum-to-minimum slope ratio of 10 to 1, then the ratio of the gain of divider network 1 to that of 5 should theoretically be 1 to 10. But since there are only a finite number of networks (5), a compromise must be made, with the result that the maximum-to-minimum network gain ratio may be only 5 to 1. Since the gain of each passive network must be less than 1, the amplitude of the output waveform must be considerably less than that of the input waveform. In practice it has turned out that the amplitude of the output waveform is about 1/4 that of an input hyperbola of 16 to 1 slope ratio.

Empirically, the various values of divider resistance and reference voltage are determined in the following manner. The hyperbolic output-waveform of the proper amplitude and slope ratio is applied to the network input terminal. An oscilloscope with linear sweep is connected to the output. Crystals 2, 3, 4, and 5 are disconnected while the ratio of R2 to R3 is adjusted to give the desired output slope. Next, crystal 2 is connected, and the bottom end of R5 is connected to a low-impedance source of variable dc voltage. This voltage is then lowered so that crystal 2 cuts in at the proper voltage. This voltage will be determined by the amount of curvature that can be tolerated in the output waveform prior to the point of cut-in of crystal 2. When this voltage point has been established, the ratio of R4 to R5 is adjusted so that the initial slope of that portion of the curve produced by crystal 2 is essentially equal to the average slope of that portion of the curve produced by cyrstal 1. The R5 return voltage may then require slight readjustment. The same procedure is then followed with the other crystal networks until the output waveform approaches a straight line (sawtooth) over the whole

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range of the hyperbolic input voltage. The final voltage readings from the low-impedance voltage supplies are recorded, and resistive voltage-divider networks operated from a common supply voltage are designed to replace the low-impedance supplies. The over-all impedances of these networks must be equal to those of the original (R3, R5, R7, R9, and R11 respectively).

The output voltage from the CMPD is of the order of 2 volts for a 60% frequency-modulated signal (4 to 1 hyperbola voltage ratio and 16-to-one slope ratio.) This voltage must be amplified about ten times before it is applied to the input of the crystal-matrix voltage inverter. (A crystal matrix is very difficult to design if the voltage intervals between crystal cut-in points are too small; and the fact that the diodes are imperfect switches, each with a different conduction-current-vs-voltage curve, would make the characteristics of the output waveform too strongly dependent on the diode characteristics.) A low-distortion amplifier having inverse feedback was designed to perform the required amplification. Figure 4 is a circuit of the complete voltage inverter designed to take care of a 55% frequency-modulated signal. It should be noted that the voltage divider for crystal 1 is returned to a slightly negative voltage to assure good conduction of this crystal for signals of low amplitude.

Adjustment

The voltage inverter is connected to the output of the CMPD and a 50% sine-wave-modulated frequency-modulated signal supplied from a complex-modulated pulse generator[2] is sent through the CMPD. The proper frequency deviation can be accurately checked by observation of the pulse signal on a conventional multigun pulse analyzer such as the AN/SLA-2. The gain and bias controls, R_A and R_B, are adjusted for minimum second- and third-harmonic distortion. A harmonic analyzer is necessary to make this adjustment. For a 50% modulated signal, the total harmonic distortion in the output signal should not run over 5% as compared to the 25% distortion entering the voltage inverter.

CONCLUSION

Tests have indicated that the modifications of the Complex Modulated Pulse Demodulator result in considerably improved operation with respect to circuit instability due to normal supply voltage and circuit component variations. The improved pulse frequency modulation voltage inverter has proved sufficiently stable to justify its inclusion in the demodulator previously reported.

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[2] Holmes, J. C., "An Improved Complex Pulse Modulation Simulator," NRL Report 4184 (Confidential), July 30, 1953

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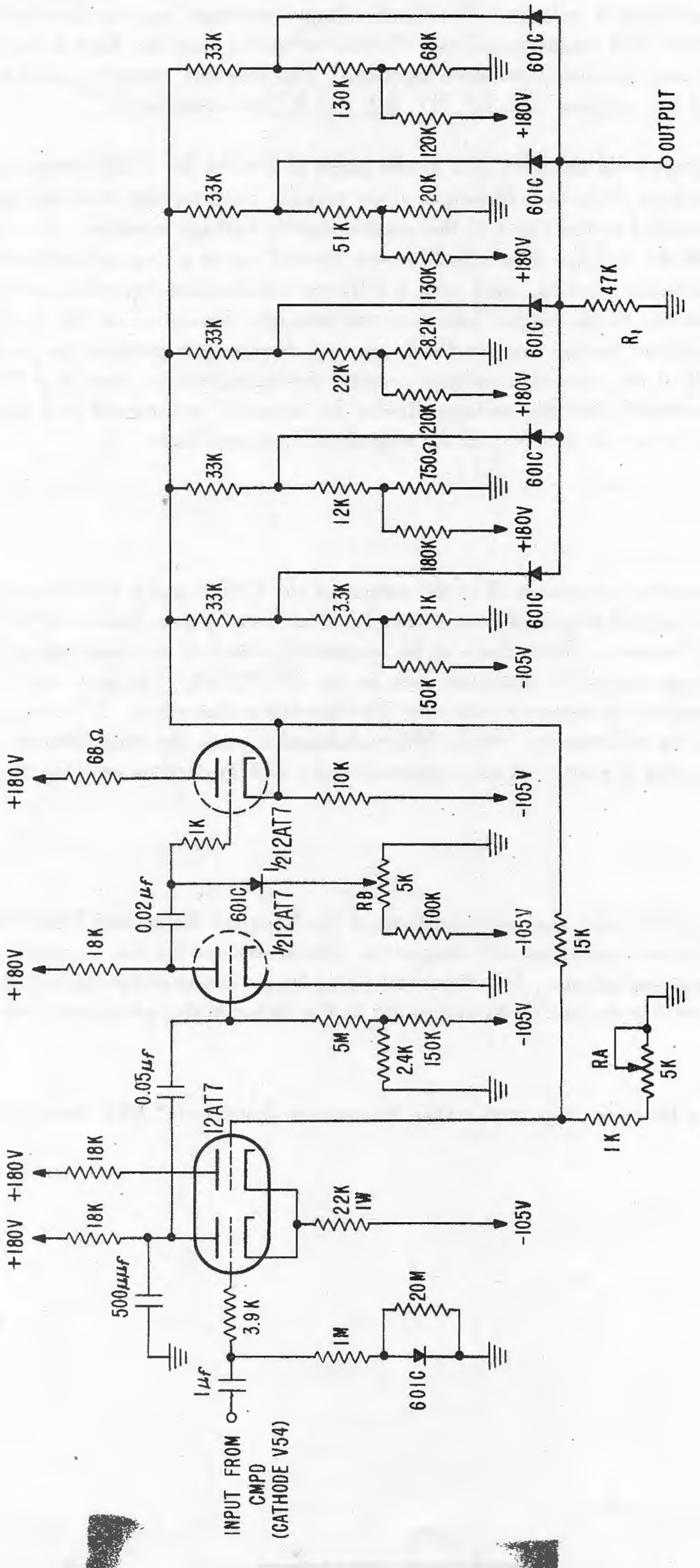

Fig. 4 - Complete circuit of voltage inverter

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APPENDIX A

Additional Changes on Complete Circuit Diagram

The following changes were not mentioned in the text:

1. Change plate load resistor in V6B to 56k.
2. Change resistor shunting SW6 to 56k.
3. Change cathode resistor in V16B to 680 ohms.
4. Insert 1k resistor in series with crystal diode in ringing circuit in the PM contact of SW8.
5. Interchange 750 ohm and 560 ohm resistors in WM contact of SW8 and SW13.
6. Eliminate 33-$\mu\mu$f capacitor connecting PM contacts of SW8 and SW13.
7. Insert 500-$\mu\mu$f capacitor between cathode of V18 and PM contact of SW13.
8. Insert 6.2k and 6.8k resistors in grid circuit of V22B.
9. Change resistor in grid circuit of V22A to 20k.
10. Change cathode resistor in V24A to 1.2k.
11. Eliminate capacitor from R16 to ground. Insert 10k resistor in the R16 arm lead.
12. Change grid resistor in V51B to 20M.

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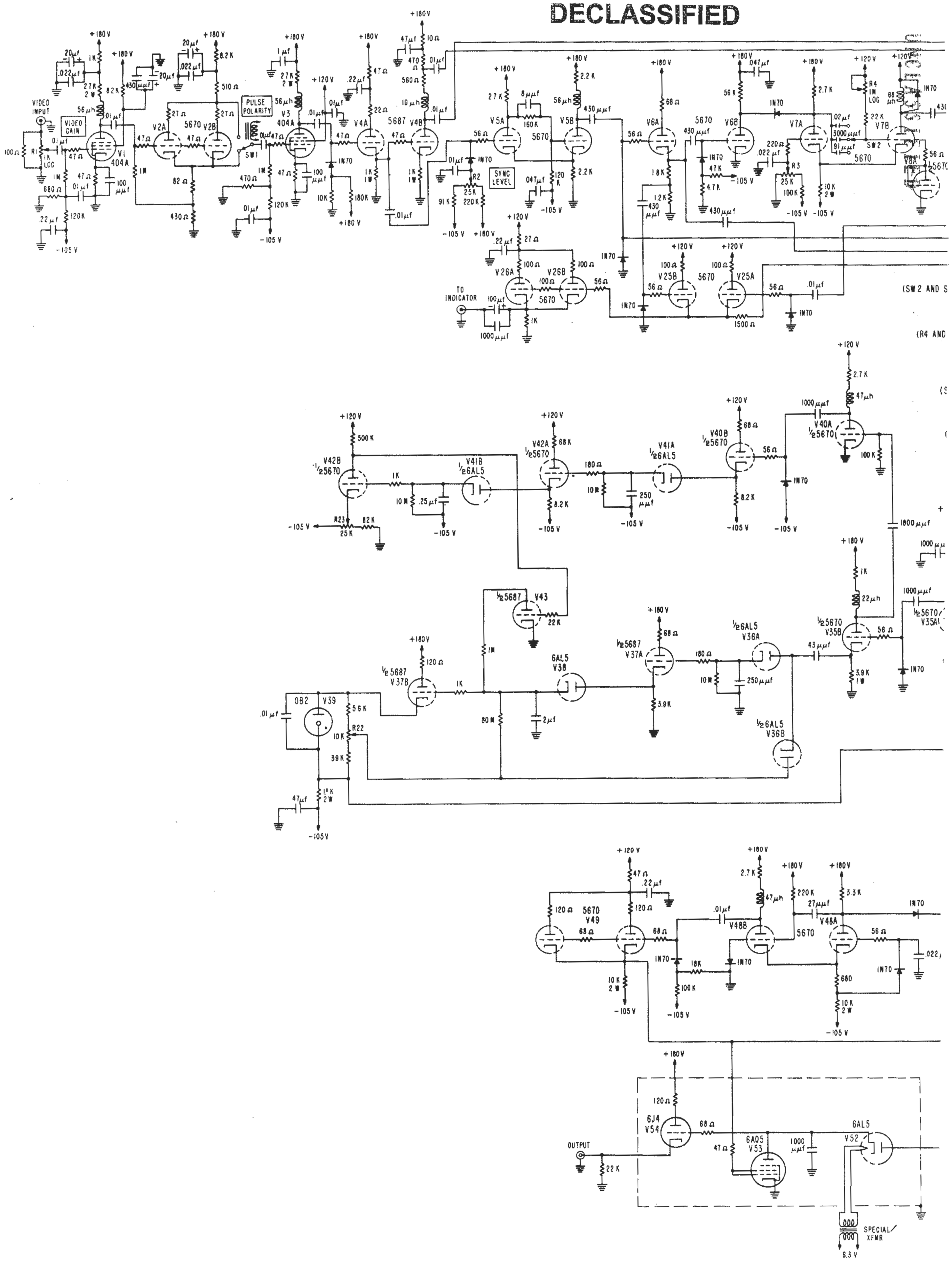

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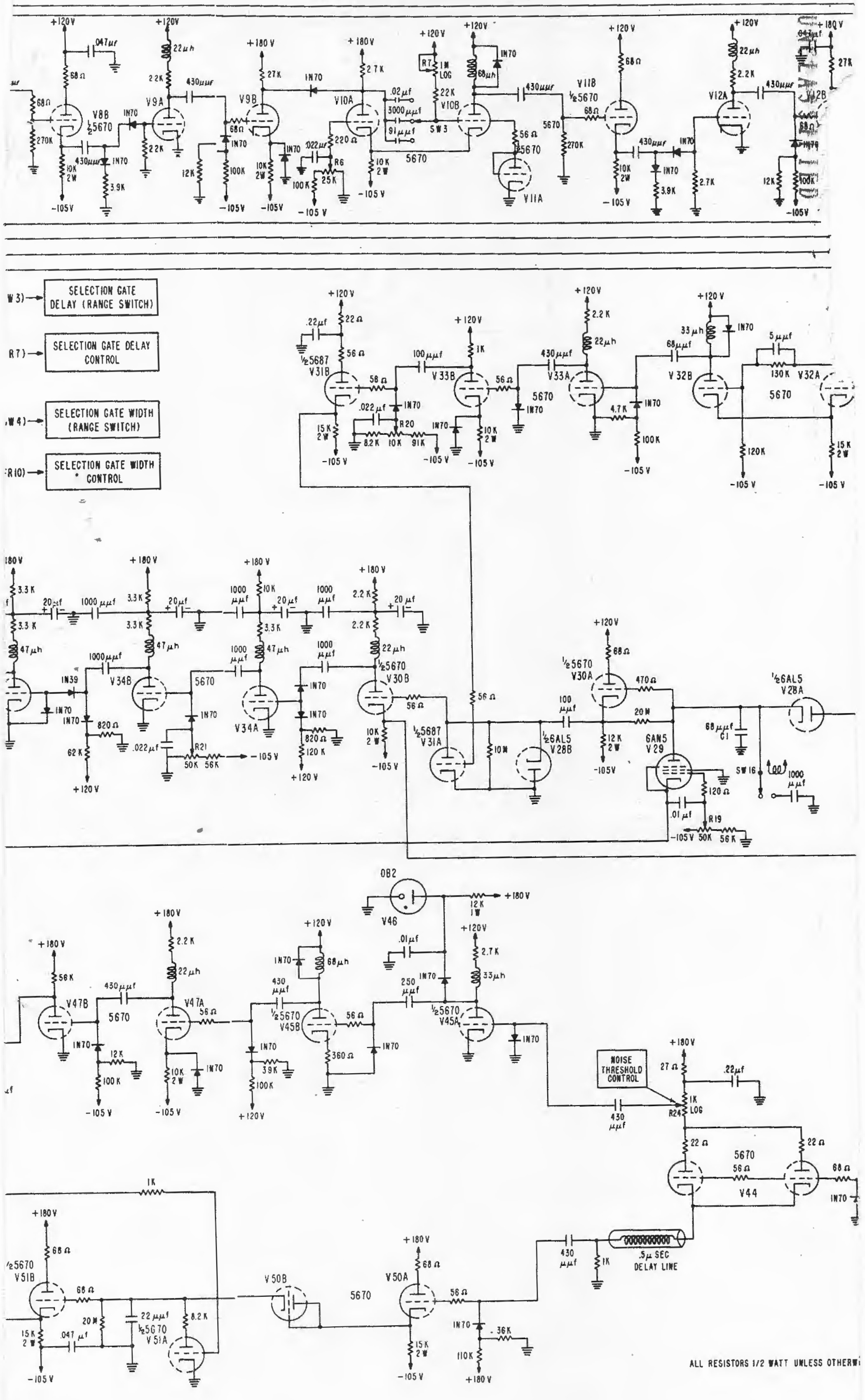

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PLATE 1 — SCHEMATIC DIAGRAM OF COMPLEX-MODULATED-

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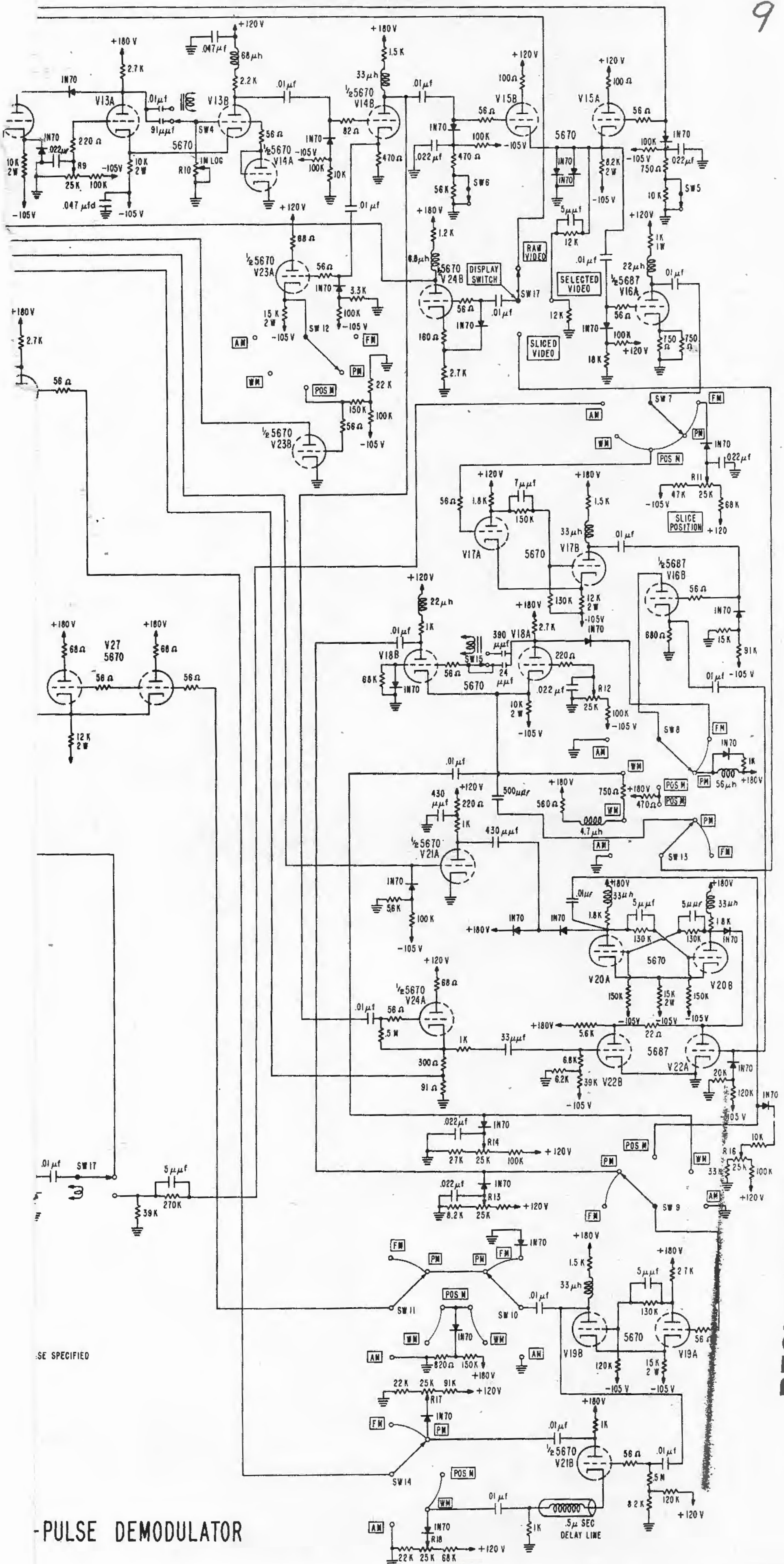

-PULSE DEMODULATOR

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