TM 9-5000-19

DEPARTMENT OF THE ARMY TECHNICAL MANUAL

NIKE I SYSTEMS
TARGET TRACKING RADAR RANGE AND PRESENTATION CIRCUITRY (U)

DEPARTMENT OF THE ARMY • MAY 1956

CONFIDENTIAL—Modified Handling Authorized 213-CB-MH-21

DEPARTMENT OF [illegible] ARMY
WASHINGTON 25, D.C. [illegible]

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USAR: None.

For explanation of abbreviations used, see SR 320-50-1.

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PART I

TARGET TRACKING RADAR RANGING SYSTEM

CHAPTER 1

INTRODUCTION

1. Purpose and Scope

a. Purpose. The purpose of this text is to present to the officers and technicians who will maintain the Nike I systems an understanding of the functions and circuitry of the target-tracking radar range and presentation systems.

b. Scope. This text contains a complete discussion of the range and presentation systems of the target-tracking radar from two viewpoints. First, a block level discussion and, second, a detailed functional study at schematic level. Each discussion is keyed to a diagram and will explain the diagram. The diagram in turn will aid in the understanding of the text. Part I of this text will contain the target-tracking radar range system and Part II, the presentation system.

2. References

Unless otherwise stated, a reference in this text will be to TM 9-5000-25, Nike I Tracking Radar Schematics. This schematic book has figure numbers assigned to each block diagram and schematic drawing. The figure numbers in TM 9-5000-25 are all hyphenated, for example, 1-2 or 1-2.1. Reference to figure numbers that are integers are to figures within this text. The system running sheets (TM 9-5000-25) will be referred to by sheet number, i. e., SH 29. For adjustments concerning chassis or assemblies contained in this text, refer to TM 9-5000-23, Nike Ground Guidance Checks and Adjustments.

3. Range System Operation

a. General. The major function of the ranging system is to generate a pulse which is delayed from transmittal time by a time accurately proportional to a shaft position. This generated pulse is used within a closed-loop type servo system to position the brush arm of a selector potentiometer whose output voltage will be representative of target slant range. In a pulse-echo type radar system, range is determined by measuring the time interval between transmission of the r-f pulse from the antenna and its return to the antenna after reflection from the target. Since the speed of r-f energy in free space is known, it is only necessary to determine the time interval between the transmitted pulse and target echo return and make the information available in a usable form. (The velocity of r-f energy is that of light, 186,272 miles per second, or 328 yards per microsecond.) For example, assume that a pulse is transmitted toward a target which is 16,400 yards distant. When the pulse reaches the target, it has traveled 16,400 yards at the rate of 328 yards per microsecond, and 50 microseconds have elapsed. The pulse is reflected with some of the energy being returned to the radar. The return trip, of equal distance, requires a second 50-microsecond period, making the total elapsed time 100 microseconds. As the distance traveled by the energy is twice the range of the target, the effective velocity may be considered to be half its true value, or 164 yards per microsecond. Precise range determination requires accurate measurement of the extremely short time intervals encountered. The tracking radars measure range by introducing an accurately calibrated variable delay between the transmitted pulse and the appearance of a movable range marker. This marker is kept in alinement with the receiver echo pulses on the tracking scopes by controlling the phase of a sine wave which is synchronized with the transmitted pulse. The amount of phase shift determines the time of redevelopment of the movable range marker and, therefore, provides a means of measuring time in terms of the period of the sine wave. The phase of the sine wave is shifted by rotation of the range handwheel. In this manner, the range notch is moved along the baseline of the tracking indicators to the position of the target echo. Rotation of the range handwheel also positions the track range dials, and the brush arm of the range data potentiometer. The brush arm picks off a d-c voltage whose amplitude is proportional to the slant range of the target. This slant range voltage is sent to the computer for use in prediction of future position and development of steering orders. Whether tracking is manual, aided, or automatic, the principle of operation is similar. Thus the phase of the sine wave is shifted, the range notch is moved along the baseline of the tracking indicators, and the range dials and the brush arm of the range data potentiometer are properly positioned.

b. Functions.

(1) The ranging system provides continuous target slant-range data for the computer and remote range dials.

(2) This system provides various gates, marks, and signals for target-tracking radar receiving and presentation systems.

(3) As determined by the setting of a MAN-AID-AUTO selector switch located on the target-tracking radar control drawer at the operator's position, this system may operate in any one of three modes. The automatic mode is functionally desirable, due to greater accuracy, but either of the other modes may be used when acquiring a target or tracking through interference. These three modes will be covered in more detail in the discussion of the range servo circuits.

c. Overall Block. Figure 1–2.1 shows the relationship of the range system to the other major blocks of the target-tracking radar. It is suggested that the reader makes and retains a mental picture of this figure to facilitate a proper understanding of the range system. As can be seen from figure 1, the range system can be broken down into three major parts when the range system is used in automatic operation. These are the range determination circuits, automatic ranging circuits, and the range servo circuits. (The range slew circuits, range calibrator, and the control circuitry is discussed in chapters 6, 7, and 8 respectively, of this text.)

The range determination circuits generate a calibrated, variable radar range mark. In automatic range tracking, this range is compared to the target range in the automatic ranging circuits. The range servo circuits then adjust the range determination circuits until the generated radar range is equal to the target range. The range mark can then be used to supply target range data. From figure 2 it is apparent that the range system can be further broken down into eight major sub-assemblies. (LPSA 6 and 7 are identical units.)

Each will be discussed in detail along with its relationship to the other units. Which of these units are used to position the range system at any particular time is determined by switch and relay action, or in other words, by mode of operation. The slew control circuits position the system when acquiring a target from the acquisition radar, or during manual slewing. The range calibrator is used only during the range calibration procedure. The handwheel assembly and LPSA 7 are used in manual and aided operation. The range error detector, range modulator, and LPSA 6 drive the range servo in automatic operation. The ATC unit will cause the system to coast on stored rates if the target is lost during automatic tracking. The range unit assembly consists of: the timing wave generator; the range mark generator; numerous motors, synchros, dials, gears, and tachometers. Also contained in this assembly

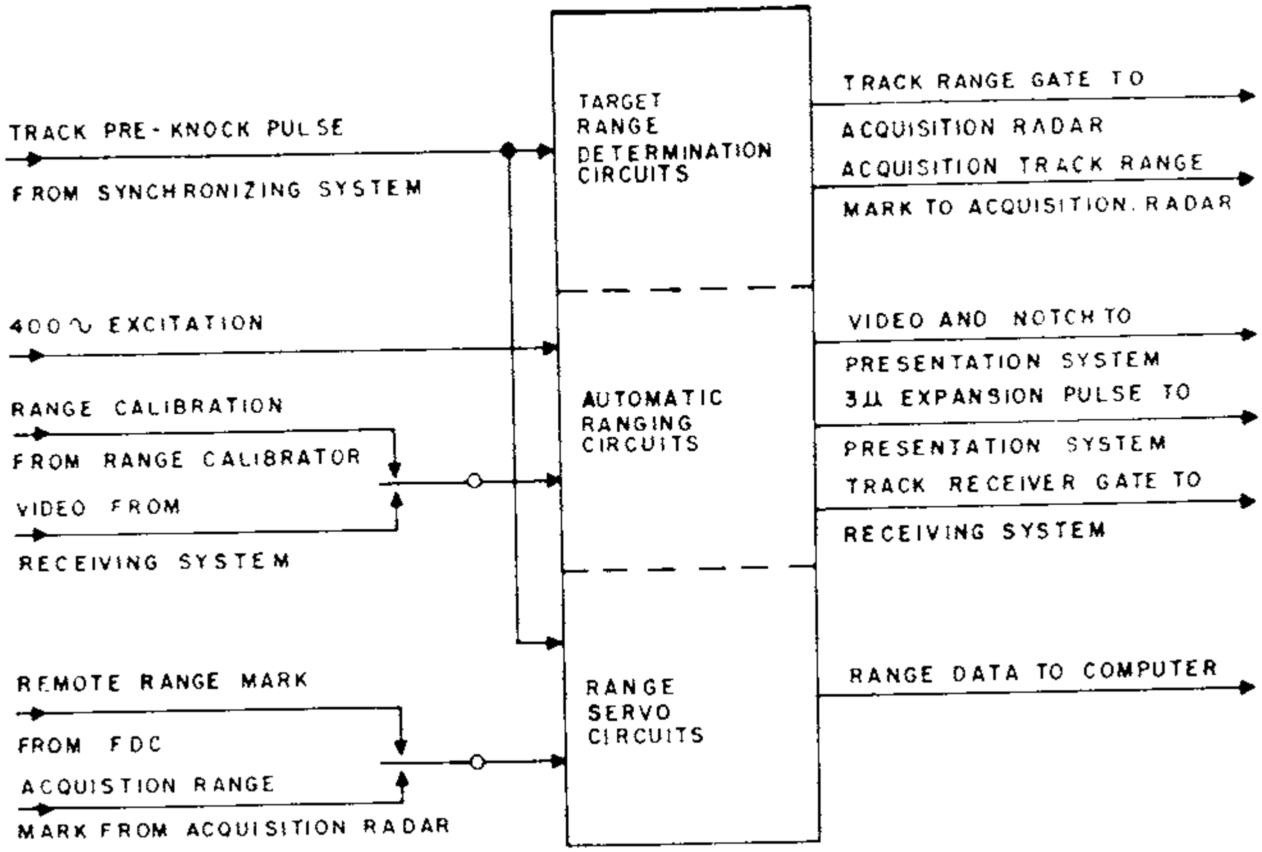


Figure 1. Target ranging system, functional block diagram.

is the range data potentiometer from which is obtained the slant range voltage that is necessary for computer functioning. The range unit assemblies are located in the radar range and receiver cabinet. (Both target and missile radars use identical assemblies.) The range system determines the range setting of the target-tracking radar and thereby the range input to the computer. The range unit assembly, an integral part of the range system, develops signals which are the basis for range determination. The outputs of this unit are used to trigger the expansion pulse channel of the range error detector; to help produce the electronic cross; to gate the precision indicator of the radar control trailer in range; and when the ACQUIRE switch is operated, to cause the target range system to slew to the range setting of the acquisition radar.

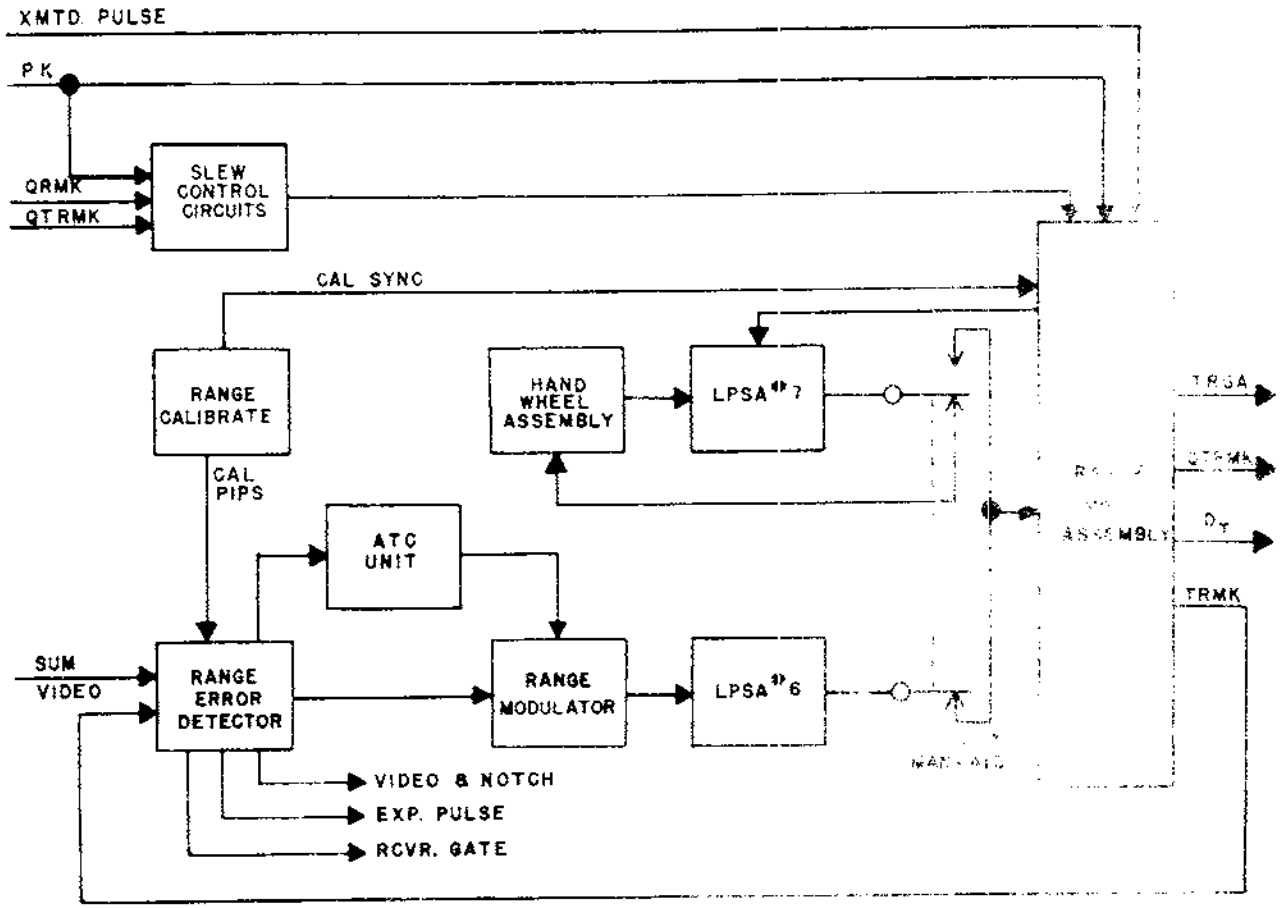


Figure 2. Target range system, simplified block diagram.

CHAPTER 2

RANGE UNIT ASSEMBLY

Section 1. BLOCK DIAGRAM DISCUSSION

4. Timing Wave Generator

[illegible]

The timing wave generator [illegible] develops a timing [illegible] time and is sufficiently [illegible] easily varied in phase [illegible] the [illegible] main gate generator [illegible] oscillator, phase-shift [illegible] tentiometer and the calibrating system.

a. Main Gate Generator. The main gate generator section [illegible] and V2. The two halves of V1 are connected [illegible] circuit is triggered by the transmitted [illegible] 100 volts negative in amplitude, approximately [illegible] the [illegible] in conjunction with V1 [illegible] V2 would be about 100 [illegible] which [illegible] since its [illegible] made [illegible] mitted pulse when switch [illegible] Relay K2 is energized when the transmitter is [illegible] When [illegible] placed in TEST and the TEST [illegible] energized causing the pickoff [illegible] or the pickoff pulse will trigger the main gate generator. [illegible] is applied to the 82KC [illegible]

b. Oscillator. The oscillator section includes the two halves of V[illegible] by the main gate and [illegible] frequency of 82 KC. [illegible] circuit of V[illegible]. When V[illegible] the tank circuit [illegible] When V[illegible] oscillates with constant amplitude [illegible]. The tank circuit [illegible] temperature in order to stabilize the [illegible] output [illegible] an 82 KC sine wave taken from the cathode of V[illegible]

c. Cathode Follower V[illegible] and Transformer T1. Tube V[illegible] in parallel. The primary of [illegible] into the secondary of transformer T1 producing two outputs [illegible] out of phase with the oscillator output. These two outputs are [illegible] networks and phase-shifting capacitor C9. These phase [illegible] of which leads the oscillator output by 90° and the other lags [illegible] phase-shifting capacitor C9. Thus, there are four sine wave voltages [illegible] capacitor which have 0°, 90°, 180°, and 270° phase relationships [illegible]

d. Phase-Shift Capacitor. Capacitor C9 couples varying amounts of the four [illegible] to the feedback amplifiers depending upon the position of a dielectric [illegible] within the capacitor. This disc is so geared to the range system that it makes one revolution for each [illegible] 360° phase shift of the timing wave.

e. Feedback Network. The phase-shift capacitor C9 may be considered as a coupling capacitor. Its capacitance is small and would not normally be a good coupling circuit. However, to improve this deficiency, feedback is used to increase the input impedance of V5A and the time constant of this coupling circuit.

f. Selector Potentiometer. The selector potentiometer R19 is helically wound and driven by gearing from the phase shift capacitor. The output is a d-c voltage which is applied to the phantastron circuit of the range mark generator. This voltage allows the expansion pulse and the range marks to be moved continuously in range. If this voltage should fail, the expansion pulse and range mark would move in range, then jump 2,000 yards in the opposite direction, always remaining within a 2,000 yard interval.

g. Calibrate Synchro. Synchro B3 is used only when the range system is being calibrated. It causes the range system to be positioned in 2,000 yards increments.

5. Range Mark Generator

(fig. 8–21)

The range mark generator consists of the pip generator channel, phantastron (variable delay) channel, first selector gate generator, first pip selector, range gate generator and cathode follower, the second selector gate generator, second pip selector and acquisition track range mark channel.

a. Pip Generator Channel. This channel consists of amplifier V1A; the positive clipper circuit CR1, CR2, CR7, CR8; Squarer V1B; differentiating amplifier V2A; and clipper-amplifier V2B. The pip generator channel squares, then differentiates the timing wave to produce a positive pip whenever the timing wave passes through zero in the positive direction.

b. Phantastron. (Variable delay channel.) The phantastron has two inputs, the variable voltage from selector potentiometer R19 and the target preknock pulse. The preknock pulse is applied to tube V5A whose positive output pulse triggers phantastron V6. The output of V6 is a negative square wave whose duration is controlled by the voltage from the selector potentiometer R19. Tube V7A speeds the recovery time of the timing capacitor of the phantastron. Tube V5B serves to clamp the plate of the phantastron to the voltage appearing at the brush arm of potentiometer R19. The output of the phantastron is differentiated and amplified by V7B and applied to clipper V8A where the positive pulse is clipped. The resultant output is a series of negative pulse which are coincident with the trailing edge of the phantastron output waveform.

c. First Selector Gate Generator. One-shot multivibrator (V8B and V9A) is triggered by the negative pulse from V8A. The negative square wave at the output of V9A is applied to a quarter-cycle oscillator Z2. The negative 11.0 microsecond gate developed by Z2 is clipped, inverted, and amplified by V9B, and then applied to the first pip selector.

d. First Pip Selector, V10. Tube V10 serves as a coincidence detector and can conduct only when the control and suppressor grids are positive simultaneously. Inasmuch as the positive pips appearing at the control grid are separated by 12.2 microseconds, only one of the pips can be coincident with the 11.0 microsecond gate at the suppressor grid. Due to the phase-shifting capacitor and the pip selector potentiometer being driven by the same gear train, the same pip will be gated from zero to maximum range. The output is a series of negative pulses which are applied to the range gate generator.

e. Range Gate Generator V11 and Cathode Follower, V12A. Tube halves V11A and V11B form a one-shot multivibrator. It is triggered by the negative pulse output from V10. The output of the multivibrator is a positive square wave 30 microseconds in duration, or equal to 5,000 yards. This signal is applied to cathode follower V12A and to the second selector gate generator. The output from the cathode follower is the track range gate (TRGA) and is used to gate the acquisition indicators.

f. Second Selector Gate Generator V3, Z1 and Second Pip Selector V4. V3A, Z1, and V3B form the second selector gate generator which produces a positive 14.0 microsecond pulse starting slightly later than the first selected pip due to inherent circuit delays. This pulse is applied to the suppressor grid of the second pip selector V4 when switch S2 is in the TARGET position. The train of 2,000 yard pips is applied to the control grid. Tube V4 is a coincidence detector similar to V10 and will conduct only when both the control and suppressor grids are positive at the same time. This will occur when the pip following the first selected pip appears (12.2 microseconds later). The output of this stage is the track range mark (TRMK) and is applied to the range error detector.

g. Acquisition Track Range Mark Channel. The positive track range gate applied to the input to V12B is clipped, amplified, and inverted. This negative 30-microsecond pulse is applied to Z3, a quarter cycle oscillator. Z3 yields a negative square wave 14.3 microseconds in duration. This signal is amplified by V13A and V13B. The square wave is differentiated in the plate circuit of V13B and the input circuit of V14. Tube V14 is operated near cut off so that the negative pips have little effect upon its conduction. The positive pips, however, cause a surge in plate current and a positive pulse will appear at jack J7. This is the acquisition track range mark (QTRMK). This signal is applied to the acquisition indicators. It is also applied to the target range slew control unit for use in transferring a target from the acquisition radar to the target-tracking radar.

Section II. DETAILED SCHEMATIC ANALYSIS

6. Timing Wave Generator

(fig. 8-3.1)

a. Main Gate Generator. Tubes V1 and V2 form the main gate generator. V1A, V1B and V2B are connected as triodes, while V2A is connected as a diode. A variation of circuitry in the multivibrator is that the plates of V1A, V1B, and V2A are tied to ground and the cathodes are tied to minus 250 volts, making ground B+ for the circuit. The two sections of V1 form the multivibrator. In a quiescent condition, V1B is conducting since its grid is returned to B plus. Current flow through resistor R2 causes the cathode of V1A to be sufficiently positive with respect to the grid that V1A is cut-off. The plate of V1A is connected directly to the grid of V2B. Tube V2B functions as a cathode follower so that the voltage appearing at the plate of V1A is reproduced at the cathode of V2B and is coupled by capacitor C4 to the grid of V1B. When a positive pulse is applied to the grid of V1A, multivibrator action takes place, resulting in V1A conducting and V1B being cut-off. V1B is held cut-off due to the discharging of C4 through resistors R6 and R7, the minus 250 volt supply, and resistor R10. When capacitor C4 has discharged sufficiently to allow V1B to again conduct, multivibrator action occurs and V1A is cut-off while V1B conducts. The charge path of capacitor C4 is through V2B, the minus 250 volt supply, capacitor C3 and V2A. The cathode of V2A is held at a negative voltage as determined by the voltage divider resistors R8 and R9. V2A keeps the grid of V1B at this potential when V1B is conducting. When V1B is cut-off, the plate of V2A is negative with respect to its cathode and is cut-off. When the grid of V1B swings more positive than the cathode of V2A, V2A conducts and quickly charges capacitor C4. If V2 were not in the circuit, the charge path of capacitor C4 would include resistor R3, the minus 250 volt supply resistor R2, and the grid-to-cathode resistance of V1B. A comparison of the two charge paths reveals how the charging time constant of capacitor C4 is shortened by the use of V2. The output of the multivibrator is taken from the plate of V1A and applied to the 82kc oscillator (V3). Capacitor C4 is paralleled by capacitor C5 to enable the multivibrator to produce an output sufficiently long for the maximum range of the target-tracking radar. Switch S1 is a bus bar connection between two terminals. This connection must be made when the unit is used in the target-tracking radar and must be open when used in the missile-tracking radar. The main gate potentiometer R6 is used to control the duration of the output of the main gate generator.

b. Oscillator. Tube V3B and Z1 form an oscillator which is activated by the main gate. In the quiescent condition, V3A is conducting and the tank circuit Z1 cannot oscillate. During this time, current is flowing through the inductor of Z1 and tube V3A setting up a magnetic field about the inductor. When V3A is cut-off by the main gate, the magnetic field collapses, tending to keep the current flowing and causing oscillations in the tank circuit. These oscillations are coupled directly from the tank circuit to the grid of V3B. The cathode of V3B is connected to a tap on the inductor and a series-fed Hartley oscillator is formed. Positive feedback from V3B to the tank circuit causes these oscillations to continue and to be of constant amplitude. When V3A again conducts at the end of the main gate the tank circuit is heavily damped and the oscillations die out very rapidly. A 120 volt a-c signal is applied to terminals [illegible] and 8 of Z1 for use in the heater. Capacitor C6 provides a means of tuning the tank circuit. The output of the oscillator is taken at the cathode of V3B and applied to cathode follower V4.

e. Cathode Follower V4, Transformer T1, and Phase Shift Capacitor C[illegible].

(1) The method of phase shifting employed here requires that the master timing wave be first converted to a four-phase alternating voltage. The conversion is first done in the phase-shifting network. The quadrature network, which splits the given single phase into four phases, operates most accurately at a low impedance. Considerable current amplification is therefore required for driving the quadrature network. This current amplification is provided by the dual triode V4 whose two sections are parallel-connected in a cathode follower circuit. The input to the grids (pins 2 and 7) is applied from the cathode (pin 8) of V3B through capacitor C[illegible]. Resistors R13 and R15 in the grid circuits of V4 are parasitic suppressor.

(2) Quadrature network T1 splits the single-phase voltage into four phases, each being in quadrature (90 degrees out of phase) with the two adjacent phases. A simplified schematic of T1 is shown in figure [illegible]. The components of this network are labeled as follows: the resistor and capacitor connected to terminal 4 of T1 are R1 and C1; the resistor and capacitor connected to terminal 5 are R2 and C2. The operation of the quadrature network will now be explained in terms of the simplified schematic and the vector diagrams shown in figure 3. The four outputs E_1, E_2, E_3, and E_4 of the quadrature network are referred to point G in the vector diagram, which corresponds to ground in the schematic.

$$E_1 = E_{GB} \quad (1)$$
$$E_2 = E_{GA} \quad (2)$$
$$E_3 = E_{GD} \quad (3)$$
$$E_4 = E_{GC} \quad (4)$$

Since C and A are at opposite ends of the transformer secondary winding E_{GC} (E_4) and E_{GA} (E_2) are 180 degrees out of phase as shown on the vector diagram. (According to the usual convention, the vector starting at point G and ending at point C represents amplitude and phase of the alternating voltage at point C with respect to point G.) The voltage across resistor R1, i. e., voltage E_{DA}, and the voltage across capacitance C_1, i. e., voltage E_{CD}, will now be determined. When an alternating voltage is applied across a series R-C circuit, the voltage across the capacitor lags the voltage across the resistor by 90 degrees. Since the vectors (vector from point A to point D on the vector diagram).

$$\overline{DA}+\overline{CD}=\overline{AB}+\overline{BC}=\overline{CA} \quad (5)$$

$\overline{DC}$ and $\overline{AC}$ form a right triangle with the right angle at point D. Consequently, point D must lie on a semi-circle with $\overline{AC}$ as the diameter, this being the locus of all points so that $\overline{AD}+\overline{DC}=\overline{AC}$ and $\overline{DC}$ lags $\overline{AD}$ by a right angle. The position of D on the semi-circle depends on the ratio of capacitive reactance to resistance. Capacitor C1 is adjusted so that its capacitive reactance (at 81.947 kc) is equal to the resistance of R1. Then the length of vector $\overline{AD}$ must equal the length of vector $\overline{DC}$. This fixes the point D vertically above G. Point B on the vector diagram is determined in a similar manner. The voltage across capacitor C_2 (voltage E_{BA}) lags the voltage across R2 (E_{CB}) by 90 degrees. Accordingly, vector $\overline{AB}$ lags vector $\overline{BC}$ by 90 degrees. Capacitor C2 is adjusted so that its capacitive reactance (at ≈ 81.947 kc) is equal to the resistance of R2. This makes $\overline{AB}$ and $\overline{BC}$ equal in length, and fixes point B on the lower semi-circle vertically below G. Thus it is seen that the output voltages, E_1, E_2, E_3 and E_4 of the network are all equal in amplitude and have the required quadrature rela-

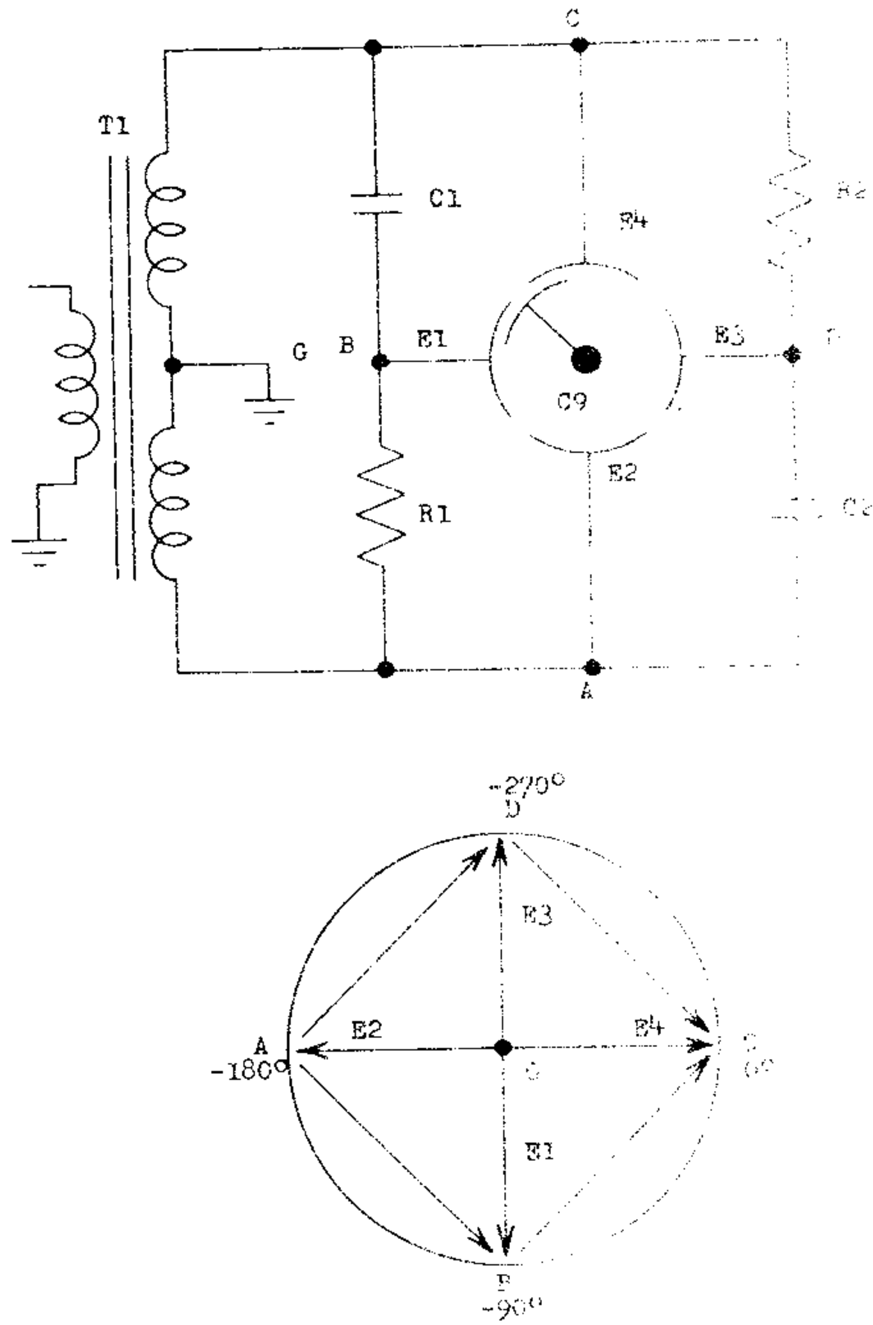
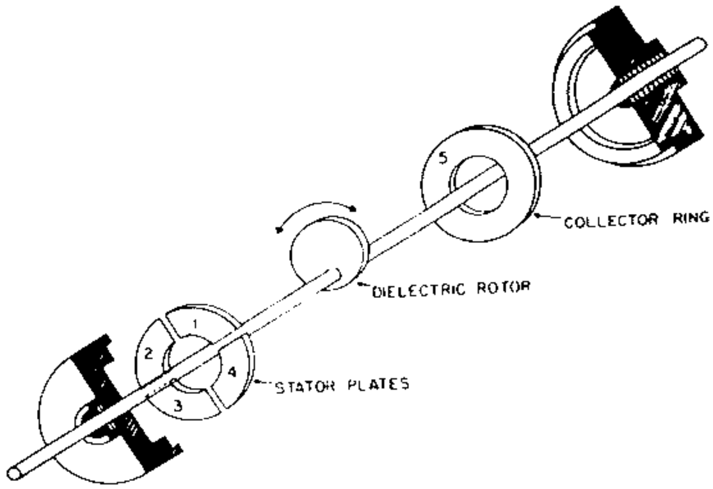


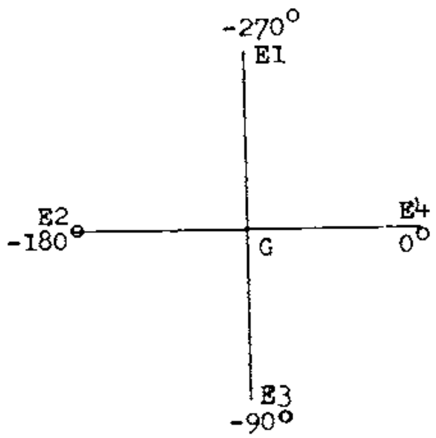
Figure 5. Phase shifter and vector diagram.

tionship. The two capacitors connected to plates 3 and 1 of phase capacitor C9 are used to achieve capacitance balance of the transformer secondary winding with respect to the center tap.

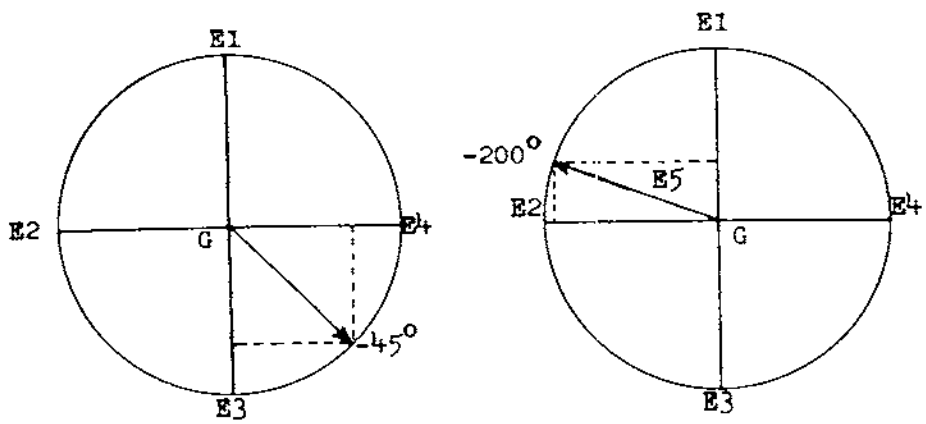
(3) The four output phases of the quadrature network are applied to the four stator plates of the phase-shift capacitor C9. The purpose of the phase-shift capacitor is to yield a voltage whose phase relationship with respect to the timing-wave oscillator output is continuously variable and equal to the angular displacement (amount of rotation) of the rotor shaft. The construction of the capacitor is shown in A of figure 4.



A. Phase shift capacitor, functional diagram



B. Voltages applied to stator plates



C. Output voltages for various rotor settings

Figure 4. Phase shift capacitor, functional and vector diagrams.

The four-quadrature stator plates 1, 2, 3, and 4 are of equal area. Collector ring 5 has an area equal to the total area of the four stator plates and is parallel to them. All five electrodes, the four stator plates and the collector ring, are inserts integrally molded with the insulating supporting member. The rotor, a dielectric disc eccentrically mounted on the shaft, is located between the stator plates and the collector ring. The capacitance between any one stator plate and the collector ring gradually increases as the space separating both is gradually filled with the dielectric material of the rotor. The phase relationships of the voltages on the various stator plates are shown by vector diagram B of figure 4. When the dielectric rotor lies directly between one stator plate and the collector ring, the capacitance between this stator plate and the collector ring will be many times greater than the capacitance between any of the other stator plates and the collector ring, and the phase of the voltage picked up on the collector ring will be very closely the same as that applied to the stator plate. When the rotor covers portions of two adjacent stator plates, the phase angle of the voltage picked up by the collector ring will depend on the relative magnitude of the voltages picked up from each stator plate. It will lie between the phase angles of the two stator plate voltages. The vector diagrams in C of figure 4 indicate the relationship between the phase of the output voltage and the angular rotation of the control shaft. The output voltage is determined by the magnitude and phase angle of the vector sum of the four voltages fed from the four stator plates to the collector ring. It is seen that this resultant output voltage has a constant amplitude, represented by the radius of the circle, and a phase angle equal to the angular displacement of the rotor from that stator plate whose voltage has zero phase angle.

d. Feedback Amplifiers V5A and V5B. Phase shift capacitor C9 may be considered as a coupling between T1 and the feedback amplifiers. It has a small capacitance, therefore it is not normally a good coupling circuit. To create a better coupling circuit, negative feedback is used between V5B and V5A to increase the input impedance of V5A and the time constant of the coupling circuit, thereby providing better coupling. Degeneration occurs due to the unbypassed cathode resistance of V5A and to the feedback from V5B to V5A. This feedback network consists of resistors R26, R27, capacators C12 and C13. The feedback effect on the input impedance may be seen by considering first the circuit with resistor R20 grounded. For a given input signal, a certain amount of current will flow through resistor R20 and capacitor R9. When resistor R20 is tied to the junction of resistors R22 and R23 and the grid swings positive, the cathode also swings positive. Thus, a smaller voltage appears across resistor R20 and a small current flows through resistor R20 and capacitor C9. Since the current flow in resistor R20 is less than if it were tied to ground, resistor R20 appears as a higher resistance than it actually is and coupling is improved. The entire swing of voltage appearing at the plate of tube V5B is coupled across capacitor C13 and developed on resistors R23, R22, R26, and R27. Only that portion of the voltage appearing across resistors R22 and R23 is used as feedback.

e. Selector Potentiometer. Potentiometer R19 is in series with resistors R40 and R41 (in the range mark generator) between plus 150 volts and ground. The pick-off arm of potentiometer R19 is positioned by the range system gearing and sends a voltage to the phantastron circuit to control its output duration.

f. Calibrate Synchro B3. Synchro B3 positions the range system for calibration purposes when the RANGE CALIBRATE-ZERO switch is placed in the CALIBRATE position. Tachometer excitation is applied at all times to the rotor and S2 is grounded. When the RANGE CALIBRATE switch is operated, the voltage appearing at S1, which is tied to S3, is applied to the range coupling network and causes the range system to be positioned until zero voltage appears at S3. If the timing wave frequency is correct, the range error meter will show the same deflection for each 2,000 yard change in range.

g. Mechanical Connections and Gearing of the Range System (fig. 8–4). The phase shift capacitor is driven through gearing by the large 512-tooth gear directly connected to the range data potentiometer.

Mounted on this shaft are two dials. The lower dial rotates with the shaft and is graduated from zero to 2,000 yards. The upper dial rotates at one-fiftieth the speed of this shaft and is graduated from zero to 100,000 yards of range. These dials are used to provide a reference setting when removing the timing wave generator so that when it is replaced with the same dial readings the selector potentiometer will be correctly matched to the gearing. The dials appearing to the right of those just discussed are identical in graduation and gearing ratio. They are used to read the range setting directly when calibrating or adjusting the range system.

7. Range Mark Generator

a. Pip Generator Channel. The timing wave from the feedback amplifiers of the timing wave generator is fed to V1A of the range mark generator. Tube V1A amplifies and inverts the timing wave. The cathode resistance is [illegible] so that the full gain of the stage is not realized and operation of the stage is [illegible]. The output is coupled across capacitor C7. The right plate of capacitor C7 is maintained at zero volts by two similar voltage dividers. One voltage divider is between minus 250 volts and ground and consists of resistors R[illegible], R6 and crystal CR7. The other is between plus 250 volts and ground and consists of resistors R10 and R7 and crystal CR8. In the quiescent condition, the junction of resistor R7 and crystal CR8 is at a small positive potential and the junction of resistor R6 and crystal CR7 is at a like negative potential. Tied in series between these two points are crystals CR1 and CR2. Thus, zero voltage appears at the junction of crystals CR1 and CR2 and at the right plate of capacitor C7. When the plate swings in positive direction, electrons flow into capacitor C7 through crystal CR[illegible]. The two paths having equal resistance, capacitor C7 does not develop a charge and the right plate of capacitor C7 swings about ground potential. Crystal CR2 permits the negative swing of the output [illegible] of V1A to be passed to V1B but blocks the positive swing. The negative alternations of the timing wave [illegible] appear at the grid of V1B.

b. Square Wave Generator V1B. This stage, in the quiescent condition, conducts heavily since the grid is at a small positive potential and cathode resistance is very small. When the negative alternations appear at the grid, the stage is driven to cut off developing a square wave with steep leading and trailing edges at the plate. This square wave is applied to the differentiating circuit consisting primarily of capacitor [illegible], R16, capacitor [illegible], resistor R14, and V2A.

c. Pip Generator V2A and V2B. Differentiation of the square wave appearing at the plate of V1B produces positive and negative pips which appear at the grid of V2A. Feedback from the plate of V2A through capacitor [illegible] and resistor R16 makes these pips steeper. When the plate of V1B swings positive, a positive pip appears on the right plate of capacitor C2 and at the grid of V2A. Conduction of V2A increases due to the positive pip on the grid and the plate voltage drops. This drop drives electrons out of the left plate of capacitor C[illegible] through resistor R16 and charges quickly capacitor C2 thus sharpening the pip. The pips appearing at the plate of V2A are coupled through capacitor C6. Positive pips are [illegible] pass through resistor R11 and then shorted to ground by crystal CR1. Thus, they do not appear at the grid of V2B. Negative pips are passed by crystal CR3, blocked by crystal [illegible] and therefore appear at the grid of V2B. These pips are amplified and inverted by V2B. Feedback through capacitor [illegible] and resistor R17 further steepens the pulses. The positive pulses appearing at the plate of V2B are applied to the two pip selectors.

d. The Pip Selector Channel. The pip selector channel is a coarse ranging device acting to gate a single pip in the train of pips received from the pip generator channel. The output from this channel is the selected pip used in succeeding stages to generate the three output signals of the range unit assembly.

(1) The phantastron stage of the range unit assembly is almost identical to the one contained in the acquisition radar range unit assembly. Detailed information on this assembly will be found in TM [illegible], SECTION III, Par. [illegible]

(a) *Cathode limiting.* The major difference between this stage and the corresponding phantastron stage in the acquisition radar is in the cathode circuit of V6. Immediately following the termination of the output waveform of the phantastron, capacitor C19 charges to a value approximately equal to the voltage difference between the cathode of V6 and the brush arm of selector potentiometer R19. The charge path is from ground through resistor R47, cathode to grid of V6, capacitor C19, from cathode to plate of V7A, and to ground through the positive 250 volt supply. This charging current may tend to develop a transient peak voltage at the cathode of V6. This is prevented by action of crystal CR6 whose anode is connected to the cathode of V6 and whose cathode is connected to a large capacitor, C21. The cathode potential of V6 is prevented from exceeding the 12 volt charge provided across capacitor C21 due to voltage divider action of resistors R106 and R107.

(b) *Duration.* The duration of the output waveform is a function of the magnitude of the voltage at the brush arm of potentiometer R19. As this voltage increases, duration of the phantastron waveform also increases. The d-c control voltage determines plate voltage magnitude of V6 during the quiescent condition (when plate current does not flow in V6). When this plate voltage is relatively high, the cathode voltage of V7A is also high. In this condition, the charge across capacitor C19 (which is equal to the potential difference existing between the control grid of V6 and cathode of V7A) is low. Due to the quiescent control grid potential of V6 being unchanged, charge across capacitor C19 is relatively small. Therefore, the quiescent charge across capacitor C19 is a direct function of the magnitude of the d-c control voltage obtained from potentiometer R19. Application of the preknock pulse initiates the phantastron waveform. During the period of phantastron waveform, the control grid voltage of V6 rises until the increasing plate current, and screen-grid current, flowing through cathode resistor R47, finally increases the cathode voltage (also the suppressor-grid bias) to the point where a further rise in control grid voltage will act to reduce plate current. The output waveform of the phantastron terminates at that instant. Regardless of whether the voltage at the plate of V6 was high or low at the instant of triggering, the voltages and currents in V6 and V7 at the instant of waveform termination, are always the same. It follows that the charge across capacitor C19 is always the same at this termination. From the initiating transient to the terminating transient, the various voltages change linearly, as does the charge on capacitor C19 from its controlled initial value to its fixed value at termination. Therefore, the time required for the charge on capacitor C19 to reach its fixed terminating value is determined by the magnitude of the charge which is initially present. This intial charge is a function of the value of the d-c voltage at the brush arm of the selector potentiometer and it follows that the duration of the phantastron waveform is controlled by that voltage.

(c) *Range calibration.* Relay K1 provides a means of switching the input to the range unit assembly from the preknock or transmitted pulse, to a calibrating sync pulse. Range calibration procedure will be found in TM 9-5000-23.

(2) *Differentiator V7B and clipper V8A.* The negative rectangular waveform at the cathode of phantastron tube V6 is coupled through capacitor C20, developed across resistor R51, and applied to the control grid of triode V7B. V7B amplifies the signal. The cathode circuit consisting of resistor R53 and capacitor C22 has a time constant of 10 microseconds. The waveform applied to the grid has a duration that varies between 5.2 and 676 microseconds. Therefore, this cathode circuit will be degenerative during the long period of the waveform with capacitor C22 assuming a charge determined by the magnitude of the negative input voltage. However, the time constant is long with respect to the rapid transient which takes place at the positive going trailing edge of the phantastron waveform and no degeneration is introduced to this portion of the waveform. Hence, this portion of the waveform will receive

maximum amplification. The plate signal of V7B is applied to V8A through peaking transformer T2. This transformer is poled so that positive and negative peak signals appear at terminal 6 of transformer T2 and at the cathode of diode clipper V8A. The positive pips, coincident with the leading edge of the phantastron waveform, act to cut off V8A. However, the negative pips, which coincide with the variable trailing edge of the phastastron waveform, cause increased conduction through V8A. This increased current flows through resistor R54. Resistor R54 also serves as the grid return for the following stage and, therefore, a negative pulse is applied to the grid of V8B.

(3) *Multivibrator V8B and V9A.* This stage is a one-shot plate-coupled multivibrator designed to produce a negative output waveform whose duration exceeds 11 microseconds. Tube V8B conducts between pulses with a small positive potential at its grid. The negative potential is produced by voltage divider resistors R57 and R58. The appearance of the negative pip at the grid of V8B acts to cut V8B off and causes V9A to conduct. Regenerative action takes place by means of coupling signals from each plate to the opposite control grid. However, the exponential regenerative rise in the voltage at the control grid of V8B is not only a function of the time constant of capacitor C23 and resistor R54 but this rise is accelerated by the exponential decrease which occurs in the voltage at the control grid of V9A as capacitor C24 charges. The charge path for capacitor C24 is from the upper plate of capacitor C25 (a negative 50 volt source), through resistor R59, capacitor C24, resistor R56, R55, and through capacitor C3A to ground and to the lower plate of capacitor C25. As the grid voltage of V9A decreases exponentially, the plate voltage increases proportionately. The coupling provided by capacitor C23 causes this change to appear at the grid of V8B in addition to the change resulting from the discharge of capacitor C23. Hence, the duration of the output waveform is determined not only by the rate of discharge of capacitor C23, but also by the rate of charge of capacitor C24. The output waveform is applied to the selector gate generator.

(4) *Selector gate generator V9B.* The negative output of the multivibrator is applied to network Z2, a series L-C circuit. The straight leading edge of the applied signal appears at terminal 2 of the network and acts to cut off amplifier V9B. The capacitors of the L-C circuit then discharge through the inductance and a sinusoidal change occurs in the voltage at terminal 2. This voltage change has the form of a damped sine wave rising from the negative peak to the zero axis. The constants of the circuit are chosen so that tube V9B is returned to conduction 11 microseconds after being driven below cut-off. Therefore, a positive 11 microsecond gate pulse appears at the plate of V9B. Capacitor C26 is connected in series with the parallel capacitors of network Z2 to obtain the desired 11 microsecond period. When V9B resumes conduction, its grid begins to draw current placing a very low resistance across the inductor. The damping, thus introduced, immediately quenches the oscillation and the energy stored in the inductor is dissipated by the low shunting resistance. The positive step which occurs at the trailing edge of the multivibrator waveform, has no appreciable effect on network Z2 since, when it appears, the inductor of Z2 is shunted by the low resistance grid circuit of V9B. The output from V9B will go to suppressor grid (pin 7) of pip selector V4 when switch S2 is in the MISSILE position.

(5) *Pip selector V10.* This stage consists of coincidence tube V10 and associated circuit elements. The inputs to this stage are the 11 microsecond gate pulse from the selector gate generator and the train of positive pips (at 12.2 microsecond intervals) from the pip generator channel. When the 11 microsecond pulse and one pip of the train of pips are in coincidence, a single negative pip appears at the plate of V10. Both the control grid and the suppressor grid of V10 are biased below cut-off. Therefore, plate current can flow only when a positive signal is applied simultaneously to both grids. This occurs when a pip from the pip generator channel

is positioned within the 11 microsecond gate generated from the trailing edge of the phantastron waveform. It can be seen that a timing error may be present in the phantastron channel without introducing a range inaccuracy. For example, assume that at minimum range the selected pip is exactly centered within the 11 microsecond gate. If the phantastron introduces a total error of 4 microseconds at maximum range, the same selected pip will still be gated at maximum range. The pip will merely have moved from the exact center of the 11 microsecond gate to the point off center by the amount of the phantastron channel error (4 microseconds). The 11 microsecond width of the gate is sufficient to allow for expected inaccuracies in the phantastron channel, but is not so great as to allow two adjacent pips from the pip generator channel to be gated simultaneously.

e. 5000 Yard Gage Generator (Range Gage Generator). The function of this channel is to provide the tracking range mark (TRMK), the tracking range gate (TRGA), and the acquisition tracking range mark (QTRMK). These signals serve the following functions; the tracking range mark goes to the range error detector where it is used to trigger the unit; the tracking range gate goes to the PPI and PI indicators to form part of the electronic cross; the acquisition tracking range mark goes to the range slew control unit for target acquisition, and also to the PPI indicator to form the arc of the electronic cross. These outputs of the range mark generator are all variable in time with relation to the transmitted pulse but are not variable in time with respect to each other.

(1) *Range gate generator.* The range gate generator consists of V11 and its associated components. Its operation is that of a conventional cathode-coupled one-shot multivibrator. Between pulses V11B (pins 1, 2, and 3) is conducting and V11A is cutoff. The cathode voltage of V11B during the quiescent period is approximately 52 volts and voltage divider resistors R75 and R76 establishes the voltage on the grid of V11A at half this value, or 26 volts. Capacitor C34 acts to hold the grid at 26 volts during the time V11A conducts. The negative pulse from V10 passes through crystal CR5, which isolates V11 from the low impedance of V10 except during the period of the negative pulse to V11B. When V11B is cutoff by the negative pulse, the cathode potential drops and V11A conducts, dropping the grid of V11B to a lower value through capacitor C35. The discharge time of capacitor C35 through resistor R80 and potentiometer R79 primarily determines the width of the output pulse. As capacitor C35 discharges, the grid of V11B rises toward cutoff and the conduction of V11B returns the stage to its quiescent condition. The output pulse is approximately 30 microseconds wide and 40 volts in amplitude and is a reasonably good square wave with steep leading and trailing edges. This output may be shifted in time through the operating range of the range unit assembly and the leading edge coincides with the leading edge of this first selected pip. From the plate of V11B, the positive square wave is fed to three channels; the tracking range mark channel, the tracking range gate channel, and the acquisition tracking range mark channel.

(2) *Tracking range gate channel.* Cathode follower V12A is used because its low impedance at the output makes it suitable for coupling signals into the coaxial line to the acquisition indicators. The input is a positive 30 microsecond range gate from range gate generator V11. Another function of V12A is to make the 30 microsecond signal more square by clipping both the top and bottom. The bottom portion is clipped by biasing the tube below cutoff with a negative 24.3 volts on the grid and when the 30 microsecond signal is applied to V12A, it must raise the grid above cutoff. Any irregularities which show up on the top part of the wave are clipped when the grid draws current. This combination of baseline clipping and grid limiting produces a square wave at the output. This output is known as the track range gate, and is a positive 10-volt, 30 microsecond square wave.

f. Acquisition Tracking Range Mark Channel.

(1) *14.5 microsecond gate generator.* This stage consists of V12B, Z3, and V13A. Except for the width of the output signal, the operation of this stage is identical to that of the range selector

gate generator. The difference in width, while using the same time delay unit, is obtained by omitting the external capacitor which is used with Z2. Omission of this capacitor increases the resonant frequency of Z3. This stage is triggered by the leading edge of the 30 microsecond signal from V11B. The output from the plate of V13A is a positive square wave 14.5 microseconds wide coincident with the leading edge of the 30 microsecond signal from the tracking range gate channel.

(2) *Amplifier V13B.* This stage inverts and squares the output of the 14.5 microsecond gate generator. It accomplishes the squaring action by the use of base line clipping. The tube is biased below cut-off by a negative 37.2 bolts on the grid. When the positive 14.5 microsecond signal is fed to the grid, it must first overcome the bias before V13B conducts. This action passes only the upper portion of the wave and clips off the irregular base. The output from the plate is a negative 14.5 microsecond square wave.

(3) *Differentiator amplifier V14 and transformer T4.* The output from the plate of V13B is coupled to the control grid of V14 through capacitor C45 and developed across resistor R101. Since the R-C time constant of this coupling network is extremely small (approximately 0.06 microsecond) as compared to the 14.5 microsecond duration of the negative input signal, differentiation takes place. The signal appearing on the control grid of V14 is a negative pip followed 14.5 microseconds later by a positive pip. With V14 self-biased almost at cutoff, the negative pip has little effect on the tube current, whereas the positive pip will cause a surge of tube current and produce a negative pulse at the plate. This pulse will occur 14.5 microseconds after the leading edge of the 30 microsecond signal originating in V11. The pulse from V14 is coupled to the coaxial line at jack J7 through transformer T4 (which is so poled that the output at J7 is a positive pulse). This signal, known as the acquisition tracking range mark (QTRMK), is fed to the PPI and PI indicators and to the range slew control unit.

g. Track Range Mark Channel.

(1) *Selector gate generator V3, Z1.* This stage receives the positive 30 microsecond output from V11 and clips the top and bottom of the wave before passing it on to Z1. The action of clipping the bottom portion is similar to that described for V13B in the acquisition tracking range mark channel. When the input signal overcomes the negative 35.3 volts on the grid, the lower portions are eliminated. The upper portion of the wave is eliminated when the signal rises high enough to cause grid current to be drawn through resistor R23. Network Z1 and V3B perform actions identical to those of the range selector gate generator except that the output is a positive 14 microsecond square wave applied to the suppressor grid of V4 when S2 is in the TARGET position. Testpoint two (TP2) is provided for monitoring purposes.

(2) *Pip selector V4 and transformer T3.* Tube V4 acts as a coincidence tube. Either the negative 17.7 volts on its control grid or the negative 78.4 volts on its suppressor grid is sufficient to hold the tube cutoff. Tube V4 will remain cutoff until both bias voltages are overcome at the same time. This action takes place when one of the positive pips in the string of pips from the pip generator coincides with the positive 14 microsecond signal from V3B (or the 11 microsecond signal from plate of V9B when S2 is in the MISSILE position). The pips are applied to the control grid and the 14 microsecond (or 11 microsecond) signal to the suppressor grid. At the time of coincidence, plate current flows and a negative pip is developed at the plate. The pip selected by this stage is the one following the first selected pip if switch is in TARGET position. In the MISSILE position of switch S2, the pip selected by this stage is the first selected pip. From the plate of V4, the negative pip is sent to transformer T3 where it is inverted and coupled to the coaxial line at jack J6. This positive pip, known as the track range mark (TRMK) is sent to the range error detector.

h. Output Signals, Time Relationship and Functions. The acquisition tracking range mark (QTRMK) starts 14.3 microseconds after the leading edge of the track range gate (TRGA). This delay will cause it to appear in the center of the TRGA. These two signals are applied to the acquisition indicators to produce the electronic cross. The QTRMK, which is gated in azimuth by the track azimuth gate (TAGA), is used to produce the arc of the electronic cross. (Refer to TM 9-5000-9, chapter 6.) The TRGA will gate the track azimuth mark (TAMK) to produce the radial line of the electronic cross. The time relationship of the TRMK and the TRGA is such that the two lines forming the electronic cross will intersect at their respective centers. When the range settings of the target tracking radar and the acquisition radar are equal the QTRMK will coincide with the acquisition range mark (QRMK) and is used in the target range slew control unit to acquire the target designated by the acquisition radar operator. The track range mark (TRMK) is delayed from the TRGA and the QTRMK to establish the proper time relationship between the target and acquisition range systems. The TRMK is used only in the target range system to trigger the circuits of the range error detector.

i. Unmodified Range System (fig. 8-3). Relay K2, which determines whether the preknock pulse or the transmitted pulse will trigger the main gate generator, is not present in the unmodified range system. The preknock pulse is fed directly from contact 3 of relay K1 to jack J2 of the range mark generator. Hence, in the unmodified range system, the main gate will always be triggered by the preknock pulse, whereas, in the modified system it could start at preknock or at the time of the transmitted pulse, depending upon the condition of relay K2.

CHAPTER 3

RANGE ERROR DETECTOR

Section I. BLOCK DIAGRAM DISCUSSION

8. General

(See figs. 5, 6-1, 8-1.1, 8-5, and 8-6.) The range error detectors of the missile-tracking and target-tracking radars are identical in circuitry, purpose, and operation. Any statement with regard to the range error detector of the target-tracking radar is also applicable to that of the missile-tracking radar. This unit receives the tracking range mark from the range mark generator, and the 500 yard calibrating pips from the range calibrator or the sum video signal from the video and phase unit. Outputs from the range error detector are the mixed video and notch, 500 yard sweep expansion pulse, the 0.4 microsecond receiver gate (AGC gate), the d-c range error signal, and the automatic tracking control signal (ATC). It also develops a range gate that is used internally for time comparison with the video pulses and to produce the range error voltage. The range of the 500 yard sweep expansion pulse, the receiver gate, the range notch, and range gate are directly controlled by the range setting of the range servo system. The position of video in time is determined by the range of the target. As shown on figure 3, the range error detector may be divided functionally into several channels; the sweep expansion pulse channel, notch channel, video and notch mixer, amplifier, delay line, range gating circuit, and ATC channel. The outputs of the first four channels are generated as a result of the track range mark and

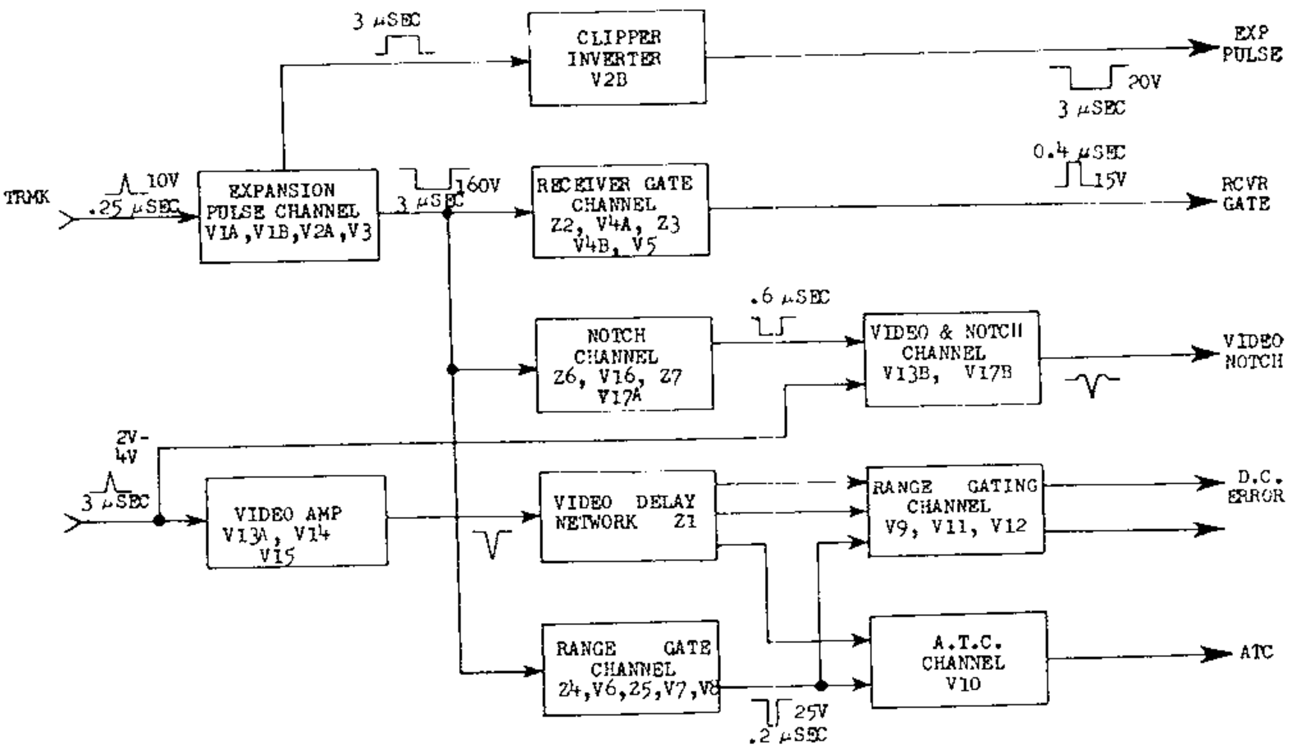


Figure 5. Range error detector, simplified block diagram.

have a fixed time relationship with respect to the track range mark. The sweep expansion pulse causes the expanded portion of the tracking indicator sweeps and is used also as a gating pulse in the angle error detector. The receiver gate pulse gates several circuits within the radar to permit operation as a result of the input from the tracked target only. The range gate is used in the range gating circuit. The notch is used in the video and notch mixer which mixes the 0.6 microsecond video and notch for application to the video circuits of the tracking indicators. The video amplifier increases the amplitude of the video in order to drive the delay line. The delay line and range gating circuit function to compare the radar range (which uses the range gate) with the target range to produce a d-c range error. The ATC channel compares the range gate with the video to produce a signal which is used in the automatic tracking control unit. The ATC unit causes the range servo system to shift from automatic to aided tracking if the target is lost and to use a stored rate causing the range system to continue at the same rate as before the target was lost.

9. Range Error Detector Channels Block Discussion

a. Expansion Pulse Channel. This channel consists of a 3-microsecond multivibrator, cathode follower, pulse inverter, and a network driver. This channel has one input, the track range mark, and produces two negative 3-microsecond pulses beginning simultaneously with the occurrence of the track range mark. One of the outputs, of a 20 volt amplitude, is known as the sweep expansion pulse, and the other, of 160 volt amplitude, is used to drive three other channels of the range error detector. The sweep expansion pulse is used in the tracking indicators to produce the expanded portion of the sweeps, and in the angle error detectors as a gating pulse to allow the angle error detectors to have outputs to the error pulse rectifier only during the 3 microsecond period about the radar range. Since it has the same polarity and duration the 160-volt pulse is also called the sweep expansion pulse. It is used only within the range error detector to trigger the receiver gate channel, the notch channel, and the range gate channel.

b. Receiver Gate Channel. This channel consists of two quarter-cycle oscillators, pulse inverter, and two cathode followers. This channel receives the 160 volt output of the expansion pulse channel as an input and produces a positive 20-volt, 0.4 microsecond pulse output starting 1.27 microseconds after the track range mark. This output is the receiver gate but is sometimes called the AGC gate. It is used as a gating pulse in the error pulse rectifiers, the AGC unit, the missile AFC unit, and the video and phase unit to permit operation of these circuits only with regard to the gated target. It allows the gain of the receiver to be automatically controlled in the AGC units as a result of the amplitude of signal from the gated target. It allows the frequency of the local oscillator to be determined by the frequency of the input signal from the gated target when the missile AFC is in use. (The missile AFC unit is used only in testing the target-tracking radar.) The receiver gate also allows the level of amplitude of the returned signal from the gated target to be monitored in the video and phase unit. The time duration of the signals in the range error detector is established by the extreme accuracy of an L-C oscillatory circuit, utilizing one quarter of a cycle of oscillation of the circuit to establish the time duration. The inductor is slug-tuned to permit establishment of an exact time duration.

c. Notch Channel. This section consists of two quarter-cycle oscillators, V6 and V17A. It receives the 160 volt output of the expansion pulse channel as an input and produces one output, a negative 0.3-volt, 0.6-microsecond pulse, occurring 1.2 microseconds after the track range mark. This output is the 100 yard range notch and is sent to the video and notch mixer. This notch is used on the tracking indicators to aid the tracking operators in manual and aided tracking of the target.

d. Video and Notch Mixer. This section consists of two amplifiers, V13B and V17B (which have a common plate load for mixing the video input to the range error detector and the notch output of the notch channel), and two parallel cathode followers V18A and V18B. The output of the video and notch mixer is a positive 0.3 volt notch mixed with the negative 1 volt video. This output of the range error detector is sent to the tracking indicators. This signal will cause a negative notch and positive video to appear on the scopes.

e. Video Amplifier and Delay Line. The video amplifier consists of three stages of amplification to amplify the video from an average amplitude of 2 volts to an amplitude of 20 volts. The final stage uses the 0.22 microsecond delay line as part of its plate load. The outputs of the video amplifier and delay line are: non-delayed video and delayed video (delayed by 0.22 microsecond) both of which are used in the range gating circuit, and mid-delay video (delayed by 0.11 microseconds) which is used in the ATC channel. All outputs are negative and normally approximately 20 volts in amplitude.

f. Range Gate Channel. This section consists of two quarter-cycle oscillators, pulse inverter, and a clamper. It receives the 100 volt output of the expansion pulse channel as an input and produces one output, a negative 25-volt, 0.2-microsecond pulse which occurs 1.5 microseconds after the track range mark. This output is the range gate (sometimes called the 35 yard range gate) and is used in the range gating and ATC channels.

g. Range Gating Circuit. Range comparison of radar range setting and target range occurs in the range gating circuit where the range gate is compared in time with the non-delayed and delayed video. The system is so arranged that when radar range setting is the same as the range of the target, the range gate will occur at the time halfway between delayed and non-delayed video. The range gating circuit consists of the non-delayed channel and the delayed channel. Each channel consists of a triode coincidence section, a diode detecting section terminated by an integrating capacitor, and a cathode follower. The range gate is applied to each channel. The more nearly coincident the video is with the range gate, the less the coincidence triode conducts. Therefore, the difference of charge on the two integrating capacitors will be indicative of the range error. The outputs of the range gating circuits are two d-c voltages acting as push-pull output. The difference of voltage will indicate the magnitude and direction of the range error. This voltage is applied to the range modulator which will produce a 400 cycle voltage, the phase of which is dependent upon the polarity relationship of the input voltages, the magnitude of which is dependent upon the magnitude of the input. The output of the range modulator is amplified by a low power servoamplifier to drive the range servomotor. The range servomotor will move the phase shift capacitor and pip selecting potentiometer. This will cause the track range mark and thus the range gate to change in range in such a direction that the range gate will move to a point halfway between the non-delayed and delayed video. Thus, by using the range gating circuit, the actual range to the target and the range setting of the radar are compared and an error signal is developed which will cause the range error to be decreased. This is one paramount requirement of an automatic ranging system.

h. ATC Channel. The automatic tracking control (ATC) unit is a device which enables automatic tracking whenever a usable signal is within 50 yards of the system range setting. This causes the system to shift from automatic to aided-manual tracking whenever this condition ceases to exist. In order to function, the ATC unit utilizes the d-c range error from the range gating circuit and the d-c output from the ATC channel. The ATC channel consists of a triode coincidence section and a diode detecting section, terminated by an integrating capacitor, which are identical to those of the range gating circuit. A time comparison is made between the range gate and the mid-delay video. The d-c voltage output will be most positive when the system is at the same range as the target.

10. Detail Block Diagram Discussion

(fig. 8-5)

a. Sweep Expansion Pulse Channel. This consists of one-shot multivibrator V1, cathode follower V2A, pulse inverter V2B, and network driver V3. The multivibrator is triggered by the positive track range mark and develops a positive 3-microsecond square wave at its output. This signal is applied through cathode follower V2A to the pulse inverter which develops a negative pulse at its output. This negative signal, equivalent to 500 yards range, is the sweep expansion pulse. It is sent to the indicators of the tracking radar and to the angle error detectors. It will be noted that the leading edge of the sweep expansion pulse occurs at the time of the track range mark, hence the center of the pulse occurs 1.5 microseconds after the track range mark. The positive output of the cathode follower is also applied to network driver V3, which conducts only for the duration of the applied signal. A negative signal appears at the plate of V3. The leading edge of this signal coincides with the track range mark. This signal is applied to the receiver gate channel [illegible]

b. Receiver Gate Channel. This consists of network [illegible] network driver V4A [illegible] pulse shaper V4B, cathode follower V5A, and cathode follower V5B. The negative signal at the [illegible] of network driver V3 is applied across network Z2. This network is a series L-C circuit which is [illegible] lation by the applied signal. The negative going leading edge of the applied signal [illegible] at the junction of the coil and capacitor. Following this abrupt change, the negative potential [illegible] sinusoidally to zero. This signal is applied to the grid of V4A. As the voltage at the grid of V4A rises above ground potential, the resulting flow of grid current rapidly damps out further oscillations. The resonant frequency of this network is such that the grid of V4A is held negative for 1.27 microseconds. The positive signal from network driver V4A is applied across L-C network Z3. The negative going trailing edge of the positive signal causes the voltage at the junction of the coil and capacitor to go below ground. At the instant (1.27 microseconds after the tracking range mark) network Z3 begins a quarter cycle of oscillation. The circuit constants are so chosen that the output signal of the network is negative for a 0.4-microsecond period. This period fixes the duration of the receiver gate. The negative 0.4-microsecond signal is applied to pulse shaper V4B and appears at the plate of V4B as a positive 0.4 microsecond rectangular waveform. This signal is applied to cathode follower V5A and from there to cathode follower V5B. These cathode followers provide isolation, impedance matching, and power gain. The signal which appears at jack J5 is the receiver gate. This gate is applied to the error pulse rectifiers, video and phase unit, and AGC unit and is used primarily in these [illegible] the signal being tracked in automatic operation. The receiver gate is also applied to [illegible] unit of the target-tracking radar which is used only in testing the system.

c. Range Gate Channel. The negative 3-microsecond signal at the plate of network dr[illegible] sweep expansion pulse channel, provides the input to the range gate channel. This neg[illegible] applied across network Z4, a quarter cycle oscillator, that generates a negative 1.5 [illegible] The signal is amplified and inverted by the range gate generator V6. The trailing ed[illegible] signal at the plate of V6 occurs 1.5 microseconds after the track range mark. [illegible] network Z5. The negative going trailing edge of the signal initiates a quarter [illegible] that is damped after 0.2 microsecond. The resulting narrow negative signal [illegible] range, cuts off gate inverter V7. The positive 0.2 microsecond signal at the [illegible] clipper V8A which is cut-off between pulses. The positive signal applied to [illegible] to conduct. The clipped signal at the plate of V8A is applied to [illegible] the negative extremity of the signal at ground potential. The [illegible] negative 35 yard gate, is applied to the range error channel and to [illegible]

d. Range Notch Channel. The positive signal from network [illegible] network Z6. The negative going trailing edge of the input [illegible] Circuit constants are chosen so that the output [illegible] signal is amplified and inverted by the notch [illegible] work Z7. The trailing edge of the signal from V16 [illegible] requires 0.6 microseconds. The negative wave[illegible] microseconds after the tracking range mark, is applied [illegible] V17A to cut-off resulting in a negative rectangular wave[illegible] signal is the 100 yard range notch and is applied to the video and notch channel.

e. Video and Notch Channel. This section consists of amplifier [illegible] cathode followers V18A and V18B. Mixing of the video and notch [illegible] plate load for amplifiers V17B and V13B. The range notch is applied to V17B and the tracking video from jack J2 is applied to V13B. These signals are mixed across the common plate load of the amplifiers. At this point the range notch is positive and the video is negative and applied to cathode followers V18A and V18B which are connected in parallel to meet the current requirements. The video and notch are applied to the video amplifiers of the tracking indicators.

f. Video Amplifier. Relay K1 is controlled by the RANGE CALIBRATE switch on the target-tracking console. If relay K1 is deenergized, sum video from the video and phase unit is applied to amplifier V13A through jack J2. If relay K1 is energized, 500 yard range marks from the range calibrator are applied to V13A. The range calibrate input is used only when aligning the range servo system. The first stage, V13A, is a voltage amplifier with frequency compensation. The negative signal from V13A is applied to V14 where it is amplified and inverted. The signal is then applied to power amplifier V15 which is the output stage of the video amplifier. Negative feedback voltage is taken from V15 and returned to the cathode of V14. This feedback produces a low output impedance to match the impedance of the delay line.

g. Range Error Channel. This channel consists of two identical sections; a non-delay section, and a delay section. Each section receives the negative 35-yard range gate and the negative video pulse as input signals. However, the video input to the non-delayed section (V9A, V9B, and C18) is obtained directly from the video amplifier while the video input to the delayed section (V11A, V11B, and C19) is delayed 0.22 microsecond by delay line Z1 before being applied to V11A. The over-all operation of each of the sections is to control the charge on the associated capacitor, C18 or C19. The charge on each capacitor is a function of the time relationship between the 35-yard range gate and the video signal applied to that section. Tube V9A operates on a principle similar to that of a coincidence tube. For this type of operation, instead of two coincident signals aiding conduction, the two applied signals have opposite effects upon the conduction of the tube. The negative range gate is applied to the grid of V9A. Thus, when a video signal appears in coincidence with the range gate, it counteracts the effect of the gate. The nearer the two signals are to coincidence, the larger the signal from V9A. The output of V9A is applied to capacitor C18 through diode V9B. The capacitor is therefore caused to discharge and charge in agreement with the time displacement of the video signal and range gate. The principle of operation of the components of the delay section is the same as that of the non-delay section. The only difference in the over-all operation of the two sections results from the 0.22 microseconds time difference of the input video signals. For a condition of zero range error, the range gate occurs exactly between the delayed and non-delayed video signals. When this condition exists, the charge on both capacitors C18 and C19 is equal. A time position (due to an under-ranged or over-ranged tracking of the range servo system) will cause the video and gate signals in one section to be nearly coincident and those of the other section to be further from coincidence. This will cause a difference in the charges on the capacitors and a push-pull signal will appear on the grids of cathode follower V12. When the range gate is more nearly in coincidence with the undelayed video than it is with the delayed video (under-ranged) the potential at the output plate of capacitor C18 is positive with respect to that of capacitor C19. Similarly, for an over-ranged condition, the voltage at the output plate of capacitor C19 is more positive with respect to that of capacitor C18. The difference in potentials on the cathodes of V12 forms the range error output of the range error channel. The output of the range error channel is applied to the range modulator and to the ATC unit. It is also applied to the range error meter located in the range and receiver cabinet.

h. ATC Channel (Range Error Detector). The ATC channel (V10) of the range error detector functions the same as gating circuits V9 and V11. Video for the ATC channel is delayed 0.11 microsecond. The range gate, a 0.2-microsecond negative signal, is applied to the cathode of V10 and the negative video is applied to the grid. If the gate and video are coincident, the conduction of V10A is very small and the output voltage from V10B is relatively high. If these waveforms are not coincident, the conduction of V10A is increased and the output voltage from V10B is relatively low. This voltage together with the average of the range error voltage is applied to the ATC unit.

Section II. DETAILED SCHEMATIC ANALYSIS

11. Sweep Expansion Pulse Channel

a. One-Shot Multivibrator V1. Twin-triode V1 is a one-shot, cathode-coupled multivibrator. In the quiescent condition V1A is cutoff and V1B is conducting. Tube V1A is triggered by the positive track range mark. Resistor R1 is an impedance matching device at the termination of the cable. Circuit components are chosen so that the duration of the output waveform may be made equivalent to 500 yards range, or approximately 3 microseconds. Pulse duration is adjusted by means of MV BIAS control R4 and 500 year EXPANSION control R9. The output signal from the plate of V1B, is a positive 40-volt, 3-microsecond rectangular waveform. This signal is coupled through capacitor C4 to cathode follower V2A. Resistor R70 and capacitor C22 form a decoupling network.

b. Cathode Follower V2A. This tube is a conventional cathode follower. The low impedance source of the cathode circuit is used to furnish a positive pulse to network driver V3 through capacitor C7 and to pulse inverter V2B through capacitor C5.

c. Pulse Inverter V2B. Tube V2B is held cut-off between pulses. Tube V2B draws grid current during the 3 microsecond period that the signal is applied. Grid resistor R16 prevents the flow of excessive grid current during the signal period. The 3 microsecond signal appears at the plate of V2B as a negative 20 volt pulse. This is the sweep expansion pulse applied to the tracking indicators from jack J4 and to the angle error detectors.

d. Network Driver V3. The pulse which is coupled through capacitor C7 from cathode follower V2A is developed across resistors R19–R20 and applied to the grid of V3. In the absence of an input signal, V3 is held below cut-off by a negative 36 volt potential obtained at the junction of voltage divider resistors R19–R20. The amplitude of the positive 3 microsecond input signal is sufficient to overcome this bias and cause the tube to conduct. A negative pulse appears at the plate of V3 and is applied across networks Z2, Z4, and Z6. The leading edge of this signal coincides in time with the track range mark. Because of the capacitance between plate and ground, the positive going trailing edge of the waveform does not adversely affect the operation of the networks to which the signal is applied.

12. Receiver Gate Channel

a. 1.27 Microsecond Delay Network Z2. Delay network Z2 is a series resonant circuit which is shocked into oscillation and whose oscillation is damped after one quarter of a cycle. Prior to the appearance of the input signal, network driver V3 is cut-off. The capacitors of network Z2 is charged to the full value of the applied voltage and zero potential is present at terminal 2 of the network (the junction of the capacitor and inductor). When V3 conducts, the voltage at its plate drops. This drop in voltage is coupled through the network capacitors causing the potential at terminal 2 to go below ground. The capacitor then starts to discharge through the inductor to the new value of applied voltage. Because of the inductance, the discharge of the capacitors produces a sinusoidal voltage rise at terminal 2. In one quarter of a cycle of oscillation, the capacitor will assume a charge equal to the new applied voltage and the voltage at terminal 2 will return sinusoidally to zero potential. The field about the inductor then starts to collapse, tending to drive the voltage at terminal 2 above ground. However, terminal 2 is connected to the grid of V4A and to ground through crystal CR1. As the grid voltage becomes positive with respect to ground, grid current flows in V4A and crystal CR1 conducts. This places a low-resistance path in parallel with the network inductor. As a result, the oscillation is damped out after slightly more than one quarter of a cycle. The value of the inductor and the value of the capacitors of the delay network are so chosen that the negative signal applied to the grid of V4A will hold the stage below cut-off for 1.27 microseconds.

b. Network Driver V4A. The grid of V4A is connected to terminal 2 of network Z2 and its cathode is grounded. Tube V4A conducts heavily in the absence of the applied signal causing a low plate potential. The signal appearing at terminal 2 of network Z2 drives the grid of V4A below cut-off. During the applied signal, V4A remains cut off until 1.27 microseconds after the tracking range mark. During the period that V4A is cut off, a positive signal appears at the plate and is applied to delay network Z3.

c. 0.4 Microsecond Delay Network Z3. This network operates in the same manner as network Z2. The negative going trailing edge of the positive waveform starts the quarter cycle of oscillation. Circuit constants are chosen so that the signal produced holds V4B below cut-off for 0.4 microseconds. Network Z3 controls the width of the receiver gate.

d. Pulse Shaper V4B. The negative output of Z3 is applied to the grid of V4B. This tube conducts under no signal conditions. The applied signal drives tube V4B below cut-off and hence, the positive extreme of the inverted waveform at the plate is quite flat. The output waveform is coupled through capacitor C8, developed across resistor R24, and applied to cathode follower V5A.

e. Cathode Followers V5A and V5B. The cathode followers provide the necessary isolation, impedance matching and power gain for proper transmission of the signal to the various units. The output goes to jack J5. At jack J5 on the schematic diagram, the output is called the AGC gate. The positive [illegible] gate is 0.4 microseconds in duration and [illegible] volts in amplitude. This gate is applied to the error pulse rectifiers, the video and phase unit, the AGC unit, and the missile AFC unit of the associated tracking radar.

13. Range Gate Channel

a. 1.5 Microsecond Delay Network Z4. Network Z4 functions in the same manner as the delay networks previously discussed. The oscillation is damped when grid current flows in V6. The circuit constants are chosen so that V7 is held cut off for 1.5 microseconds. Resistor R29 damps parasitic oscillations which tend to occur in the grid circuit of V6 between the inductance of Z4 and the grid-to-cathode capacitance of V6.

b. Range Gate Generator V6. The 116 volt signal at the grid of V6 holds it cut off for 1.5 microseconds. The signal is amplified and inverted by range gate generator V6 and applied to network Z5.

c. 0.2 Microsecond Delay Network Z5. Network Z5 controls the width of the range gate and functions in a manner similar to network Z4. The values of circuit elements are selected so that the signal which is developed causes V7 to be cut off for 0.2 microseconds. Resistor R35 is a parasitic suppressor.

d. Gate Former V7. Tube V7 operates in the same manner as V6. The pulse which is applied to the grid of V7 holds it cut off for 0.2 microseconds. As a result, a postive rectangular pulse, 0.2 microseconds in width, and occurring 1.5 microseconds after the tracking range mark, appears at the plate of V7. This pulse is applied to clipper V8B.

e. Clipper V8B. Tube V8B is held cut off between pulses by a voltage developed across the voltage divider R[illegible], R[illegible] connected from minus 250 volts to ground. When the positive pulse from V7 overcomes the cut-off [illegible], V8B conducts. Base-line clipping is accomplished by V8B due to the biasing arrangement. The output of V8B is a negative gate 0.2 microseconds duration.

f. [illegible] V9A. This is a triode connected as a diode. The signal is clamped negative in respect to the potential developed at the top of resistor R56 by current flow through V9A, V10A, and V11A. The potential at the top of V56 is normally about 25 volts. The negative 35 yard range gate, approximately [illegible] volts in amplitude, is applied to the cathode circuits of tubes V9A, V10A, and V11A.

14. Range Notch Channel

a. 1.2 Microsecond Delay Network Z6. This network operates in the same manner as the networks previously described. It develops a signal which will cut off V[illegible] for 1.2 microseconds. The quarter cycle of oscillation is damped by grid current flow in V[illegible] when the grid goes positive with respect to ground.

b. Network Driver V16. With the cathode grounded and the control grid returned [illegible] the inductor of network Z6 this stage conducts heavily in the absence of any signal. The waveform at terminal 2 of Z6 appears at its grid and V6 is cutoff for a period of 1.2 microseconds. A positive 1.2 microsecond pulse appears at the plate of V16 and is applied to network Z7.

c. 0.6 Microsecond Delay Network Z7. This network is similar in operation to network Z6. Z7 controls the width of the range notch. Circuit constants are chosen so that a [illegible] holds V17A cut off for 0.6 microseconds. The oscillation is damped by the action of [illegible] grid current which flows in V17A when the grid goes positive with respect to ground. [illegible] the capacitance of network Z7 form a capacitive voltage divider which will cause the amplitude of the pulse at the grid of tube V17A to be 20 volts.

d. Cathode Follower V17A. The 20 volt, 0.6 microsecond pulse from Z7 is applied to V17A. Between pulses this tube is conducting with about 3 volts at its cathode. When the pulse occurs, V17A is cut off producing a rectangular negative pulse at the cathode. Crystal CR1 passes only the most negative portion of the waveform to NOTCH AMPLITUDE potentiometer R94. A [illegible] from 1 volt, rectangular waveform appears at terminal 3 of resistor R94. The NOTCH AMPLITUDE potentiometer R94 is adjusted so that the 100 yard range notch is about [illegible] as displayed on the tracking indicators. The amplitude of the signal applied to amplifier V17B when the NOTCH AMPLITUDE potentiometer is properly set, is 0.3 volt. Capacitor C52 provides degenerative feedback which maintains the shape of the waveform at the output of V17A.

15. Video and Notch Mixer

a. Amplifiers V13B and V17B. The 100 yard range notch is amplified and [illegible] V17B. The video, which enters the range error detector at jack J2, is amplified and inverted [illegible]. Resistor R98 forms a common plate load for V13B and V17B and mixing is accomplished [illegible] along with capacitor C34 and resistor R97 form a frequency compensation network. At the plates of V13B and V17B, the 100 yard range notch is positive and the video is negative. The outputs are coupled by capacitor C35, developed across resistor R100, and applied to cathode followers V18A and V18B.

b. Cathode Followers V18A and V18B. These tubes are connected in parallel to meet current requirements. Negative video and positive range notch appear at the cathode of these tubes as a result of the signal from V13B and V17B. The cathodes of V18A and V18B are connected directly to jack J6. From jack J6 the mixed video and notch is applied to the video amplifier of the range indicator and to the video error signal panel for display on the scopes.

16. Video Amplifier

a. Voltage Amplifier V13A. This stage is class "A" amplifier with cathode [illegible] providing the operating bias. Resistor R74 and inductor L1 provide the plate [illegible] the high frequency response of the circuit by overcoming the [illegible] to slow down the rise in voltage at the plate of V13A. Inductor L1 [illegible] rapidly charges this stray capacitance. The input to V13A enters the [illegible] at jack J2 [illegible] link switch S2 and contacts of relay K1. In the target-tracking radar, S2 is placed in the TARGET position. In the missile-tracking radar, S2 is placed in the MISSILE position. Relay K1 is associated with the use of the range calibrator and is energized when the range system is being calibrated. When relay K1 is energized, 500 yard range markers are fed to V13A by the range calibrator. Relay K1 is energized by the RANGE CALIBRATE switch on the control drawer of the target tracking console.

b. Amplifier V14. The negative video from V13A is applied to V14. The signals are amplified and inverted by V14. Positive video signals appear at the plate of V14.

c. Power Amplifier V15. The positive video pulses from V14 are coupled through capacitor C26 to the grids of V15A and V15B. This stage develops the power necessary to drive delay line Z1. A voltage divider consisting of resistors R82–R83 provides a fixed voltage which, in addition to the voltage developed across cathode resistor R112, provides the bias. Network Z1 acts as a plate load for V15A and V15B. Negative video pulses, normally 20 volts in amplitude, appear at pin 1 of network Z1. This negative signal is also returned to the cathode of V14 through an R–C network consisting of resistor R84 and capacitor C28. This feedback voltage is in phase with the signal voltage at the grid of V14 and is therefore degenerative. The purpose of this feedback is to provide low output impedance to match the impedance of the delay line and to minimize distortion.

17. Range Error Channel

a. General (figs. 6 and 6–6). The range error channel derives an error signal proportional to any time difference which may exist between the 35 yard gate and the selected video signal. This error signal is obtained by comparing the voltage across two integrating capacitors (C18 and C19). Equal capacitor voltages result in no potential difference being applied to V12, but unequal capacitor voltages do produce a potential, the magnitude and polarity of which indicates the direction and extent of range error. The channel consists of V9A, V9B, V11A, V11B, delay network Z1, and integrating capacitors C18 and C19. The inputs to the channel are the 35 yard range gate from the plate of V8A, and the video from the plates of V15. The video at terminal 1 of network Z1 is the undelayed video while the video at terminal 3 of network Z1 is the delayed video. Network Z1 is a conventional L–C delay line which introduces a total signal delay of 0.22 microseconds. Tubes V9A and V9B and capacitor C18 form the non-delay section. Tubes V11A and V11B and capacitor C19 form the delay section. The large common cathode resistor R50 provides sufficient self-bias for V9A and V11A to keep them very near cut-off during the quiescent period. During this period, V9B and V11B are cut-off by the presence of a positive potential at their cathodes. During the quiescent period, the plates of these diode-connected triodes are at a less positive potential than their cathodes. The cathode potential, approximately 25 volts, is obtained from the voltage divider R60–R61. As can be seen by figure 6, with V9A and V11A cut-off, the integrating capacitors, C18 and C19, will charge through resistors R52–R53 toward the 25 volt potential existing at the junction of R60–R61. Upon application of the range gate to the cathodes of V9A and V11A, these tubes conduct heavily and a negative pulse appears at their plates. This pulse is impressed upon the cathodes of V9B and V11B causing them to conduct heavily. Thus, for the period of the range gate, current flows through V8A, C16, R51, V9A, C17 and V9B, discharging integrating capacitor C18.

At the same time, the discharge current for capacitor C19 flows through V8A, C16, R51, R56, V11A, C20 and V11B. Upon expiration of the 35 yard range gate, capacitors C18 and C19 again recharge through resistors R52–R53 toward the 25 volt potential. It is therefore apparent that, in the absence of any video, the integrating capacitors experience a period of charge and a period of discharge during each pulse repetition period. In this condition, the discharge of the capacitors by the tube currents during the range gate is equal to the recharge of the capacitors through resistors R52–R53 during the time between range gates.

b. Channel Operation, Zero Range Error. When a target is being tracked automatically, negative video signals appear at the control grids of V9A and V11A when the negative range gate is present at their cathodes. Signals of the same polarity applied to the grid and to the cathode have opposite effects upon the plate current. Thus, while the negative range gate applied to the cathodes of V9A and V11A will tend to increase plate current, the negative video signals at their grids will counteract this increase. When a zero range error condition exists, the 35 yard range gate occurs coincident with the mid-delay video. In this condition, the amount of plate current in V9A is partially limited by the non-delay video signal and the plate current in V11A is equally limited by the delayed video signal.

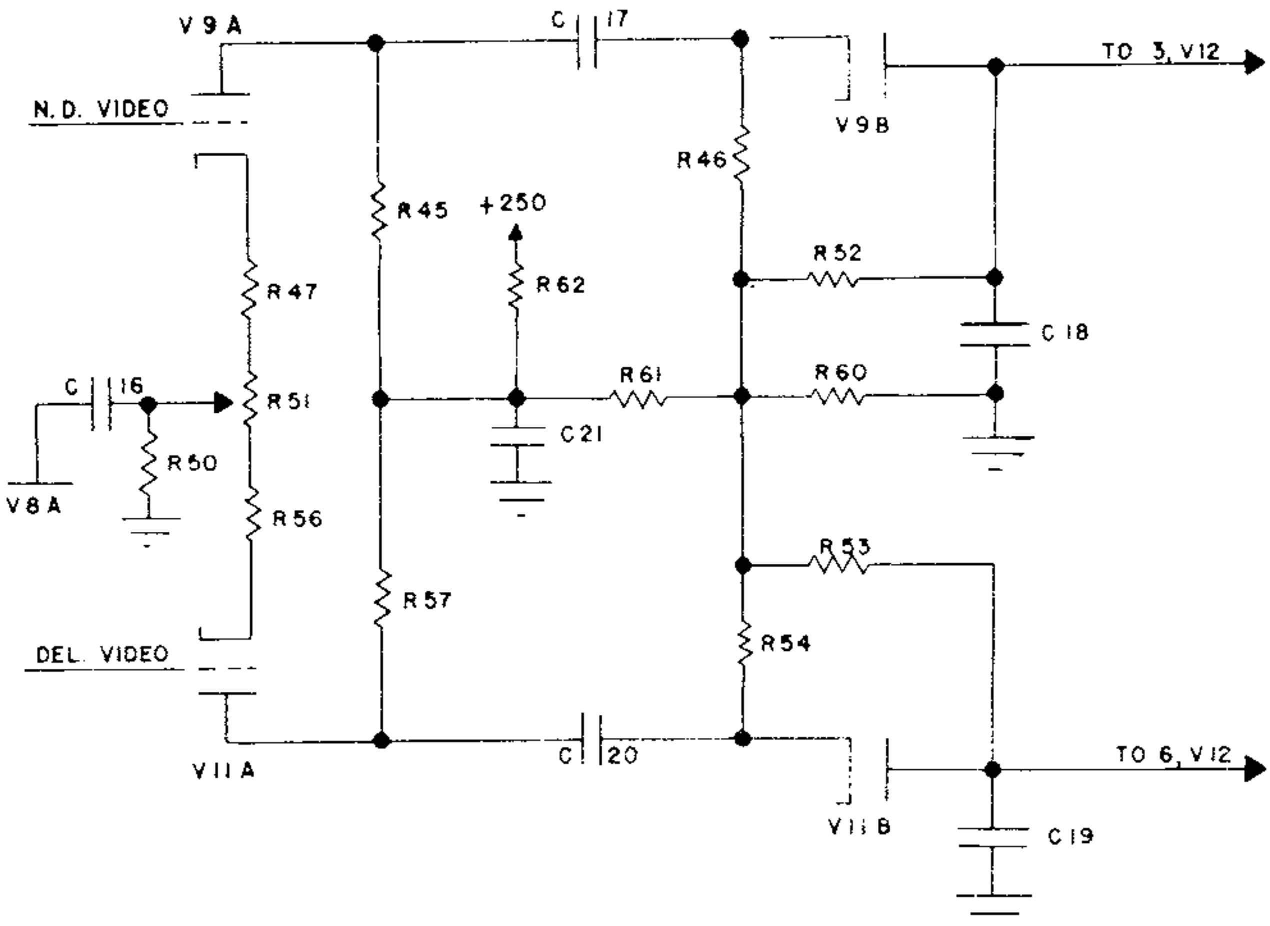


Figure 6. Range error channels, simplified schematic.

Thus, the equal negative signals which appear at the plates of V9A and V11A are smaller in amplitude than when no video is present. These signals are coupled through capacitors C17–C20 to the cathodes of V9B and V11B. These tubes conduct, discharging capacitors C18–C19 equally. However, the discharge of the two capacitors is less than their discharge when no video is present. Therefore, for a zero range error condition, the operation of the channel is such that the average voltage across each of the integrating capacitors increases, but the potential difference between the output voltages of the capacitors remains zero. The potential difference between the capacitors is a measure of the range error and is zero for zero range error even though the voltage across each capacitor experiences an increase. Whenever video is coincident with the range gate, there will be an increase in the average voltage across the capacitors with respect to ground. This is true regardless of the degree of coincidence of the gate signal and the video.

c. Channel Operation, Under-Ranged Condition. From the preceding discussion it is evident that the voltage across capacitor C18 will vary with the degree of coincidence of the non-delayed video and the range gate, and that the same is true of capacitor C19 with respect to the degree of coincidence of the delayed video and the gate. Therefore, any difference in potential between capacitors C18–C19 must be a function of the degree of coincidence or time displacement of the video and the range gate. When the range gate occurs coincident with the mid-delay video (zero range error), the difference in potential between C18 and capacitor C19 is zero. However, a time displacement of the gate in either direction [illegible] range system being under-ranged or over-ranged, will give rise to a [illegible] capacitors. For an under-ranged condition the range gate is more [illegible] delayed video signal and is further removed from coincidence with the [illegible] the current flow through V[illegible] will be less than that flowing into capaci-[illegible] capacitor C18 will be more positive than the voltage across capacitor C19 [illegible] represents the range error and is applied to the range modulator, where it is [illegible] range error signal. This signal in turn is used to drive the range system during [illegible]

[illegible] *Over-Ranged Condition.* The 35 yard range gate is now more nearly coincident [illegible] signal than with the non-delayed video signal. In this condition, the [illegible] of V9A. A negative signal, smaller than at the plate of V9A, appears at the [illegible] current of capacitor C19 flowing through V11B, is smaller than that of [illegible] Again, a difference in potential exists between the capacitors, [illegible] capacitor C18.

[illegible] *Signals.* When a [illegible] is being tracked automatically, it is necessary [illegible] from other targets [illegible] from affecting the charge on the integrating [illegible] of the range error chan[illegible] such that it blocks any video signal which does [illegible] of the range gate. As previously stated, V9A and V11A operate very near [illegible] and V9B and V11B are completely cut-off by their positive cathode po-[illegible] the range gate, negative video signals at the grids of V9A and V11A will [illegible] their plates which are coupled to the cathodes of V9B and V11B. [illegible] positive signals at their cathodes only serve to drive them further [illegible] signals occurring between gate signal have no effect on [illegible]

[illegible] This tube is a twin triode with both sections connected [illegible] from the integrating capacitors is applied to the grid. The [illegible]

[illegible] AFC Channel

[illegible] *Condition.* In the absence of video signal [illegible] cathode of V[illegible] causes an increase in conduction, and a [illegible] negative signal is coupled to the cathode of V[illegible], causing [illegible] discharged, that is, to become less positive. Capacitor C38 is [illegible] same as that of capacitors C18 and C19.

c. Action of V10 With Video and Range Gate Coincident. The video applied to the grid of V10A is delayed 0.11 microseconds due to the action of the delay line. When this video appears on the grid of V10A in coincidence with the range gate, there is no range error. Since both of these signals are negative, the conduction of V10B is changed slightly and a small signal appears at the plate of V10A. This signal, coupled to V10B, causes capacitor C38 to be discharged slightly. If the video and range gate are not exactly coincident, a larger signal appears at the plate of V10A and capacitor C38 is discharged a greater amount. The voltage at the plate of V10B is maximum positive when the range error is zero and decreases as the range error increases. This voltage is applied to P1-5 of the ATC unit.

CHAPTER 4

AUTOMATIC TRACKING CONTROL (ATC) UNIT

19. General

The ATC unit causes the radar to be switched from automatic to aided tracking at the existing rates when a target is lost, and at the same time, to indicate this loss by illumination of the COAST light. In the missile radar, the unit also initiates the timing action which causes the missile radar to slew to a new missile 3 seconds after the beacon signal is lost. The automatic tracking control (ATC) unit is divided into two channels for study. The first of these channels is the range error channel consisting of V1, V2 and relay K1. The second channel is the ATC channel consisting of V3, V4 and relay K2. These channels are similar and either may cause relay K3 to be energized. The ATC unit has three inputs; the two range error voltages and a voltage from the ATC channel of the range error detector.

20. Block Diagram Discussion

(fig. 8-8)

a. Differential D-C Amplifier V1. This is a dual triode with one range error voltage being applied to each section. If the two input voltages are of the same amplitude, there is very little effect in the circuit due to cathode follower action. If the input voltages are of different amplitudes, the conduction of V1A and V1B is changed and an output exists to V2.

b. Relay Amplifier V2. Both sections of V2 are normally cut-off due to voltage divider action between −250 volts and the plates of V1. When the current flow of V1 is upset, the plate of one section rises while the plate of the other section drops. When a plate of V1 rises the grid of the associated section of V2 also rises, allowing the section to conduct. The plate current of V2 flows through relay K1.

c. Relay K1. When the conduction of V2 is sufficiently heavy, relay K1 becomes energized. This will normally occur when the range error is between 2.5 and 50 yards. The closing of the contacts of relay K1 causes relay K3 to become energized.

d. ATC Channel (ATC Unit). This channel functions in a manner similar to the range error channel. The inputs to this channel are the ATC voltage and the average value of the range error voltages. Relay K2 is energized only when the ATC voltage is more positive than the average of the range error voltage. The cathode voltage, as well as the grid voltage, is used to control the conduction of V4 and the operation of relay K2. Relay K3 is normally energized by the action of relays K1 or K2. It causes the COAST light to be extinguished when a target is in the range gate, or completes circuits in the missile and target radars, causing the existing tracking rates to continue if the target or missile is lost. In the missile-tracking radar, it will also initiate the action which causes the missile radar to slew to a new missile if the beacon signal is lost for 3 seconds, or if the burst signal has been given, to slew to the new missile in 0.4 seconds.

21. Detailed Schematic Analysis

(fig. 8-9)

a. Differential D-C Amplifier. The inputs to V1 are the two range error voltages. The operation of V1 depends upon a difference in amplitude of these two voltages. In the quiescent condition, with no video in the gate, both grids are at a small positive potential. When video appears in the gate, both grids go positive, but one grid will go more positive. With an over-ranged condition, grid 2 will be more positive than grid 7. Each cathode tries to follow its own grid, but, being tied together, they rise an amount something less than the average rise of the grids. Thus, the bias on V1A decreases and its plate voltage drops while the bias on V1B increases and its plate voltage rises. For an under-ranged condition the grid and plate voltages are reversed. The plate voltages of V1 are applied through a resistive network to the grids of V2. The input voltages are averaged by means of resistors R1 and R2, and the average voltage is applied to the grid of V3A.

b. Relay Amplifier V2. The grids of V2 are tied to the voltage dividers between −250 volts and the plates of V1. In the quiescent condition both sections of V2 are cut-off. With V2 being cut-off a drop in plate voltage of V1 has no effect serving only to drive it further below cut-off. A rise in the plate voltage of V1 will effect the conduction of V2, since the grid of V2 also rises. When V2 is conducting sufficiently, relay K1 is energized. Capacitor C1 charges to the voltage applied to the grids of V2 and provides a delay of 50 milliseconds in the deenergizing of relay K1 if the target is momentarily lost. For an under-ranged condition, grid 2 of V1 is more positive than grid 7 and plate 1 drops while plate 6 rises. The drop in plate voltage of V1B causes V2B to conduct and relay K1 to be energized. Relay K1 is normally energized when the range error is less than 50 yards but more than 2.5 yards.

c. ATC Channel, ATC Unit. Tube V3 functions the same as V1. The input voltages are the average value of the range error voltage and the ATC voltages from V10 of the range error detector. When the range error is varied from 18 to 50 yards the voltage applied to grid 2 of V3 begins to rise while the voltage applied to grid 7 remains relatively constant. This causes the plate voltage of V3A to drop while that of V3B rises, and the grid of V4A goes negative while the cathode goes positive due to increased conduction of V4B. These two actions cause V4A to be cut-off and prevent relay K2 from energizing. When the range error becomes less than 18 yards, grid 7 of V3 begins to rise while grid 2 begins to drop. This action causes the plate of V3A to rise while the plate of V3B drops, and grid 2 of V4 rises while the cathode drops due to decreased conduction of V4B. This action causes V4A to conduct and relay K2 to be energized. Since the contacts of relays K1 and K2 are in parallel, relays K1 and K2 have the same effect upon the circuits controlled by the ATC unit. Capacitor C2 provides a 50 millisecond delay if the target signal is momentarily lost.

d. External Connections of the ATC Unit (Sh 33 and Sh 44). The connection to P1–10, 12 and 6 are the same in both radars. P1–12 is grounded. P1–10 is connected to the K1 relays of the range and angle modulators. Whenever relay K3 of the ATC unit is energized, relay K1 in each modulator is also energized, which in turn permits automatic tracking. This circuit is completed through the COAST DISABLE switch. P1–6 is connected to the COAST light in both radars. Whenever relay K3 is energized, that is, when there is a target in the range gate, the COAST light will be extinguished; it will be illuminated when there is no target in the gate. In the target radar there is no connection to P1–11. P1–9 is connected to ground through contacts of relay K8, the acquisition control relay. P1–7 is connected to the K2 relays of the angle and range modulators and to the MAN-AID relays K3, K4, K12, K13, and K17. These connections to P1–7 and 9 cause the target radar to go into aided tracking when the target is lost and into automatic during acquisition. In the missile radar, P1–11 is connected to the missile slew control unit. P1–9 is connected to ground through K2, the burst relay in the target-tracking console. There is no connection to P1–7. The connections to P1–9 and 11 initiate the timing action which causes the missile-tracking radar to slew to a new missile when a missile is lost.

CHAPTER 5

RANGE MODULATOR, HANDWHEEL ASSEMBLY, AND GOING RATE DEMODULATOR

22. General

The range modulator in the missile radar is identical to the range modulator in the target radar. Both modulators serve the same basic function though there are a few small differences in the operation of the equalization network and the enabling relays. The range modulator receives a d-c range error signal from the range error detector and produces a 400-cycle range error signal with an amplitude proportional to the amount of range error and a phase which depends upon the direction of the range error. All of the handwheel assemblies in the missile and target radar consoles are identical and differ only in their application. The handwheel assembly is used to furnish the manual and aided-tracking signals. The going rate demodulator is used in the target-tracking radar range system to give a smooth transition from aided to automatic modes of operation.

23. Block Diagram Discussion

(figs. 8-1.1 and 8-10)

a. Range Modulator (fig. 8-10).

(1) *Equalization network and enabling relays.* The equalization network consists of an R-C combination which shunts the input. The impedance of this combination is infinite at zero frequency, but as the d-c input begins to fluctuate, the impedance is decreased and the input attentuated. Higher frequencies of fluctuation are attentuated more than lower frequencies. This drooping frequency response is required so that changes in the input will not cause the range servo system to try to react faster than its physical capabilities will permit. The enabling relays, K1 and K2, serve slightly different purposes when the range modulator is used in the target radar than they do when the same type unit is used in the missile radar. Relay K1 in both radars is used to disconnect automatic range error signal which is the input to the modulator from the range error detector. Relay K1 is energized only in the automatic mode. Relay K2 in the target radar permits capacitors C2–C3 to charge to a rate voltage which will permit smooth switching from aided to automatic operation. It also furnishes an input for the aided-rate voltage which is used to maintain tracking if the target is lost in automatic. Relay K2 in the missile-tracking radar is used to furnish input contacts for the fine range slew control signal which comes from the range slew control unit. In both radars K2 is de-energized only in automatic.

(2) *Balanced modulator V1, V2.* The balanced modulator is composed of the four triode sections of the two twin triodes V1 and V2. Before the d-c voltage is applied to the modulator stage, it is sent through a bridge balancing circuit which is inserted in the channel to compensate for tube and circuit inequalities in the balanced stages that follow, and to isolate the modulator from the range error detector. The d-c error voltage output of the bridge balancing circuit is applied between the grids of the triodes while the 400-cycle servo excitation voltage is applied between the cathodes. The output of this modulator is taken from the plates and is a push-pull a-c voltage.

(3) *Cathode follower V3 and T1.* The two triode sections of V3 are connected in a current amplifier circuit. Both triodes are connected as cathode followers. The push-pull a-c output from the modulator is applied to the cathode followers whose load is the primary winding of T1. The operation of this transformer is such that the push-pull signal is converted to a single-ended signal at its secondary. The output from this transformer, the 400-cycle range error signal, is also the output of the range modulator. This a-c signal is sent to the low power servo-amplifier for amplification before application.

b. Handwheel Assembly (fig. 8–1.1). The handwheel assembly is located in the control drawer and has certain functions to perform in all modes of operation. In manual, the handwheel is turned causing the rotor of a tachometer to generate a voltage proportional to the rate of rotation. This voltage drives the range servo. In aided operation, a movement of the handwheel will displace the arm of the rate potentiometer in the handwheel assembly. The output from the rate potentiometer is used to drive the range servo at a rate depending upon the amount of arm displacement. In automatic operation of the target radar, a portion of the tachometer output from the range drive unit is used to drive the motor in the handwheel assembly. The motor in the handwheel assembly operates until the voltage picked off by the arm of the rate potentiometer is of sufficient amplitude to drive the servo at the automatic rate then present in the system. If the target should be lost during automatic tracking, the system drops into aided-tracking and uses the rate voltage discussed in the preceding sentence. It serves to maintain the tracking rate until the target again is picked up in automatic. The motors in the handwheel assemblies of the missile-tracking radar are not used.

c. Going-Rate Demodulator (fig. 8–1). Going-rate demodulators are used only in the range channel of the target-tracking radar. It is located in the control drawer of the target radar console. It is required during normal tracking because if the automatic system did not have some sort of anticipating signal, it is probable that the process of switching from aided to automatic would find the system hesitating until the automatic rate signal brought the servo up to operating speed. This hesitation might cause the target to be lost and would certainly cause an uneven tracking for a short period of time. The going-rate demodulator takes a portion of the aided-rate voltage and converts it into a d-c voltage used to charge capacitors in the range modulator. Then when the system is switched to automatic, the charge on these capacitors will cause movement of the servo to be maintained and the automatic signal will have to make only a very slight adjustment.

24. Detailed Schematic Analysis

(fig. 8–11)

a. Range Modulation.

(1) *Equalization network.* The inputs to this circuit are applied to terminals 1 and 3 of P1. These points are connected to cathodes 2 and 7 of V12 in the range error detector circuit. The voltages on the cathodes vary with the position of the selected target with respect to the range gate. If the system is ranged correctly, terminals 1 and 3 of P1 are both at the same potential. If the system is under-ranged, the voltage at P1–1 will go in a negative direction and the voltage at P1–3 will go in a positive direction. The maximum deviation will occur at 50 yards range error. If the radar is over-ranged, the opposite condition will exist. Connected across the input is the equalization network consisting of resistors R8, capacitors C2, and C3. The impedance of this series R-C branch, which shunts the input, is infinite at zero frequency and decreases with increasing frequency because of the capacitor. High frequencies are thus attenuated more than low frequencies with the result that fast fluctuations in the input will have less effect on the error output than slow fluctuations. This drooping frequency response is required to compensate for the rising frequency response inherent in the range servo system. Resistors R1 and R2 have a displacement voltage applied to them for checking the servo system. Jack J2 is a test point for monitoring the average voltage between pins 1 and 3 of P1.

(2) *Target radar enabling relays.* During automatic tracking, relay K1 is energized by a ground circuit from the ATC unit. The automatic range error signal is fed into the modulator and capacitors C2 and C3 are charged by this input. If the target radar range error exceeds ±50 yards, the ground for relay K1 is lost and the relay is deenergized, thus disconnecting the automatic range error signal from the modulator. The range servo will go into aided-tracking until the target is again tracked automatically or another mode of operation is selected. Relay K2 is energized except in automatic operation, and since the Nike system was designed for automatic operation, this relay facilitates the switching from some other mode of operation to the automatic mode. Assuming that the system is in aided-range-tracking, relay K1 is deenergized and relay K2 is energized. Capacitors C2–C3 are now being charged by the output of the rate potentiometer in the handwheel assembly and the amount of charge is proportional to the range rate. When the operator switches to automatic, capacitors C2–C3 already have a charge proportional to the range rate so there is no jerk or slew as the modulator is switched into the range servo system and the system adjusts itself to the new mode of operation.

(3) *Missile radar enabling relays.* During automatic range tracking, relay K1 is energized by a ground circuit from the ATC unit. The automatic range error signal is fed into the modulator and capacitors C2–C3 is charged by this input. If the missile is lost, the ground circuit from the ATC unit is lost and the automatic range error signal is disconnected. The range servo will then go into a coast condition and the charge on capacitors C2–C3 will continue to drive the servo. This coast condition will last for 3 seconds; at the end of which the radar will slew to a new missile if the original missile is not recovered. Relay K2 will be energized at the end of the three-second period and the fine range slew signal from V4 in the range slew control unit will be the input to the modulator. The fine range slew voltage will not control the range servo until the range servo is within approximately 2,000 yards of the correct range to the missile. Three seconds after the missile radar is locked on the new missile in range, relay K2 will deenergize, relay K1 will energize and automatic operation will resume. If the missile bursts, the time period for coasting is 0.4 seconds instead of the three-second action described above.

(4) *Bridge balancing circuit.* The bridge balancing circuit, consisting of the resistors in Z1 and TRANS-BAL ganged potentiometer R19, is inserted in the channel to allow compensation for tube and circuit inequalities in the balanced stages that follow. It also isolates the bridge balancing network from the range error detector. Potentiometer R19 is ganged so that both arms move up or down together (schematically). If potentiometer R19 is adjusted so that both contact arms have zero potential between them, the voltage taken off the bridge at terminals 6 and 5 is exactly proportional to the d-c error voltage applied at terminals 1 and 2. If this input d-c error voltage is zero, but an output appears at T1 due to circuit inequalities, potentiometer R19 is adjusted so that the output of the bridge will cancel the effect of the circuit inequality. To illustrate the operation of the bridge balancing network, observe figure 7 and assume that a circuit inequality in the modulator makes it necessary to have terminal 6 of the bridge slightly more positive than terminal 5. (Remember that it is necessary to have zero potential difference between points A and B, because these points if unbalanced as a result of this compensating voltage, will cause errors in the range error signal.) Assume that terminals 3 and 4 pick off 5 volts and 15 volts, respectively, from potentiometer R19. Resistor R1 equals resistors R2 plus R3 so that the voltage drop across resistors R1 equals 5 volts, and so the necessity of maintaining zero potential between points A and B has been satisfied. The voltage across resistor R6 is 4.5 volts, so that terminal 5 is 4.5 volts above point C for a total potential of 9.5 volts. The voltage across resistor R2 is 0.5 volts, so terminal 6 is 0.5 volts above point A. This results in 10.5 volts at terminal 6. This potential difference will take care of the assumed

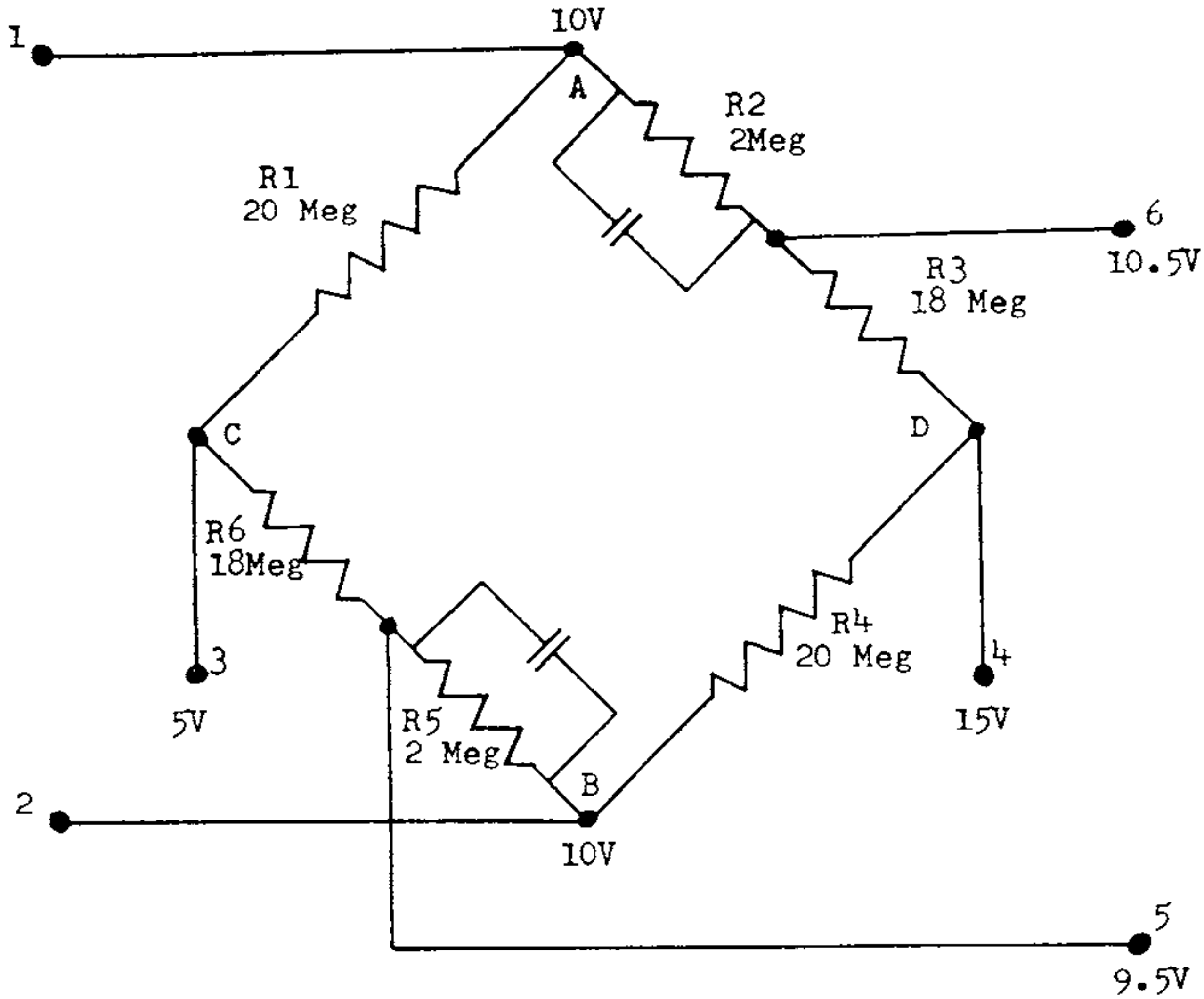


Figure 7. Bridge balancing network Z1 with balancing voltage applied to terminals 3 and 4.

inequality in the modulator without upsetting the balance between points A and B. Any range error voltage will add to or subtract from these potentials and the same proportional error will exist at terminals 5 and 6 as is sent to terminals 1 and 2 from the error signal source. Simple Ohm's law calculations will aid in proving the operation of this circuit for any assumed set of conditions. Potentiometer R19 is the balancing potentiometer and potentiometer R16 is the sensitivity and range adjustment for R19. The capacitors in Z1 improve the response of the system.

(5) *Balanced modulators.* Tubes V1 and V2 form the balanced modulator. The action of this circuit is similar to that of other balanced modulators which have previously been encountered in the Nike I system. Since special texts for the acquisition radar and the computer discuss this circuit, a detailed discussion will not be undertaken here. The major difference in the operation of this circuit as used is the nature of the d-c input voltage. In the balanced modulators previously studied, a single ended d-c output was applied to two of the modulator triodes and the grids of the two remaining triodes were returned to ground through a balance

potentiometer circuit. The outputs of these modulators are produced by variations of the control voltage above or below ground level. In the balanced range modulator, all of the triodes receive an input. The grids of V1A and V2B are tied together and receive one component of the input; the grids of V2A and V1B receive the other input component. The grids of all the tube sections are at some positive potential with respect to ground at all times. With the circuit in the balanced condition, the grids of V1A and V2B are at the same potential as the grids of V1B and V2A if no circuit inequalities exist. In this condition the currents of V1A and V1B flow through resistor R24 and cancel, while the currents of V2A and V2B flow through resistor R25 and cancel. As a result, the circuit yields no output. The grids of the tubes may be at the same potential under two conditions. As long as relay K1 is deenergized, the grid potentials will be equal to some positive voltage (plus 4 volts for example). When a target is being tracked automatically and there is no zero range error, the grid potentials are again equal but have a higher value of voltage (plus 6 volts for example). In either case, the modulator remains in a balanced state and yields no output. When a range error exists, an unbalance in the grid potentials is created. For over-range condition, the grids of V1A and V2B rise to a possible plus 7 volts while the grids of V1B and V2A drop a corresponding amount to plus 5 volts. In this condition, conduction in V1A will be greater than conduction in V2A and an output sine wave will be produced, the phase of which will be the same as that of the servo excitation voltage applied to the cathode of V1A. In the other half of the modulator, tube V2B will conduct more heavily than V1B, producing an output sine wave in phase with the cathode voltage of V2B. It follows that a reversal in the direction of the range error will reverse the polarity of the difference in grid potentials. This, in turn, will reverse the condition of conduction in the modulator tubes and effect a phase reversal in the output voltage. There are two phase-equalizing networks associated with the balanced modulator. The one in the cathode circuit of the modulator tubes consist of resistors R20, R21, R22, R23 and capacitor C6. The other, between output leads of the modulator, consists of resistors R26, R27, R28, R29 and PHASE BAL potentiometer R30. The phase equalizing network in the cathode introduces a phase lag in the servo excitation voltage, while the one in the modulator output circuit produces a phase lead. Potentiometer R30 is factory adjusted so that at 400 cycles per second, the phase lead is equal to the phase lag previously introduced in the cathode network. When the frequency of the servo excitation voltage deviates from 400 cycles per second, the combined effect of the phase-equalizing networks causes an over-all lead for frequencies slightly below 400 cycles per second and an over-all lag above 400 cycles. In the final analysis, these leads and lags help to maintain the range error output signal exactly in phase or exactly 180° out of phase with the servo excitation voltage. A second function of the cathode network is to minimize modulator response for variations in the input potentials with respect to ground. For instance, if terminals 1 and 3 of P1 are at 13 and 11 volts, the error voltage output should be the same as when these terminals are at 11 and 9 volts. This would not be the case, however, if this shift or level resulted in an appreciable shift of the quiescent operating points of the modulator tubes. (Remember that the amount of current through the tubes determines output amplitude.) The high resistance in the cathode circuits provide negative feedback which increases stability and makes the voltage amplification less dependent upon operating voltages and tube coefficients.

(6) *Cathode follower and output transformer.* The output of the balanced modulator is fed to the grids of V3A and V3B. The two triode sections are connected as cathode followers and form a push-pull current amplifier for driving output transformer T1. Capacitor C9 counteracts the inductance of the primary of transformer T1, thereby making the load impedance of V3A

and V3B nearly a pure resistance and preventing an undesirable phase shift in the output voltage. The output from the secondary of transformer T1 is fed to the range servo system.

b. Handwheel Assembly (Sh 32).

(1) *General.* The handwheel assemblies in the target and missile radars are identical. They furnish the manual and aided-tracking signals in both radars. However, since the missile radar is designed to perform its basic function of tracking the missile in automatic only, the handwheel assembly performs some functions in one radar that does not perform in the other. These differences will be pointed out as the various components of the handwheel assembly are discussed.

(2) *Servomotor.* The servomotor is identical to other servomotors used to drive small loads in the Nike I system. It is a two-phase induction motor containing a squirrel-cage rotor and two stator windings spaced 90° from each other. The motor serves no function in the handwheel assemblies of the missile-tracking radar and consequently has no excitation or control voltages applied to its windings. In the handwheel assemblies of the target-tracking radar, the motor is used only in automatic. Its function is to position the rate potentiometer so that if the radar should lose the target during automatic tracking, the rate potentiometer will supply a voltage to drive the system at the rate which was present at the moment automatic tracking was lost. The voltage which drives the motor must originate from a source which is driven at the automatic rate and can furnish a proportional voltage. In range, this source is the tachometer of the range servo motor. The tachometer's output is used because it is rotated at a speed directly proportional to the automatic rate and therefore can furnish the correct driving signal. When the output from the rate potentiometer balances the tachometer signal, the motor will stop. If the tachometer slows down, speeds up, or changes direction, the motor will cause correct movement of the rate potentiometer to balance the changed input.

(3) *Tachometer.* The tachometer is a two-phase induction generator similar to the servomotor. It is geared to the same shaft as the motor and is located in the same housing. The servomotor and tachometer comprise a component often referred to as the motor-tach unit. A 400-cycle tachometer excitation voltage of fixed phase and amplitude is applied to one of the stator windings of the tachometer. When the rotor is driven, a 400-cycle voltage is induced into the other stator winding. This induced voltage is nearly proportional to rotor speed and its phase depends upon the direction of rotor rotation. In manual operation of both radars, the output from the tachometer is used as the driving voltage for the respective servo systems being operated. In automatic operation of the target radar, this output acts as a negative feedback. PHASE potentiometer R2 is a 100-ohm potentiometer in series with the excited winding of the tachometer. Potentiometer R2 is used to adjust the phase of the voltage on the excited winding so that the output from the tachometer has the proper phase relationship with feedback and reference voltages appearing in later stages of the servo system.

(4) *Rate potentiometer R3.* When the magnetic clutch is engaged, it couples potentiometer R3 to the handwheel shaft so that approximately 5½ turns of the handwheel will move the contact arm of potentiometer R3 from its center position to either extreme. Either extreme of potentiometer R3 will furnish maximum rate voltage for the servo being controlled. It is possible to continue to turn the handwheel after the contact arm hits the stop at either end of potentiometer R3, because the magnetic clutch will slip. The output of potentiometer R3 is used in both radars as the control voltage in aided-tracking. In the target-tracking radar, a portion of the output is sent to the modulator, while in aided-tracking, this output is stored on capacitors and serves to smooth the process of switching to automatic tracking. While in automatic operation, the contact arm of potentiometer R3 is positioned by the servomotor because it is desired that the system drop back into aided-tracking if the target is lost momen-

tarily. The missile-tracking radar uses a different system of attaining this coast condition so that potentiometer R3 in the missile-tracking radar handwheel assemblies is used only for aided-tracking. Whenever the magnetic clutch in any of the handwheel assemblies is disengaged, potentiometer R3 is returned to its center position by spring action.

(5) *Magnetic clutch.* Coil L1 operates the magnetic clutch and is shunted by varistor VR1. When the circuit of the coil is interrupted, the voltage generated in the coil because of the collapsing field is shunted by the varistor and the energy stored in the coil is rapidly dissipated. This circuit prevents excessive arcing at contact points of control switches and relays. Coil L1, when energized, disengages the clutch. When the clutch is engaged, it will also act as a slip clutch when any mechanical movement tries to rotate the rate potentiometer beyond its mechanical limit stops.

(6) *Balance potentiometer R4.* The BAL potentiometer R4 is used to eliminate a slow movement, or drift, in the servo system that would result from a small induced voltage in the output winding of the tachometer. This voltage is present even though the rotor is stationary. Drift is eliminated by applying a 400-cycle voltage in series with the output winding so that it cancels the zero-speed induced voltage. Potentiometer R4 is connected across the secondary of a transformer which has its center tap grounded. Up to 6.5 volts of opposite phase may be picked off of opposite ends of potentiometer R4. Resistors R5 and R1 act as a voltage divider which reduces the balancing voltage to the correct value.

c. Going-rate Demodulator (Sh 32 and fig. 8).

(1) Transformers T5 and T6 in the going-rate demodulator have over-all turns ratios of 1:2 and have center-tapped secondaries. This gives a 1:1 ratio from the primary to each half of the secondary. All resistors in the bridge are of equal value and the rectifiers are polarized to pass electrons as indicated in figure 8. The reference voltage is applied to transformer T6 and must be large enough to control the bridge regardless of the rate-voltage input at transformer T5. The rate voltage comes from the rate potentiometer in the handwheel assembly.

(2) Assume that the reference voltage has the phase as shown by the waveforms on figure 8 and consider only the action which takes place during the first alternation. Also consider that no signal is present on transformer T5. Electrons will flow from terminal 4 of T6 to point A on the bridge then through CR9, R9, R11, CR11, point B and back to terminal 6 of T6. Point D is established at half the potential across the bridge because of equal values of R9 and R11. Terminal 5 of T6 will be at half the potential across the secondary of T6, due to the fact that terminal 5 is the center cap. These deductions then make it obvious that point D and terminal 5 are at the same potential and no charge will exist because of the reference signal except that the top half of the bridge will control C2, C3 will not charge unless a rate signal is applied to T5.

(3) Now consider the action of the circuit with the first alternation of the indicated reference waveform and also the first alternation of the rate voltage waveform. CR10 and CR12 will not conduct during this first alternation because of the polarities existing across the bridge. In order to keep CR10 and CR12 from conducting at this time, the reference voltage must be larger than any possible rate voltage present in this circuit. The negative voltage present at terminal 1 of T5 will modify the voltage at point D and cause more current through R11 and CR11 and less through CR9, R9. (This action can probably be better understood if the reader considers the negative side of the crystal as the cathode of a diode, and the positive side as the plate.) Point D going slightly more negative produces more current through R11 and less current through R9. CR9 will not be cut off because of the large value of reference voltage, but conduction through that leg of the bridge will be reduced. The bridge is now unbalanced, and electrons will flow from terminal 5 of T6 to the bottom of C2, C3 through the lower half of T5 secondary and then to D, R11, CR11, and back to T6. The results of this flow will

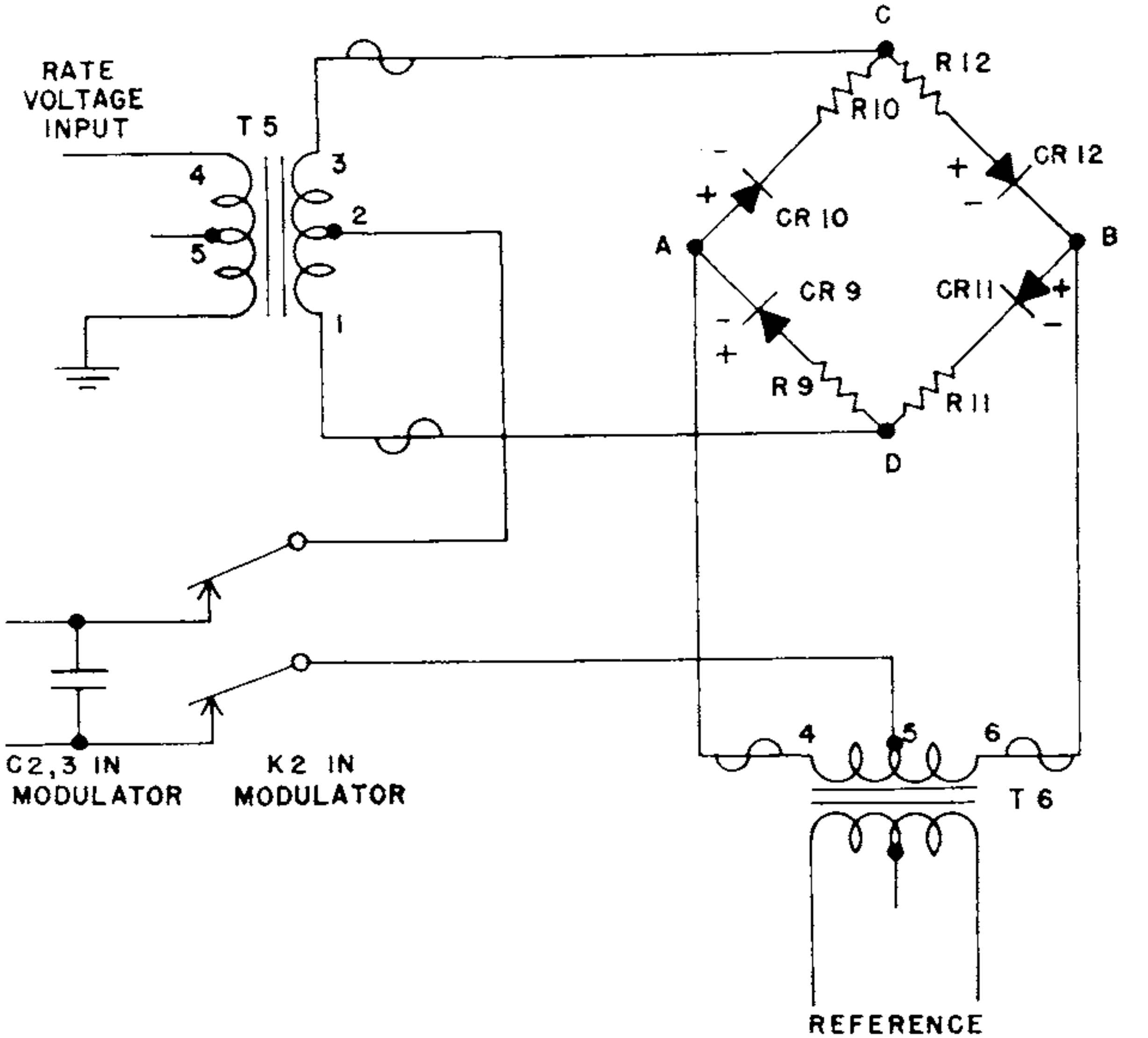


Figure 8. Going-rate demodulator, simplified schematic.

charge C2, C3 with a negative potential on its bottom plate. On the next alternation, the top half of the bridge will control and the increased current through CR10 and R11 and will give the same polarity charge on C2, C3. Only if the phase of the rate voltage should change, in comparison with the reference voltages will the polarity of the charge on capacitors C2–C3 be reversed. The action with reversed phase of the rate voltage is similar to that already described except that different legs of the bridge will control and produce opposite charges on C2, C3.

d. Range Coupling Unit (Pg 142, Vol. 2x). This unit is located to the right of center and along the rear panel of the target track control drawer. The coupling unit is a junction point for the many range servo signals used by the radar during the three modes of operation. The target range coupling unit determines the level and matches the input impedances of the various signals that are applied to the servo amplifiers during range servo operation.

CHAPTER 6

RANGE SLEW CONTROL UNIT

25. General

The range slew control unit controls the operation of the range slew motor or the range servomotor during target acquisition. In addition, associated circuitry of this unit provides the means by which the tracking range servo system may be slewed under manual control through large increments of range in a short period of time. The target range slew control unit is located in the control drawer of the target tracking console. At any one time, three input signals are applied to the range slew control unit. These three signals are normally the target preknock pulse, the acquisition range mark from the acquisition range system, and the acquisition tracking range mark from the target range unit. The range slew control unit compares the period of time between the preknock pulse and the acquisition tracking range mark with the period of time between preknock and the acquisition range mark. If the two time periods are equal, the target range servo system is already set to the designated range of the target. If the time periods are different, the range slew control unit will cause the range slew motor to change the range setting of the target radar in the direction necessary to remove the difference. A d-c control voltage is also applied to the unit. This voltage disables the unit so that it produces no output until the ACQUIRE switch on the control drawer is operated. When the ACQUIRE switch is operated, the d-c control voltage is removed, and the slew control unit is permitted to function and to exercise control over the range slew circuits and the range slew motor. A ground connection may be applied to the range slew control unit from the SLEW switch. This switch provides manual control of the range slew circuits and the range slew motor.

26. Block Diagram Discussion

(fig. 8-12)

a. Acquisition Range Mark Amplifier V1A. The positive acquisition range mark is applied to V1A, which is connected as an amplifier-inverter. One stage of voltage amplification supplies all the gain that is required. The output, taken from the plate of V1A, is applied as a trigger to one grid of flip-flop multivibrator V2.

b. Preknock Amplifier V1B. The operation and biasing of tube V1B is identical to that of V1A. Its output is applied to the control grid of V2B.

c. Flip-Flop Multivibrator V2. Multivibrator V2 is a bistable (flipflop) multivibrator similar to multivibrator V6 in the tracking AFC unit. The stage has two stable operating conditions and must be triggered twice in order to complete a full cycle of operation. It is triggered by the preknock pulse and again by the acquisition range mark. The output waveform from tube V2 is a square wave. The positive alternation extends from the preknock pulse to the acquisition range mark and the negative alternation from the acquisition range mark to the following preknock pulse. The durations of the positive and negative alternations of the waveform vary with the position of the acquisition range mark. The output of V2 is applied to paraphse amplifier V3B.

d. Paraphase Amplifier V3B. The output square wave of the multivibrator is applied to the paraphase amplifier V3B. This stage converts the single-ended input voltage into a push-pull output voltage. One of the output voltages from V3B is applied to tube V4A, and the other output is applied to tube V4B. The output which is applied to V4B is positive-going prior to the acquisition range mark and negative-going after that mark. The output which is applied to V4A is negative-going prior to the acquisition range mark and positive-going after that mark.

e. Delay Line Z1. The acquisition range mark is generated in the battery control trailer and is brought to the radar control trailer through coaxial cable. This signal experiences an over-all 0.45-microsecond delay with respect to the acquisition tracking range mark. When the range settings of the two radars are the same, these two signals should coincide in the range slew control unit. To insure that this coincidence will exist, the acquisition tracking range mark is applied through an LC network, Z1, which introduces a corresponding 0.45-microsecond delay.

f. Coincidence Tubes V4A and V4B. The push-pull square wave from tube V3B and the negative acquisition tracking range mark from tube V3A are applied to V4A and V4B. Only one section of tube V4 can function at one time. Conduction can occur only when the acquisition tracking range mark and a positive alternation of the square wave are present at the same time. This condition is met for V4A when the acquisition tracking range mark occurs after the acquisition range mark. V4B operates when the acquisition tracking range mark occurs before the acquisition range mark. At this time a positive alternation of the square wave is present at the grid of V4B. An output signal is produced only for the duration of the acquisition tracking range mark. The output from V4A or V4B, whichever is operating, is a pulse of current. One pulse is generated in each pulse repetition period. The plate of V4A is connected to switch tube V5, and the plate of V4B is connected to switch tube V6.

g. Switch Tubes V5 and V6. The switch tubes V5 and V6 have applied to them the output of V4A and V4B, as well as a d-c potential of minus 28 volts. The minus 28-volt potential is a disabling voltage which is controlled by the ACQUIRE switch on the target console control drawer. When the ACQUIRE switch is operated, this disabling voltage is removed from V5 and V6. When the acquisition tracking range mark is at a shorter range than the acquisition range mark, V4B produces a series of current pulses. These current pulses develop a bias voltage which disables V6. V4B continues to produce an output which keeps V6 disabled as long as the acquisition tracking range occurs before the acquisition range mark. V4A is cut off during this period by a negative alternation of the square wave. As V4A cannot conduct, V5 is allowed to operate. When V5 operates, it completes the circuit to the coil of SLEW-OUT relay K18. When K18 becomes energized, it causes the slew motor to drive the range servo system out in range. This causes the range of the acquisition tracking range mark to be increased until it passes the position of the acquisition range mark. As the acquisition tracking range mark passes the range position of the acquisition range mark, a switching action takes place. V4A then starts to produce an output. V4B, which was formerly producing an output, becomes cut off. The conduction of V4A disables switch tube V5. This action deenergizes slew-out relay K18, which had caused the range servo system to slew out in range. With V4B cut off, switch tube V6 is allowed to operate. The conduction of V6 energizes SLEW-IN relay K18, which causes the range servo system to be driven to a lower range setting. This continues until the acquisition tracking range mark again overshoots the range position of the acquisition range mark. Another switching action then moves the range system out in range. Because of the speed with which the slew motor drives the range gearing (12,000 yards per second), the acquisition tracking range mark initially overshoots the position of the acquisition range mark by several hundred yards. However, after the range gearing has overshot the position of the acquisition range mark, the slew relays disconnect the slew motor and substitute the range servomotor in its place. The range servomotor then operates under the control of switch tubes V5 and V6 to bring the acquisition tracking range mark to within approximately 50 yards of the position of the acquisition range mark.

h. Rectifiers CR1 and CR3. Selenium rectifiers CR1 and CR3 are used in the circuit which provides manual control of the range slew circuits and the range slew motor. When the SLEW switch on the control drawer is operated, it completes a ground connection to either CR1 or CR3, depending upon the direction in which it is desired to slew. This energizes the proper slew relay which in turn causes the slew motor to drive the range servo system in the desired direction. The SLEW switch allows the range operator to slew manually to any desired range setting.

27. Detailed Schematic Analysis

a. Acquisition Range Mark Amplifier V1A. This stage consists of one section of a 2C51 twin triode. The grid is biased to minus 13 volts (below cut-off) by voltage divider resistors R2–R3. The positive acquisition range mark is applied at jack J2 and is coupled by capacitor C2 to the grid of V1A. Resistor R12 is the plate-load resistor for V1A and also for the B-section of multivibrator V2. Thus, the negative acquisition range mark at the plate of V1A is applied as one input to the multivibrator.

b. Preknock Amplifier V1B. This stage is identical to V1A. The tube is biased below cut-off by the same voltage divider. The preknock pulse is applied at jack J3 and is coupled to the control grid through capacitor C8. The plate-load resistor R18 is shared by the A-section of multivibrator V2. The negative output of V1B provides the second input to the multivibrator.

c. Flip-Flop Multivibrator V2.

(1) *General.* V2 is a bistable multivibrator. A multivibrator of this type has two stable operating conditions. In one of its stable operating conditions V2A conducts and V2B is cut off. In its other stable operating condition V2A is cut off and V2B conducts. The multivibrator will remain in either of its stable conditions until a switching action is initiated by an appropriate trigger, at which time it will switch quickly to its other stable operating condition. It is therefore evident that V2 must be triggered twice in order to complete one full cycle of operation.

(2) *Operation with V2A conducting.* In the condition in which V2A conducts and V2B is cut off, plate current of 8.2 ma flows through the common cathode resistor, R15. This current develops a 42-volt potential at the cathodes. The voltages at the grid of V2A and at the plate of V2B are determined by the voltage divider consisting of R19, R14, and R12, which provides potentials of 242 volts at the plate of V2B and 42 volts at the grid of V2A. Hence, the A-section is conducting with zero bias, which is the bias required to produce a plate current of 8.2 ma. The current through plate-load resistor R18 consists of the space current of V2A, plus the current flowing from ground through resistors R11 and R13. This combined current produces a drop of 130 volts across R18. Therefore, the voltage at the plate of V2A is 120 volts. This voltage, impressed across R11 and R13, establishes a 21-volt potential at the grid of V2B. Since the cathode potential is 42 volts, a 21-volt bias exists on V2B and that tube cannot conduct. The multivibrator will remain in this condition until a negative trigger is applied to the grid of V2A, the conducting section.

(3) *Operation with V2B conducting.* When V2A is cut off and V2B conducts, the operating voltages are the reverse of those described in the preceding paragraph because the circuit is balanced in its design. The stage is stable in this condition also, requiring the application of a negative signal to the grid of V2B before a switching action can occur. During one full cycle of operation a square wave is generated at the plate of V2B. The amplitude of this square wave, 122 volts, may be found by determining the difference between the plate voltage with V2B cut off and the plate voltage with V2B conducting.

(4) *Application of preknock pulse.* Just before the preknock pulse arrives, V2A is cut off and V2B is conducting. The preknock pulse, inverted by V1B, is applied to the grid of V2B through capacitor C6. The negative signal drives the grid of V2B below cutoff. This causes a sudden decrease of plate current through V2B, which in turn causes the voltage at the plate potential of V2B to rise sharply. The sharp rise in the plate potential of V2B is coupled to the grid of V2A by capacitor C7. The rise in the voltage at the grid of V2A causes a surge of space current through V2A. This current surge, added to the current through preknock amplifier V1B, rapidly discharges the plate-to-ground capacitance of V2A, causing the plate voltage to drop sharply. The plate-to-ground capacitance of the tube consists of the stray capacitance (about 1 micromicrofarad) in parallel with the series combination of capacitor C6 and the input capacitance of V2B (which depends on the gain and is equal to about 25 micromicrofarads). As the

grid-to-ground capacitance of V2B is discharged, the grid potential drops. The action is regenerative, continuing until V2A is conducting and V2B is cut off. On first inspection of the circuit, it may appear that capacitor C6 (and also C7) is superfluous, since voltage divider R11–R13 causes a sufficient fraction of the drop at the plate of V2A to be applied to the grid of V2B. However, in the absence of C6, the 25-micromicrofarad input capacitance of V2B would have to be discharged through the parallel resistance of R11 and R13 to allow the grid potential of V2B to drop. The time required for this discharge is greater than 2 microseconds. However, the duration of the trigger (preknock pulse) is only 2 microseconds. Hence, the trigger pulse could come and go before the effect could be felt sufficiently at the grid of V2B. In such a case, the regenerative switching action previously described would not get sufficiently started before expiration of the trigger pulse. The function of capacitor C6 is to provide a fast discharge path for the input capacitance of V2B during the initial part of the switching action. This path is from ground through V1B, through C6, and through the grid-to-ground capacitance of V2B.

(5) *Application of acquisition range mark.* The acquisition range mark follows the preknock pulse by some interval determined by the setting of the acquisition range system. During the interval between the preknock pulse and the acquisition range mark, V2A conducts and V2B is cut off. The negative pulse from acquisition range mark amplifier V1A is applied to the grid of V2A through capacitor C7. The switching action which then occurs is similar to the switching action initiated by the preknock pulse. The acquisition range mark drives the grid of V2A below cutoff, causing a sharp decrease in plate current through V2A. The voltage at the plate of V2A then rises sharply. This rise in plate voltage is coupled to the grid of V2B by capacitor C6 and causes an increase in plate current through V2B and a corresponding decrease in voltage at the plate of V2B. This decrease in plate voltage is coupled back to the grid of V2A, causing a further drop in voltage at that grid. This switching action continues until V2A is cut off and V2B is conducting heavily. The multivibrator will remain in this condition until the next preknock pulse starts another switching action. The output signal of the multivibrator is taken from the plate of V2B. After the preknock pulse V2A is conducting and V2B is cut off, the voltage at the plate of V2B is maximum. After the acquisition range mark V2A is cut off and V2B is conducting, the voltage at the plate of V2B is minimum. The waveform at the plate of V2B for each pulse repetition period is a square wave of approximately 122 volts amplitude. This square wave is coupled by capacitor C9 to the grid of paraphase amplifier of V3B.

d. Paraphase Amplifier V3B. The output of multivibrator V2 is coupled to the grid of V3B. V3B converts this input voltage into a push-pull output voltage. V3B has two equal load resistors, R24 in the cathode circuit and R21 in the plate circuit. The voltage waveforms developed across these resistors are equal, since the same current flows through both resistors. The polarities of the two output voltages are opposite because the cathode output is taken from the more positive end of R24, and the plate output is taken from the less positive end of R21. The operating bias of V3B is limited to the voltage drop across R23, since grid resistor R22 is returned to the junction of R23 and R24. The gain of the amplifier is near unity. The output voltage from the plate of V3B, which is negative before the acquisition range mark and positive after that mark, is applied through C10 to the grid of V4A. The output voltage from the cathode of V3B, which is positive before the acquisition range mark and negative after that mark, is applied through C11.

e. Delay Line Z1. This LC network introduces a 0.45-microsecond delay of the acquisition tracking range mark to compensate for over-all system delays. This causes the acquisition tracking range mark to coincide with the acquisition range mark when the range setting of the target radar is the same as that of the range circle. The network is an artificial transmission line and is terminated in its characteristic impedance.

f. Acquisition Tracking Range Mark Amplifier V3A. Tube V3A amplifies and inverts the acquisition tracking range mark. The acquisition tracking range mark is a positive pulse of approximately 10 volts amplitude. This pulse is applied through capacitor C5 to the grid of V3A. Due to voltage divider action of R40 and R41 between −250 V and ground, a negative 5 volts exist at the grid of V3A between periods of the QTRMK pulse, serving to keep the tube at cut-off potential. This bias also serves to eliminate the negative overshoot occurring at the trailing edge of the QTRMK. When the positive acquisition tracking range mark arrives at the grid, it drives V3A into conduction, and the voltage at the plate of V3A drops to a very low value. This sharp negative pulse is applied through C12 to transformer T1 in the cathode circuit of V4.

g. Coincidence Tubes V4A and V4B.

(1) *General.* The push-pull square waves from paraphase amplifier V3B are applied to the grids of V4A and V4B, and the negative acquisition tracking range mark is applied to both cathodes. Since the plates of V4A and V4B are returned to ground through R27 and R28, respectively, V4A and V4B draw no static plate current.

(2) *Grid-clamping action of V4A and V4B.* The grid-cathode sections of V4A and V4B clamp the applied square waves at a level which is only slightly positive with respect to ground. The clamping action of V4A is identical to that of V4B. The square wave applied to the grid of V4B is positive before the acquisition range mark and negative after that mark. The positive alternation of the signal drives the grid of V4B slightly positive with respect to the cathode potential and causes grid current to flow. The cathode potential is slightly positive with respect to ground because of the small resistance in the winding of T1. The grid current quickly charges coupling capacitor C11 to the maximum amplitude of the positive alternation of the square wave. The negative alternation of the square wave drives the grid of V4B far below cutoff. Because of the large value of resistor R26, the charge lost by C11 during the negative alternation of the signal is negligible. (The time constant of the RC circuit is approximately 39,000 microseconds, as compared to the 1,000-microsecond duration of one pulse repetition period.)

Any change in the range at which the acquisition range mark appears will cause a change in the relative duration of the positive and negative alternations of the square wave. The clamping action insures that the operation of V4 is unaffected by such changes.

(3) *Circuit operation.* When the range system of the target radar is set so that the acquisition tracking range mark occurs prior to the acquisition range mark, V4B is capable of operating and V4A is cut off. At that time, a negative alternation of the square wave is present at the grid of V4B. This drives the grid of V4B slightly positive with respect to ground. When the negative acquisition tracking range is applied to the cathode of V4B, that section will conduct for the duration of the pulse. V4B continues to conduct once during each pulse repetition period as long as the acquisition tracking range mark occurs before the acquisition range mark. If the target tracking radar range setting is such that the acquisition tracking range mark occurs at a greater range than the acquisition range mark, V4A will conduct when the acquisition tracking range mark is applied to its cathode, and V4B will be held cut off.

(4) *Integrating capacitors C13 and C14.* Integrating capacitors C13 and C14 are connected in parallel with R27 and R28, respectively, and between the plates of V4A and V4B and ground. Since the operation of the two circuits is identical, only the operation of C14 will be explained in detail. When the acquisition tracking range mark occurs before the acquisition range mark, V4B conducts once during each pulse repetition period. Each pulse of current through V4B acts to charge C14. During the interval between pulses, C14 discharges through R28. The charge lost by the discharge of C14 is small because of the long time constant of the discharge circuit (approximately 8,600 microseconds). The negative voltage across C14 in-

creases with each succeeding pulse until the discharge current through R28 is equal to the current supplied to C14 through V4B during each conduction period. When this point is reached, the average voltage across C14 remains fixed at a constant level of approximately minus 9 volts. This negative 9-volt potential is applied directly to the second grid of switch tube V6 and is sufficient to prevent V6 from conducting. When the acquisition tracking range mark occurs after the acquisition range mark, V4A operates to develop a negative 9-volt bias at the second grid of switch tube V5.

h. Switch Tubes V5 and V6.

(1) *General.* Tubes V5 and V6 are grid-controlled thyratron tubes. Except during acquire or remote examine, both tubes are disabled by a negative 28-volt bias applied to the control grids through limiting resistors R30 and R31. Motor excitation (120 volts, 400 cycles) is applied to the plates of V5 and V6 through the coils of slew relays K18 and K19, respectively. Conduction of either V5 or V6 results in rectification of the applied a-c voltage and causes the associated slew relay to become energized.

(2) *Circuit operation.* When the acquisition tracking range mark occurs before the acquisition range mark, coincidence tube V4B conducts and applies a negative 9-volt bias to the second grid of switch tube V6. This voltage will keep V6 cut off. The second grid of switch tube V5 is at ground potential. When the ACQUIRE switch on the control drawer is operated, relays K8 and K15 are energized. Contacts of relay K15 open and remove the negative 28-volt potential from the control grids of V5 and V6. The control grids then rise to a voltage determined by voltage divider R34 R36. This positive voltage, approximately 7 volts, permits switch tube V5 to operate. V5 will conduct whenever the a-c voltage applied to its plate passes through a positive alternation. The conduction of V5 energizes slew-out relay K18, which is connected in series with its plate. As a result, the range slew motor drives the range gearing in the direction of increasing range. The inertia of the mechanism causes the acquisition tracking range mark to overshoot the acquisition range mark. As a result, V4A begins to operate and V4B becomes cut off. The conduction of V4A develops a negative 9-volt bias at the second grid of V5. This bias holds V5 cut off, and relay K18 becomes de-energized. With V4B cut off, however, the second grid of switch tube V6 rises to ground potential. This permits V6 to conduct, and slew-in relay K19 becomes energized. This causes the range servo system to be driven in the direction of decreasing range, thereby bringing the acquisition tracking range mark back to the position of the acquisition range mark. The acquisition tracking range mark always overshoots the position of the acquisition range mark, hence, V5 and V6, alternately conduct and cause the acquisition tracking range to oscillate back and forth about the position of the acquisition range mark. After the first overshoot, the range slew motor is disconnected, and the range servomotor then operates under the control of V5 and V6 to bring the acquisition tracking range mark to within plus or minus 50 yards of the acquisition range mark.

(3) *Miscellaneous circuit details.* Cathode resistor R29 develops a cathode bias voltage which adds to the 9-volt bias applied to the second grid of the cut-off thyratron. This cathode bias, developed by the conducting switch tube, corresponds to the positive half cycles of the 400-cycle voltage applied to the plates. Since the cathode of V5 and V6 are tied together, the positive rectified voltage at the cathode adds to the 9-volt bias voltage which is present at the second grid of the cut-off thyratron. This insures that the thyratron, which is cut off, does not accidentally fire out of turn. The cathode bias is maximum when the voltage at the plates is maximum, and it therefore reinforces the fixed bias at the most critical time. The capacitors and resistors, which shunt the coils of relays K18 and K19, smooth the rectified current flowing through the coils. This prevents the relays from chattering.

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(4) *Alternate inputs.* The foregoing discussion has been based upon the assumption that the input signals to the range slew control unit are the preknock pulse, the acquisition range mark, and the acquisition tracking range mark. These are the input signals applied under normal operating conditions. However, relay circuits external to the range slew control unit make it possible to switch these inputs. This switching is performed to make it possible to use the range slew control unit in conjunction with range-mark signals received from some remote source.

i. Rectifiers CR1 and CR3. When the range operator wishes to slew the range servo system manually, he operates the SLEW switch on the control drawer. Operation of the SLEW switch to the IN position completes a ground connection to CR3. CR3 then rectifies the 400-cycle voltage applied through K19, and relay K19 becomes energized. This causes the range slew motor to drive the range gearing in the direction of decreasing range. When the SLEW switch is operated to the OUT position, CR1 functions to energize slew relay K18. This causes the range servo system to move in the direction of increasing range.

j. Slew Relays K18 and K19 (Sh 32 and Sh 33). When the ACQUIRE switch is operated, the range slew control unit energizes relay K18 or relay K19. These two relays operate in conjunction with circuitry outside the range slew control unit to cause the range system to be slewed to the designated range. The sequence of events which causes relay K18 or relay K19 to be energized must be understood clearly. During the interval between the preknock pulse and the acquisition range mark, the output of multivibrator V2 is positive. This positive alternation appears at the plate of paraphase amplifier V3B as a negative signal, and the grid of coincidence tube V4A is held below cutoff. At the same time, coincidence tube V4B is capable of conduction because a positive alternation of the square wave, obtained from the cathode of the paraphase amplifier, is present at the grid of V4B. If the range setting of the target radar is too small, the acquisition tracking mark will appear during this interval. This signal, after being delayed and amplified, is applied to the two cathodes of coincidence tube V4, but the signal causes conduction only in V4B. The plate current of V4B develops a negative 9-volt charge on capacitor C14, and this charge holds switch tube V6 cut off. However, coincidence tube V4A does not conduct, and hence no cut-off voltage appears at the second grid of switch tube V5. Tube V5 then conducts and energizes the slew-out relay K18. Exactly opposite conditions exist when the range setting of the target radar is too great. In that condition, slew-in relay K19 becomes energized.

CHAPTER 7

RANGE SERVO SYSTEM OPERATION

28. General

The target range servo system is capable of several modes of operation. The particular mode of operation of the system is determined by the setting of switches and relays present in the control circuits of the range servo system. Some of the modes of operation of the system also depend upon the existence of certain relationships between the target echo and the signals which are developed in the target range unit and in the range error channel of the range error detector. These relationships, and the required conditions of control switches and relays, are not fully discussed in this section, but are discussed in detail in Chapter 9. The modes of operation of the target range servo system to be covered first are manual, aided-manual, and automatic. In manual operation, the range servo system is moved an amount proportional to the rotation of the range handwheel. In aided-manual operation, the range system is moved at a rate which is varied in proportion to the amount of rotation of the range handwheel. During automatic tracking the range system is positioned at a rate determined by the output of the range modulator, the direction of movement being such as to reduce any range error. When being slewed, the range system is caused to move by a high-speed slew motor at a rate which is much greater than the maximum rate of manual of aided-manual operation.

29. Block Diagram Discussion

a. Manual Operation (figs. 8-1, Sh 32, Sh 33). For all modes of operation, except slewing, the gearing of the target range unit assembly is driven by range servomotor B1. During manual operation the range servomotor is caused to run by rotation of the range handwheel. As illustrated in figure 8-1, the handwheel is mechanically connected to the range handwheel motor tachometer (also designated B1). This motor will be referred to as the handwheel motor. Turning the handwheel causes rotation of the handwheel motor and tachometer, and the tachometer develops a 400-cycle signal, which is fed through the range coupling network to low-power servoamplifier 7. The signal is amplified by the low-power servoamplifier and fed through contacts of relay K17 to the range servomotor. Rotation of the range servomotor causes its associated tachometer to develop a feedback voltage. The feedback signal is fed through the range coupling unit to the input of the low-power servoamplifier for servo system stabilization.

b. Aided-Manual Operation. For this type operation the control voltage for the range servomotor is obtained from the rate potentiometer R3. Relay K17 contacts will be as shown in Figure 8-1, and the range MAN-AID-AUTO switch S10 in the AID position. Turning of S10 to position 2 (AID) engages the magnetic clutch between the handwheel motor and the brush arm of the rate potentiometer. In this condition rotation of the handwheel displaces the brush arm of the potentiometer so that it yields a 400-cycle output voltage. This signal is fed through switch S10 and to the range coupling unit to low-power servoamplifier 7. For this type of operation an additional component of voltage is obtained from the tachometer of the handwheel motor when the range handwheel is turned. From this point on, the operation of the system is the same as for manual.

c. Automatic Operation (figs. 8-1 and 8-7). During automatic tracking the system control voltage originates in the range error detector. The d-c output of the range error detector is sent to the range modulator, the output of which is a 400-cycle error voltage. This, in turn, is fed through the range coupling unit to low-power servoamplifier 6. After amplification, the signal is sent through contacts of deenergized K17 to the range servomotor B1. The feedback from the tachometer of the range servomotor serves two functions. First, it is applied to the input of low-power servoamplifier 6 for servo system stabilization. Second, since the output of the tachometer is a function of target rate, it is used to position the brush arm of the rate potentiometer. This is accomplished in the following manner. It is applied to the input of LPSA 7, amplified, and sent to the handwheel motor through additional contacts of relay K17. The handwheel motor, through the magnetic clutch, will position the brush arm of the rate potentiometer. The output of the rate potentiometer, in turn, will be fed through the contacts of switch S10 (in the AUTO position) and relay K16 back to the input of LPSA 7. The signal from the rate potentiometer is of opposite phase to that from the tachometer of the range servomotor. The handwheel motor will run only enough to cause the rate potentiometer voltage to cancel the feedback voltage. If the target is lost, K17 will energize. The system will then return to the aided-manual mode of operation, with the range system being positioned at the same rate as when the target was lost by the output of the rate potentiometer. When the target echo reappears in the 35-yard range gate, K17 will again be deenergized, and the system will return to normal automatic operation.

30. Detailed Schematic Analysis

a. Manual Control (Sh 32). For manual operation the primary control signals for the system are generated in the range handwheel assembly. This assembly consists of the handwheel motor-tachometer, B1, magnetic clutch L1, rate potentiometer R3, and associated mechanical and electrical components. The assembly also contains PHASE potentiometer R2 and BALANCE potentiometer R4. The range MAN-AID-AUTO switch S10 is placed in the MAN position for manual tracking. As a result, the coil of magnetic clutch L1 in the range handwheel assembly is energized (clutch disengaged). No excitation voltage is applied to the handwheel motor for this mode of operation. In manual operation, the range handwheel assembly generates a 400-cycle voltage whose amplitude is proportional to the rate at which the range handwheel is turned and whose phase either leads or lags motor excitation voltage by 90 degrees, depending on the direction of handwheel rotation. The voltage generated by the handwheel drive appears between terminal 7 of tachometer B1 and ground. The control voltage from B1 is applied across load resistor R10 in the range coupling unit, through contacts 1 and 9 of K16 and contacts 3 and 10 of K15. The voltage developed across this resistor is fed through resistor R11 to the input of low-power servoamplifier 7. The amplified control voltage output of servoamplifier 7 is transmitted through contacts 11 and 5 of K17 to the control winding of the range servomotor (terminal 2). The speed feedback damping voltage is generated by tachometer B1 on the same shaft with the range servomotor. The feedback voltage is developed across resistor R3 of the range coupling unit and applied to low-power servoamplifier 7 through resistor R4.

(1) The PHASE potentiometer R2 is connected in series with the tachometer excitation winding of the handwheel tachometer to compensate for an inherent and undesirable phase shift between the tachometer excitation voltage and the tachometer output voltage. The resistance of R2 is variable between zero and 100 ohms. When the PHASE potentiometer is in the position where the series resistance is zero ohms, the phase relationship between the excitation voltage and the output voltage is incorrect by about one degree. This phase shift varies slightly with tachometer speed, with temperature, and with the frequency and amplitude of the tachometer excitation voltage. Since the impedance of the excitation winding is inductive, its voltage lags the excitation voltage. Introduction of resistance in series with the winding reduces the angle of lag and thus advances the phase angle of the output voltage. By adjustment of R2, it is possible to obtain the correct phase angle between the output voltage and tachometer excitation voltage.

(2) BALANCE potentiometer R4 eliminates servo drift, which results from a small voltage induced in the tachometer output winding although the tachometer rotor is stationary. This voltage is amplified sufficiently to cause the range servomotor to run at a low speed, even with the

range handwheel held stationary. The drift is eliminated by applying a 400-cycle voltage in series with the output winding so that it cancels the zero speed tachometer output voltage which is in phase with the signal. This is accomplished by returning the normally grounded end of the output winding to ground through resistor R1. Potentiometer R4 is connected across the secondary winding of a transformer whose center tap is grounded. The voltage output of this winding is 6.3 volts on either side of the center tap. The voltage on the potentiometer arm is zero in the center position and increases toward either extreme position. The phase of the voltage on one side of the center position is opposite to that on the other side of the center position. A voltage of 0 to 6.3 volts of either polarity can be tapped off by means of R4.

(3) Resistors R5 and R1 act as a voltage divider to reduce the compensating voltage to the value required for balancing the tachometer output when the handwheel is stationary.

b. Aided-Manual Control (Sh 32). For aided-manual tracking, the range MAN-AID-AUTO switch must be in the AID position. In this condition the magnetic clutch is engaged. In aided tracking, as in manual tracking, the primary control signals are obtained from the range handwheel assembly. In this case, however, the signals are not generated in the handwheel tachometer, but are obtained from the RATE potentiometer R3, which is mechanically coupled to the handwheel through the engaged magnetic clutch. This potentiometer is connected across the same winding of the same transformer as in the BALANCE potentiometer R4. Accordingly, the voltage on the brush arm of the RATE potentiometer is zero in the center position and increases linearly with the displacement of the brush arm from the center position. The potentiometer brush arm is suspended on springs which keep it centered when the clutch is disengaged (manual tracking). The voltage obtained from opposite sides of the center position is 6.3 volts. Six revolutions of the handwheel move the potentiometer brush arm from the zero position to the extreme position. The effect of the control voltage upon the speed of the range servomotor is such that, for each volt of control voltage, the range system gearing is caused to rotate at a speed which is equal to a range rate of 105 yards per second. The maximum aided rate is therefore about 650 yards per second. When either extreme position of the RATE potentiometer is reached, the brush arm hits a stop, but the magnetic clutch slips and allows continued rotation of the range handwheel. The control voltage from the RATE potentiometer is fed through switch S10, and the range coupling network to the input of low-power servo-amplifier 7. The effect of the rate voltage from thereon identical with the effect of the manual tracking control voltage. The composite signal applied to the input of low-power servoamplifier 7 consists of three components during aided operation. The RATE potentiometer voltage and the range servomotor tachometer feedback voltage are two of these components. The third component is obtained from the tachometer output in aided operation as well as in manual operation. This voltage is applied to the input of low-power servoamplifier 7 in the same manner as in manual tracking. This voltage is not proportional to the rate at which the range system gearing rotates, but to the acceleration or deceleration of the gearing. Such a voltage is referred to as a second derivative control voltage. It is zero when the handwheel is stationary and the range system gearing is rotated at a constant rate. When the rate is changed by rotation of the range handwheel, the second derivative voltage gives rise to an extra amount of torque required for increasing the rate of rotation of the gearing, or to the breaking torque required for slowing down the rate of rotation. The voltage supplied by the handwheel tachometer during aided tracking may also have a second function which differs from the second-derivative function. This function occurs when the maximum aided rate (650 yards per second) is insufficient for tracking. In that case further rotation of the handwheel cannot increase the rate voltage, and the voltage generated by the handwheel tachometer ceases to be a second-derivative voltage. It then simply adds to the maximum RATE potentiometer output voltage in proportion to the rate of handwheel rotation. This enables the operator to continue tracking a target even though the maximum aided rate voltage may not be sufficient. This type of operation does not come strictly under the heading of aided tracking, but rather manual tracking facilitated by aided rate.

c. Automatic Control (Sh 32). For automatic range tracking, the range MAN-AID-AUTO switch must be in AUTO position and relay K17 deenergized. During automatic tracking the magnetic clutch is engaged. The primary control signals are generated in the range modulator. The 400-cycle range error voltage from the range modulator is coupled to the input of low-power servoamplifier 6 through resistor R1 in the range coupling unit. The output of this amplifier is fed through relay K17 to the control winding of the range servomotor. The feedback voltage from the associated tachometer is fed back to the input of low-power servoamplifier 6 through resistor R2 in the range coupling unit. The feedback voltage from the tachometer of the range servomotor is used also for setting the RATE potentiometer so that if the target is lost and the system reverts to aided tracking, the RATE potentiometer will already be set to approximately the correct value. To accomplish this, part of the feedback voltage from the range servomotor tachometer is applied to the input of low-power servoamplifier 7 through R4 in the range coupling unit. Part of the voltage from the RATE potentiometer is used in this circuit action and is applied to servoamplifier 7 through switch S10 and resistor R7. Potentiometer R19 and resistor R18 in the range coupling unit form a voltage divider for this voltage. If the brush arm of the RATE potentiometer is on the correct side of the center position, the voltage from the potentiometer will be in phase opposition with the feedback voltage. The voltage across R11 and R10 results from two opposing components of current, one of which flows through R4 as a result of the feedback voltage, and the other through R7 as a result of the rate voltage. The effective voltage across R10 and R11, which is applied to the input of low-power servoamplifier 7 is due to the algebraic addition of the two current components. When the brush arm of the RATE potentiometer is in the correct position, the two currents cancel so that their sum is zero; thus, the voltage at the input of servoamplifier 7 is zero. The amplitude of the feedback voltage equals the rate voltage when zero potential is caused to exist at the input of servoamplifier 7. The values of R4 and R7 are chosen so that voltage required to produce a given range rate will draw the same amount of current through R10 and R11 as will be drawn through R4 and R7 by the feedback voltage developed at that particular rate. When the brush arm of the RATE potentiometer deviates from the correct position, there appears at the input of servoamplifier 7 a voltage proportional to the deviation. The phase of this voltage depends upon whether the rate voltage is too large or too small. This residual voltage is amplified in servoamplifier 7 and applied through contacts 6 and 7 of deenergized relay K17 to the control winding of the handwheel motor. In automatic tracking, this motor has power applied to its excitation winding. Thus, the motor drives the brush arm of the RATE potentiometer through the gearing and the engaged magnetic clutch in the range handwheel assembly. The phase of the voltage from servoamplifier 7 is such that the motor rotates in a direction to minimize the error in the rate voltage. The feedback voltage required to stabilize the servo loop which controls the RATE to the input of low-power servoamplifier 7 through contacts 1 and 9 of K16, 3 and 10 of K15, and R11 in the range coupling unit.

CHAPTER 8
RANGE SYSTEM CONTROL CIRCUITRY

31. Modes of Operation

a. General (Sh 31 and 32). This discussion will cover the operation of the relays and switches as they affect the specific operations to be discussed. Some of the relays have their coils shown on one page and their contacts on another. This discussion will give the relay number and the number of the contacts being used, but will not refer to the page unless a part of the relay being used is not shown on one of the two references given.

b. Manual Operation. For manual operation, it is necessary to energize the range MAN-AID relay K17. The path to energize this relay is completed through contacts 1 and 9 of deenergized ACQUIRE relay K15, and B and 1 of the range MAN-AID-AUTO switch S10, which is the MAN position. Contacts 5 and 11 of K17 complete the circuit between low-power servoamplifier 7 and range servomotor B1. The output from the range handwheel drive to the range coupling unit is completed by contacts 1 and 9 of deenergized RANGE CAL relay K17, and 3 and 10 of deenergized ACQUIRE relay K15. Magnetic clutch L1 in the handwheel assembly is energized by contacts A and 1 of RANGE switch S10. Energizing L1 disengages the clutch and mechanically disconnects RATE potentiometer R3 from the handwheel.

c. Aided-Manual Operation. As in manual operation, MAN-AID relay K17 must be energized for aided-manual operation. This is accomplished in the same fashion as in manual operation, except that contacts B and 2 of RANGE switch S10 are used instead of contacts B and 1. One path from the range handwheel assembly to the range coupling unit is the same as that used in manual. The magnetic clutch L1 in the handwheel assembly is deenergized since RANGE switch S10 is now in the AID position. This action engages the clutch and mechanically connects RATE potentiometer R3 to the handwheel. An output path from the RATE potentiometer in the handwheel assembly to the range coupling unit is now completed by contacts C and 2 of RANGE switch S10 and contacts 3 and 10 of deenergized RANGE CAL relay K16.

d. Automatic Operation. For automatic operation, MAN-AID relay K17 must be deenergized. This is accomplished by placing S10 in the AUTO position and removing ground from K17. The circuit between low-power servoamplifier 6 and the range servomotor is completed by contacts 10 and 3 of K17. The manual and aided-manual circuit between low-power servoamplifier 7 and the range servomotor is broken by open contacts 11 and 5 of K17. The magnetic clutch coil, L1, is deenergized, and the clutch mechanically connects the RATE potentiometer R3 to the handwheel. In case the target is lost, the range system will then go into aided tracking at approximately the same rate that existed when the target was lost. RATE potentiometer R3 is positioned by motor B1 in the handwheel assembly under control of low-power servoamplifier 7. This circuit is completed through contacts 11 and 6 of deenergized relay K17. The connection between RANGE switch S10 and terminal E51-2 is not wired in if it is desired to establish a tracking rate while acquiring a target. If this strap is in, magnetic clutch coil L1 will be energized through contacts A and 2 of S10, E51-2, E51-1, and contacts 1 and 9 of energized relay K8. Under this condition, no rate can be established while acquring a target since the magnetic clutch is disengaged. Removing this strap causes the clutch to engage and allows a rate to be established while a target is being acquired. The equipment will generally be received without the strap.

32. Slew Control Circuits, Detailed Analysis

a. General (figs. 8-1.1, 8-13, and Sh 32 and 33). The range system may be driven to the range designated either by the acquisition radar or by the fire direction center by operating the ACQUIRE switch, S5. The system may be slewed manually to any desired range by operation of the range SLEW switch S7. Slewing is accomplished by the slew motor B5 located in the range unit assembly. When the slew motor is energized, it attains full speed very quickly. The rotation of the slew motor operates a centrifugal clutch which disconnects the drive motor from the gear train and connects the slew motor.

b. Slew Motor. The slew motor is a special type of capacitor-run induction motor, especially adapted for reversible operation. Only one lead need be switched to reverse the direction of rotation. Figure 9 shows a simplified diagram of the slew motor with its control circuit. Terminal 5 of the slew motor is always connected to 120 volts motor excitation while the slew motor is being used. Terminal 4 is permanently connected to ground. Terminal 3 is connected through capacitor C1 to 120 volts when the motor is driving the range assembly in the direction of increasing range, but is connected through C1 to ground when range is being decreased. The necessary switching action is accomplished by a group of relays. Capacitor C1 provides the 90-degree phase shift for one winding of the motor.

c. Manual Slewing (Sh 32).

(1) The range slew circuits are arranged so that the operator can manually slew the tracking servo system to any desired setting. When SLEW switch S7 is placed in the OUT position, terminal

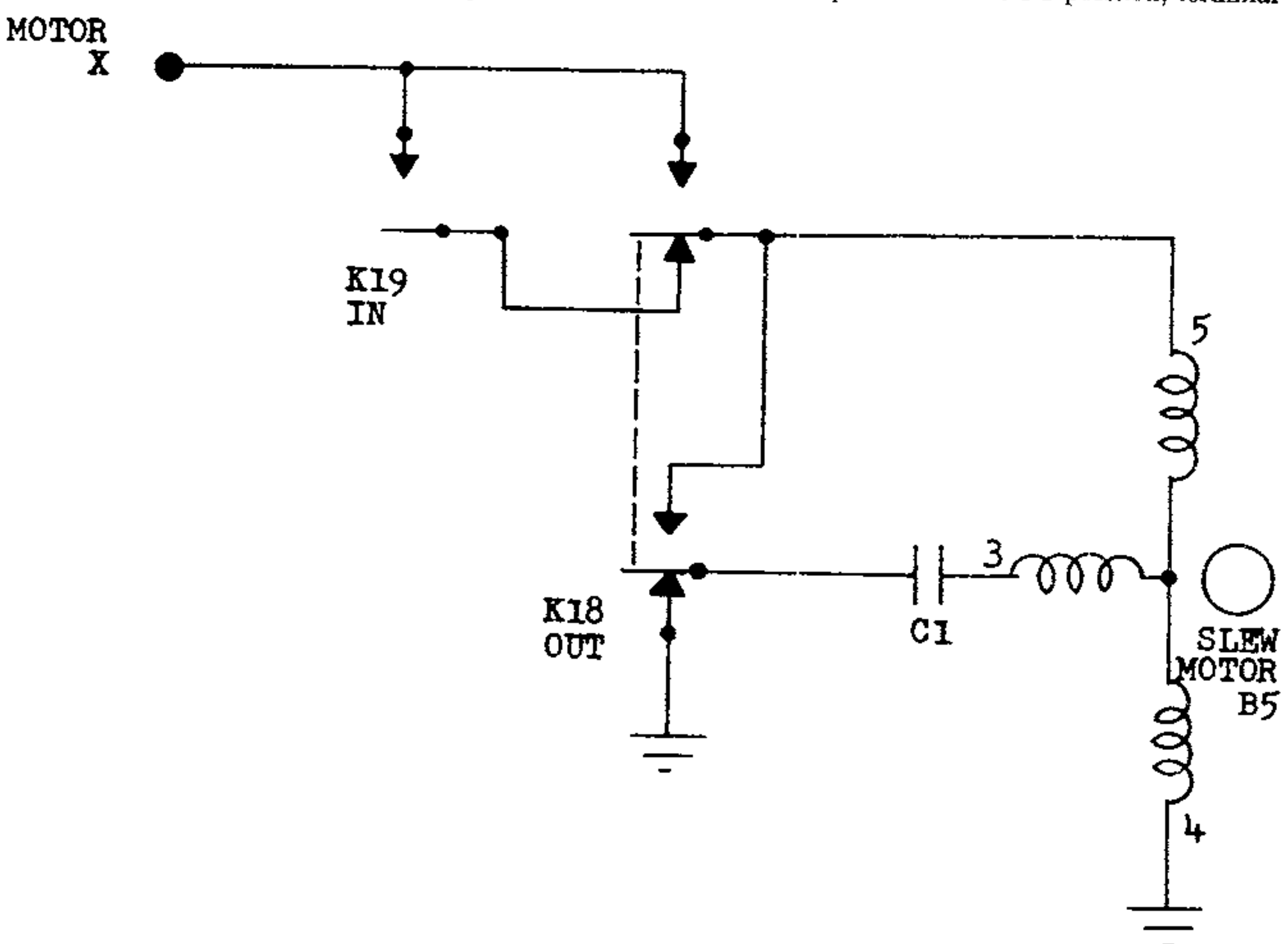

Figure 9. Range slew motor, simplified diagram.

11 of P1 on the target range slew control unit is grounded. The ground circuit is completed by contacts 1 and 2 of SLEW switch S7, 8, and 12 of the deenergized ACQUIRE relay K15 and 8 and 12 of deenergized ACQUIRE relay K6 (ACQUIRE relay K15 is energized only while ACQUIRE switch S5 is operated). It is apparent that automatic and manual slewing cannot take place at the same time. ACQUIRE relay K6 is not energized unless remote data from the fire direction center is being used and it is desired to examine this data. It is possible to slew the range system manually only if automatic slewing is not taking place and remote data is not being examined. The ground that is applied to terminal 11 of P1 completes a path for motor excitation that is applied to terminal 7 of P1. Rectifier CR1 in the range slew control unit serves as a half wave rectifier. Included in the path of CR1 is relay K18. When SLEW switch S7 is placed in the OUT position, relay K18 will become energized. Contacts of relay K18 then apply power to slew motor B5. Terminal 5 and terminal 3 (through C1) are connected to motor excitation through contacts 12 and 7, and 11 and 5 of energized relay K18, upper-limit switch S3, 10 and 3 of deenergized relay K21, and 9 and 1 of deenergized relay K22. This causes the slew motor to drive the range servo system in the direction of increasing range.

(2) The upper-limit switch S3 is provided to stop the slew motor when the range servo reaches a setting of 99,500 yards. At that point, a cam opens upper-limit switch S3, and excitation is removed from terminals 3 and 5 of slew motor B5. The limit switch is a safety device provided to prevent damage which could result if the range servo were driven against the mechanical limit with the full force of the slew motor.

(3) When SLEW switch S7 is placed in the IN position, terminal 9 of P1 on the range slew control unit is grounded. This completes a path for motor excitation through rectifier CR3. The path is the same as that through CR1, except that contacts 2 and 3 of S7 are used instead of 1 and 2, and relay K19 becomes energized instead of K18. With K19 energized, terminal 5 of the slew motor is connected to motor excitation through contacts 11 and 6 of deenergized relay K21. Terminal 3 of the slew motor is connected through C1 to ground through contacts 12 and 8 of deenergized relay K18. With motor excitation on one winding, the other two windings grounded, the slew motor will drive the range servo in the direction of decreasing range until the lower-limit switch is opened by a cam. Lower-limit switch S2 prevents the range servo from being forcibly driven into the mechanical limit. Motor excitation is removed from terminal 5 of the slew motor when the lower-limit switch operates. This action takes place at a range of approximately 500 yards. The servomotor will then drive the range system at a much slower rate until it is against the mechanical stops.

(4) There is a small folding handle on the range unit assembly to enable a maintenance man to control the rotation of the range assembly manually at the unit (in the range and receiver cabinet). Unfolding the handle opens HANDWHEEL switch S1 and thereby opens the circuit to terminal 5 of the slew motor. This arrangement prevents slewing of the range servo system, either manually or automatically when the handwheel is being used.

(5) The slew motor and drive motor are connected to the same gear train. When the slew motor starts, the centrifugal clutch disconnects the drive motor from the gear train. As soon as the slew motor stops, it is disengaged, and the drive motor is again engaged in the train. A braking voltage is applied to the slew motor when SLEW switch S7 is released, due to relays K18 and K19 both being deenergized. When the slew motor starts rotating, CENTRIFUGAL BRAKING switch S4 closes. (When the motor is stationary, the switch is open.) Although S4 may be closed, the braking voltage cannot be applied to the motor until relays K18 and K19 are both deenergized or K20 and K21 are both energized. Relays K18 and K19 are deenergized when SLEW switch S7 is released. With either K18 or K19 energized, the

braking voltage is removed from the slew motor, and only a-c potentials may be applied. However, if both are energized, the braking voltage will be applied.

d. Acquire Operation (Local) (Pg 272, TM 9-5000-25).

(1) For local operation, LOCAL-REMOTE switch S4 is in the LOCAL position. In this type of operation, the acquisition radar is used to designate targets to the target tracking radar. Relay K23 is deenergized when S4 is in the LOCAL position, as it is dependent upon contacts 2 and 3 of S4 for a ground circuit. With this relay deenergized, the inputs to the range slew control unit are the acquisition range mark (through contacts 8 and 12 of deenergized relay K23), the acquisition tracking range mark, and the target preknock pulse. For the purposes of explanation, it will be assumed that the acquisition tracking range mark is initially at a shorter range than the acquisition range mark. The range servo system must then be slewed outward in range to the position of the acquisition range mark.

(2) When a target is designated from the acquisition radar to the target tracking radar, the intersection of the range circle and steerable azimuth line is placed over the target. The tracking operators are then signaled to acquire this target. The tracking azimuth operator then operates ACQUIRE switch S5, and ACQUIRE relay K8 (KQC) is energized by the completion of the ground circuit to one side of this relay through contacts 4 and 5 of S5. Range ACQUIRE relay K15 (KQ) is now energized through contacts 12 and 8 of deenergized relay K1 and contacts 10 and 2 of energized relay K8 (KQC). Energizing relay K15 (KQ) disables the manual slew circuit by breaking its own contacts 8 and 12. Also, the minus 28-volt potential that normally disables the range slew control unit is removed from that unit by the now open contacts 6 and 11 of K15 (KQ). Contacts 9 and 2 of K15 (KQ) provide a ground circuit of relays K2 in the range modulator and for MAN-AID relay K17. The energizing of relay K17 sets up aided-manual operation of the normal range servo system. [Manual operation is disabled by contacts 10 and 3 of K15 (KQ), disconnecting the range handwheel assembly from the range coupling unit.] Motor excitation is removed from the handwheel assembly by contacts 12 and 8 of K8 (KQC). The purpose of this arrangement is to allow the range operator to establish a rate in range while a target is being acquired. To accomplish this, MAN-AID-AUTO switch S10 is operated to the AID position to engage the magnetic clutch in the handwheel assembly. The output of rate potentiometer R3 is connected to the range coupling unit through contact 2 and C of S10 and 3 and 10 of deenergized relay K16. The output of low-power servoamplifiers is connected to the drive motor through contacts 11 and 5 of energized relay K17. The drive motor will rotate at a speed determined by the rate established in the handwheel assembly. As soon as the ACQUIRE switch is released, the drive motor will drive the servo at this rate. The purpose of energizing relay K2 in the range modulator is to allow the capacitors in the input of this unit to assume a charge proportional to the range rate of the target. This is to establish an input to the range modulator before automatic operation. In other words, the capacitor will already have a charge proportional to the range rate of the target before automatic operation begins.

(3) The minus 28-volt potential is removed from the range slew control unit, and this unit can respond to the relative position of the acquisition range mark and the acquisition tracking range mark. Since an assumption was made to establish a slew-out condition, the range slew control unit will energize OUT relay K18. Contacts 2 and 9 of K18 complete a ground circuit for K20. This ground path is through 2 and 9 of energized relay K18, 12, and 8 of deenergized relay K1, and 2 and 10 of energized relay K8 (KQC). Relay K20 provides its own holding circuit through contacts 9 and 2 and cannot become deenergized until the ACQUIRE switch is released. In addition to energizing relay K20, relay K18 applies motor excitation to terminal 5 of the slew motor through contacts 9 and 1 of deenergized relay K22, 10 and 3 of deenergized relay K21, upper-limit switch S3, and 11 and 5 of energized relay K18. Terminal 3 of the slew motor is

connected to motor excitation by contacts 12 and 7 of energized relay K18. The rotation of the slew motor will drive the range servo to increase range. The rotation of the slew motor causes the normally open centrifugal clutch geared to the slew motor to engage. The slew motor now drives the gearing assembly at a rate of 12,000 yards per second.

(4) As soon as the range servo has been slewed outward to the designated range, the switching circuit in the range slew control unit disconnects the energizing path for relay K18, but this action does not take place until the exact range is reached. Due to its inertia, the motor will continue past this point, and an error will be present in the range slew control unit to produce a slew-in condition. This causes relay K19 to become energized. Contacts 2 and 9 of K19 complete a ground circuit for relay K21, using the same path as was used by K20. Relay K21 completes its own holding circuit by its contacts 2 and 9. Since relay K20 remains energized due to its holding contacts, relays K20, K21, and K19 are now energized. The breaking of contacts 10 and 3 of K21 removes motor excitation from terminals 3 and 5 of the slew motor. The d-c braking voltage is now applied to terminal 5 of the slew motor through S4, contacts 10 and 4 of energized relays K20 and K21, lower-limit switch S3, contacts 12 and 7 of energized relay K19, and 6 and 11 of deenergized relay K19. The slew motor is stopped quickly. When the motor stops, CENTRIFUGAL switch S4 opens and removes the braking voltage. The slew motor is thereby ready for the next slewing action. Also, the centrifugal clutch disengages the slew motor from the gear train and engages the drive motor.

(5) With relay K19 energized and the drive motor connected to the gear train, 6.3-volt servo excitation from transformer T6 3 through contacts 11 and 5 of K19, 11 and 6 of deenergized relay K22, and through the range coupling unit to low-power servoamplifier 7. This amplifier is connected to the drive motor through contacts 11 and 5 or energized relay K17. The drive motor will cause the range servo to decrease the range of the servo system until the range slew control unit causes K19 to deenergize and K18 to energize. (Relays K20 and K21 remain energized due to their holding circuits.) The braking voltage is not applied to the slew motor because S4 is open, but neither is motor excitation applied, so the slew motor will not operate. However, 6.3-volt a-c excitation from transformer T6 3 is applied to the low-power servoamplifier through contacts 10 and 4 of energized relay K18, 11 and 6 of deenergized relay K19, and deenergized relay K22. The servo drive motor will now drive the range system to increase range until the range slew control unit again reverses the conditions of relays K18 and K19. Until the ACQUIRE switch is returned to the normal position, relays K18 and K19 energize and deenergize alternately, reversing the phase of the servo excitation voltage fed to the range coupling unit. As a result, the servomotor oscillates back and forth. The maximum excursion from the correct value corresponds to approximately 50 yards. Oscillation of the servo system takes place even in the presence of an aided rate voltage set in as explained earlier. When the ACQUIRE switch is released, relays K20 and K21 are deenergized due to K8 (KQC) becoming deenergized, and the minus 28 volts disabling voltage is reapplied to the slew control unit through contacts 10 and 3 of deenergized relay K22, and 6 and 11 of deenergized relay K15 (KQ) to J16-4 of the range slew control unit. The relays that are energized in the correct order to slew outward in range are K8, K15, K17, K18, and K20.

(6) If the acquisition tracking range mark is at a greater range than the acquisition range mark, it is necessary to slew the target range assembly in the direction of decreasing range. This is accomplished in a manner similar to that employed for slewing out in range. The relays that are energized to slew inward in range are, in order, K8, K15, K17, K19, and K21.

(7) To slew to the range of a designated target, the slew motor provides the driving power until the range is reached and is exceeded slightly. The servomotor then takes over and causes the range servo to oscillate about the correct range. The driving voltage from the servomotor is servo excitation, and during acquisition this voltage is supplied by transformer T6. This

transformer is center tapped with 12.6 volts across the entire secondary. The phase from one terminal to ground is opposite from that of the other side to ground. This, then, will cause the servomotor to reverse direction when relays K18 and K19 switch operating condition.

c. Acquire Operation (Remote). The slewing operation of the range servo system is the same in remote as it is in local. The difference between the two is the change in inputs to the range slew control. For remote operation the LOCAL-REMOTE switch S4 is placed in the REMOTE position, energizing relays K5 and K23 by completing a ground circuit for these relays. Contacts 4 and 12 of relay K5 illuminate the REMOTE DATA lamp. Contacts 8 and 12 of relay K23 remove the acquisition range mark from the range slew control, and contacts 12 and 7 of the same relay apply the remote range mark to the range slew control. The operation of the over-all system when ACQUIRE switch S5 is operated is the same as in local. The remote range mark simply replaces the acquisition range mark.

33. Remote Examine and Trim Control Circuits

a. Remote Examine.

(1) *General.* When the tactical control officer locates a target on the PPI indicator of the acquisition radar during local operation, the intersection of the range circle and the steerable azimuth line are placed over this target. The target is then visible on the precision indicator of the acquisition radar, and a fine adjustment may be made with the acquisition controls to be sure that the correct range and azimuth of the target are established for designation to the target radar. In remote operation the targets are designated by the fire direction center. Means are provided for the tactical control officer to monitor or examine this information.

(2) *Operation* (fig. 9-13 and 8b 33). When the LOCAL-REMOTE switch S4 is placed in the REMOTE position, relays K5 and K23 are energized, as previously explained. REMOTE EXAMINE switch S6 is operated to monitor the remote data, and relays K6, K9, and K22 then become energized. The ground path for these relays is completed through contacts 2 and 1 of S6, 2 and 3 of RELEASE switch S5, and 2 and 3 of S4. A holding circuit for K6, K9, and K22 is provided by contacts 9 and 2 of relay K6 after REMOTE-EXAMINE switch S6 has been released. The complete holding circuit is through contacts 2 and 9 of energized relay K6, 3 and 9 of deenergized relay K7, 7 and 11 of deenergized relay K8, 5 and 6 of S6, 2 and 3 of S5 and 2 and 3 of S4. Contacts 12 and 7 of K22 apply the acquisition range mark to the range slew control unit in place of the acquisition tracking range mark. The inputs to the range slew control unit with relays K22 and K23 energized are the remote range mark and the acquisition range mark. The breaking of contacts 10 and 3 of K22 removes the minus 28-volt disabling potential from the range slew control unit and thereby enable this unit to function. Contacts 11 and 6 of K22 disconnect the output of transformer T6 from the range coupling unit, and contacts 9 and 1 remove motor excitation from the control circuits of slew motor B5. The target range slew control unit has now been converted for use with the acquisition radar instead of with the tracking radar. Motor excitation is applied to the acquisition range motor through contacts 9 and 2 of energized relay K22, 10, 3, or 4, depending on the condition of K19, and limit switches S2 and S3 of the target designate control panel. Relay K19 will be energized if the acquisition range mark is greater in range than the remote range mark. In this case contacts 10 and 4 of K19 will be used for motor excitation. The acquisition range motor will cause the acquisition range unit to decrease in range. The servo will stop when the acquisition range mark reaches the same range as the remote range mark, and the target that has been designated by the fire direction center should then appear on the precision indicator. The tactical control officer can now see how far the designated remote range is from the actual range of the target. If there is too much error, it may be necessary to correct or trim the information. This is discussed in paragraph *b* of this section. During remote examine the

REMOTE-EXAMINE light on the target designate control panel is illuminated. Minus 28 volts is applied to one side of this light at all times, and contacts 7 and 12 of energized relay K6 complete the ground path.

b. Trim Control Circuits.

(1) *General.* Trimming is performed only if examination has shown that the remote data is incorrect. During trim, the system is returned to local operation, and the data sent to the target tracking radar is of local origin.

(2) *Operation* (Sh 35). Before the TRIM pushbutton is depressed, the relays and switches are in the same position as in REMOTE EXAMINE. When the momentary contact trim pushbutton S7 is depressed, it completes the energizing circuit for relay K7 through contacts 2 and 1 of S7, 5 and 6 of S4. Contacts 12 and 7 of K7 illuminate the TRIM light on the target designate control panel. The remote-examine circuit is broken by contacts 1 and 9 of K7. Relay K23 is deenergized by contacts 11 and 6 of K7, and K6 and K22 are deenergized by contacts 4 and 9 of K7. With relays K22 and K23 deenergized, the acquisition range mark and the acquisition tracking range mark are the inputs to the range slew control unit. The control circuit for slew motor B5 is again established. The tactical control officer may now position the acquisition range mark to correct the inaccurate remote data. The target can now be acquired in range using the acquisition range mark. When the target is acquired and tracked, the holding circuit for K7 is broken by the operation of TRACKED switch S1. The purpose of RELEASE switch S5 is to break the holding circuit for relays K6 and K22 after remote examination and finding that no trim is necessary.

CHAPTER 9
RANGE CALIBRATOR

34. General

In steering the missile to the target, the computer is concerned with the coordinate distances between the target and missile. The computer obtains this information by comparing the missile position to that of target position. Since position is a function of range, it is extremely important that both radars have exactly the same degree of range measurement accuracy. When this condition is imposed, zero range error will be obtained only when the missile actually collides with the target. To illustrate this point assume that a target and a missile are at the same azimuth and elevation, that the target range is 10,100 yards, and that the missile range is 10,000 yards. If both radars have a 1 percent over-range error, the apparent target and missile ranges are 10,201 yards and 10,100 yards, respectively, and the calculated difference is 101 yards (10,201 yards minus 10,100 yards) instead of the actual 100 yards. The error thus generated is small and can be neglected. Assume now that only the missile radar has a 1 percent over-range error. The calculated difference is now zero instead of 100 yards. A difference error of zero indicates that the missile and target have collided, which, in this instance, is untrue since the two are actually 100 yards apart. Errors of this magnitude would render the Nike system ineffective. Thus, it can be seen that, while absolute range is not extremely important, the relative range error between the two radars must be exceedingly small. This is accomplished by calibrating the range system of the two radars against a single standard, the range calibrator. The purpose of the range calibrator is to provide sync pulses and 500-yard markers which may be used as the preknock pulse and video during range calibration. These pulses will produce the range error voltages which are necessary in simultaneous range calibration of the missile and target-tracking radars.

35. Block Diagram Discussion

(fig. 8-15)

a. General. The range calibrator is located on slide 4 in the radar range and receiver cabinet. Only one calibrator is used in the calibration of the tracking radars, since it is necessary that the range systems be in synchronism to insure accurate calibration. The meters located on the front of the slide are the RANGE ERROR meters. One meter indicates target range error and the other missile range error and receive inputs from the associated range error detector. During range calibration the range systems are adjusted to obtain zero range error difference, as indicated on these meters.

b. Oscillator V1. The range calibrator has no signal input. Oscillator V1 performs the timing for both the missile and target sections of the calibrator to insure that the range systems are synchronized during the calibration procedure. Oscillator V1 is basically a 2-stage, RC-coupled amplifier with positive feedback between stages. The oscillations of the tank circuit are sustained and stabilized by crystal-controlled feedback. The crystal varies the phase of the feedback if the frequency of the oscillator tends to change, causing an apparent change in capacitance or inductance in the tank circuit. This apparent change causes the frequency of the oscillator to return to 328 kc. The crystal which controls the oscillator is contained in an oven which is maintained at a constant temperature by a thermistor-controlled heating element. The oscillator generates sine-wave voltages at a frequency of 328 kc. The period of 1 cycle at a frequency of 328 kc is 3.05 microseconds, which is equivalent to 500 yards radar range. The output of V1 is applied to paraphase amplifier V2, where it will be used in the generation of the calibrator sync pulses.

c. Paraphase Amplifier V2. V2 is a dual-triode with its sections connected in parallel. The input from V1 is applied to the grids of V2, and outputs are taken from the plates and cathodes. The output signals are two 328-kc sine waves, equal in amplitude and 180° out of phase. These signals are applied to phase-shifting networks R52 and R53.

d. Phase-Shifting Network R52. R52 and associated circuit components comprise an RC-phase-shifting network, which is used to shift the phase of the 328-kc sine wave through any number of degrees between 0 and 360°. The phase shift introduced by R52 determines the position of the 500-yard markers in relation to the calibrator sync pulse.

e. Pulse-Forming Amplifier V3A and V3B. A 328-kc sine wave of a phase determined by R52 is applied to pulse-forming amplifier V3A, where it is amplified and inverted. The output is applied to V3B. A square wave appears at the plate of V3A because of the action of the grid circuit of V3B. During the positive half-cycle of the signal at the plate of V3A, grid current flows in V3B, effectively lowering the resonant frequency of the tank circuit and the signal is limited. The negative half-cycle is also limited by the action of the grid circuit of V3B, and the resulting square wave at the grid of V3B is clamped negative with respect to ground. The signal is amplified and inverted by V3B. A crystal limits the positive pulse, which would otherwise appear at the primary of the transformer, and the negative pulse is inverted by transformer action. The output at J2 is a series of positive 500-yard markers. These markers are applied to the missile range error detector, where they are used as video of a known range to provide range error voltages during calibration procedure.

f. Phase-Shifting Network R53. R53 functions in the same manner as R52 to shift the sine wave through 360°. R53 is used in the generation of the 500-yard markers for the target tracking radar. The signal from R53 is applied to pulse-forming amplifier V4A.

g. Pulse-Forming Amplifier V4A and V4B. V4A and V4B produce 500-yard markers in the same manner as V3A and V3B. The output from V4B is used in the target range error detector as video during range calibration.

h. Amplifier V5. The output of V1 is applied to amplifier V5. In the grid circuit of V5, the positive half-cycle of the sine wave from the cathode of V1 is limited. The negative half-cycle drives V5 below cutoff. Positive square waves appear in the output of V5. The square wave output is applied to cathode follower V6A, where it is changed to trigger pulses which are used to synchronize multivibrator V7, and to gating circuit V6B, where the pulse is gated. A pulse results which is used to trigger blocking oscillator V8B.

i. Cathode Follower V6A. The square wave from V5 is differentiated in the grid circuit of V6A. The pulses from V6A are used to synchronize multivibrator V7.

j. Multivibrator V7. V7 is a free-running multivibrator which produces a square-wave output at a frequency about 1,000 cps. The pulse from V6A synchronizes V7 with the oscillator and thus with the 500-yard markers. The square-wave output of V7 is applied to delay network Z5. The negative-going edge of the waveform is very steep. The rest of the waveform is unimportant because the negative-going edge is the only part used.

k. Network Z5. Network Z5, in conjunction with V7 and V8A, forms a quarter-cycle oscillator. The negative-going edge of the waveform from V7 starts the quarter cycle of oscillation which is damped by grid current flow in V8A and current flow through a crystal when the grid of V8A goes slightly positive with respect to ground. This action places a low-impedance shunt across the coil of the network, and the oscillation is rapidly damped. The components in the network are selected so that V8A is held cut off for 4.5 microseconds. This signal occurs at a frequency of about 1,000 pps.

l. Amplifier V8A. The negative signal at the grid of V8A holds it cut off for a period of 4.5 microseconds. The positive 4.5-microsecond square wave which results at the plate of V8A is applied to gating circuit V6B.

m. Gating Circuit V6B. V6B is a cathode follower which operates as a coincidence tube. V6B is normally cut off by a positive potential placed on its cathode. The square wave from V5 is differentiated in the grid circuit of V6B. Neither the pulse from V5 or the square wave from V8A is large enough to drive V6B into conduction. However, when these signals are coincident, their combined voltage will cause V6B to conduct and yield a positive signal at its cathode. The output of V6B is used to trigger blocking oscillator V8B. V6B insures that the blocking oscillator is triggered in synchronism with the 328-kc oscillator even though the output of V7 shifts slightly in time.

n. Blocking Oscillator V8B. V8B is a conventional blocking oscillator. Between pulses the tube is held cut off. When the positive output of V6B is applied, the tube conducts, and a negative pulse appears at the plate of the blocking oscillator. The negative pulses from the plate are inverted by transformer action and applied to jacks J4 and J5. The pulses at J4 and J5 are 0.25-microsecond pulses that are synchronized with the 328-kc oscillator and have a prf of 1,000 pps. These pulses are used to trigger the range phantastron and the main gate generator in the range unit assemblies of the target and missile radars during calibration procedure.

36. Detailed Schematic Analysis

(fig. 8-16).

a. Oscillator V1. Oscillator V1 generates a stable 328-kc sine wave used for timing the action of the entire range calibrator. The oscillator is crystal controlled by Y1 and is basically a two-stage, RC-coupled amplifier with positive feedback to sustain oscillation. Crystal Y1 is a series-tuned, high-Q circuit element which provides frequency stability at 328 kc. The inductance of Z1 resonates with C1, C7, C8, and C9, and the capacitance of Z1 at 328 kc. Minimum impedance is presented by Y1 at resonance (328 kc). The feedback from the tank circuit to the grid of V1A is in phase with the voltage at the plate of V1B, thereby sustaining the oscillations. If the frequency of the tank circuit tends to rise above the frequency of the crystal, the impedance of the crystal appears inductive. The inductance of the crystal causes the current through R2 to lag the feedback voltage. The voltage developed across R2 as a result of this current lags the voltage at the plate of V1B (the feedback). The signal from V1A is applied to V1B, causing the plate current of V1B to lag the plate voltage. The lag in plate current causes an apparent inductance to develop in series with the tank circuit. The apparent increase in inductance causes a reduction in the resonant frequency of the tank circuit, thereby maintaining frequency stability. If the frequency of the tank circuit tends to fall below the crystal frequency, the impedance of the crystal becomes capacitive, and the voltage developed across R2 leads the voltage at the plate of V1B. This causes the plate current of V1B to lead the plate voltage. The apparent capacitance reduces the total capacitance of the tank circuit. The decreased capacitance of the tank circuit tends to increase the resonant frequency to 328 kc, thereby maintaining frequency stability. R2 is relatively small compared to other grid resistors so that a small change in impedance of Y1 will be sufficient to correct the frequency of the tank circuit. The output signal is taken from the junction of C8 and C9, which act as a capacitive voltage divider, to provide a signal of the correct amplitude to V2. During replacement of tubes, C7 provides protection for maintenance personnel and the plate supply of V1. In the process of removing or inserting tubes, contact between the crystal terminal and ground might place the repairman between the plate supply and ground if it were not for C7. Also, a shorted-crystal holder could ground the plate supply. The output from the junction of C8 and C9 is applied to paraphase amplifier V2 where it is used in the production of the 500-yard markers. The output from the cathode of V1A is fed to amplifier V5 for use in the generation of the calibrator sync pulses. A change in temperature of a crystal will cause its output frequency to vary. In order to reduce frequency drift that may occur due to changes in ambient temperature, the crystal is mounted in a temperature-con-a controlled oven. The oven has a heating element built into it. Mounted externally from the oven, and thermally shielded from it, is a thermistor R67 (RT1) and a limiting resistor R1. The thermistor is in parallel with the heating element, and both are in series with R1. As the ambient temperature decreases, the resistance of the thermistor increases, thus causing more curretn to flow through the heater element. Conversely, as ambient temperature rises, the resistance of R67 decreases, and more current is shunted past the heater element, resulting in less heat being generated within the oven. The temperature of the crystal, and hence its frequency, is held constant by the action of the thermistor.

b. Paraphase Amplifier V2. The 328-kc oscillator output is applied to the grids of V2, which is a twin triode with both sections connected in parallel. The plate load consists of R7 and R9, and the cathode resistance consists of R12 and R13. Since the plate load and cathode load are equal, sine waves, equal in amplitude but opposite in phase, appear at the plate and cathode for a given input signal. These signals are applied through capacitors C5 and C6 to the phase-shifting networks. Fixed bias for V2 is obtained from voltage divider R8–R51. Parasitic suppressor R64 damps oscillations which tend to be set up between V2A and V2B. R61 and C4A form a decoupling network.

c. Phase-Shifting Network R52. In the phase-shifting network, the opposite-phased input signals are split into four phases, each phase being in quadrature (90° out of phase) with the two adjacent phases. The phase of the output may be set by positioning the brush arm of R52. The two inputs from V2 are 180° out of phase. Capacitor C13 is selected so that its reactance at 328 kc is equal to the resistance of R16. Capacitor C11 is selected so its reactance at 328 kc is equal to the resistance of R14. The operation of the phase-shifting network is identical to that discussed in paragraph 6c. of this text. As the brush arm of R52 is moved completely around, the phase of the voltage will be shifted through 360°. This voltage is fed to pulse-forming amplifier V3A and is used to determine the time at which the 500-yard markers occur in relation to the calibrator sync pulses. The adjustment of R52 is accomplished during calibration procedure and will be covered in TM 9-5000-23.

d. Pulse-Forming Amplifiers V3A and V3B. The 328-kc sine wave from R52 is applied to V3A. The plate circuit of V3A contains a coil which resonates with capacitance in the circuit at a frequency higher than the input frequency. The action of the grid circuit of V3B causes V3A to produce a square wave output. During the positive half-cycle of the output of V3A, grid current flows in V3B. This removes C37, and 82-micromicrofarad capacitor, from the resonant circuit, decreasing the resonant frequency. This change in resonant frequency tends to flatten the positive extremity of the waveform. During the negative half-cycle CR7 conducts, again removing C37 from the resonant circuit and flattening the negative extreme. During the interval when the output of V3B is not at either extreme, that circuit resonates at its natural frequency. The result is a rapid change from one extreme to the other. The square wave which appears at the grid of V3B is clamped negative with respect to ground by C16, which is charged negatively during the positive extremity of the waveform. The signal at the grid of V3A is further squared by V3B. The 328-kc square wave, which appears at the plate of V3B, is applied to differentiator C18–R20. Crystal CR2 serves to bypass the transformer during the charging of capacitor C18 (when V3B is cut off). When V3B conducts, C18 is discharged rapidly through transformer T2, producing negative pips. These negative pips, inverted by T2 and appearing 500 yards apart, are called the MISSILE 500-yard markers. These markers are applied to the video amplifier of the missile range-error detector during range calibration.

e. Phase-Shifting Network R53. Potentiometer R53 functions in the same manner as R52 to determine the phase of the input to V4A. R53 is used to determine the time that the target 500-yard markers occur in relation to the calibrator sync pulses produced in the range calibrator.

f. Pulse-Forming Amplifiers V4A and V4B. V4A and V4B are identical in operation to V3A and V3B. The TARGET 500-yard markers from J3 are applied to the target range error detector for use during range calibration.

g. Amplifier V5. The positive portions of the 328-kc sine waves are clipped at the input to V5 by crystal CR4 and limited by CR5. During the positive half-cycle, CR4 is conductive and CR5 is nonconductive, so no signal is developed across R28. During the negative half-cycle, CR4 is nonconductive and CR5 is conductive, resulting in a signal being developed across R28. The signal is squared by cut-off limiting in V5, and the resultant square wave is applied to V6A for use in triggering multivibrator V7 and to V6B for use in the gating circuit.

h. Cathode Follower V6A. The square wave from V5 is differentiated by resistor R31 and capacitor C27. The resulting pulses are applied to the grid of V6A. Tube V6A is biased near cutoff by its large cathode resistor. The negative pips resulting from the differentiation at the grid of V6A will cut off the tube, thereby producing very small negative pips at its output. The positive pip at the grid of V6A will produce a large positive pulse at the cathode. The positive pulse at the cathode of V6A is applied to the cathode of V7A through coupling capacitor C29 and is used to synchronize multivibrator V7 with the oscillator V1.

i. Multivibrator V7. Multivibrator V7 has a free-running frequency of slightly less than 1,000 cps. It is synchronized with the oscillator by the pulses from tube V6A. Assume that during one portion of the cycle that V7A is cut off and V7B is conducting at saturation. When the grid of V7A rises sufficiently (C35 has charged through R35 and R38) to permit V7A to conduct. The resultant drop in plate voltage is coupled to the grid of V7B through capacitor C31. This, in turn, will reduce the current through V7B and cause its plate voltage to rise. The rise in plate voltage of V7B is coupled to the grid of V7A through capacitor C35, where it will cause the current through V7A to further increase. This action is regenerative until V7A is conducting at saturation and V7B is cut off. The grid of V7B begins going positive, but unlike a conventional multivibrator, rises in a manner similar to a quarter-cycle oscillator. Retard coil L1 delays the rise of voltage; and instead of the voltage decreasing in an exponential manner, a quarter-cycle of oscillation takes place. This method causes the voltage at the grid to be decreasing at a very rapid rate as it approaches the cut-off value of the tube. This provides much more accurate timing that can be obtained with a conventional multivibrator. During the time that the grid of V7B is going positive, the positive pulses at the cathode of V7A cause positive pulses at the plate of V7A. These pulses are being coupled to the grid of V7B. As the grid of V7B approaches the cut-off value, one of the positive pulses will drive the grid of V7B positive enough to cause V7B to conduct. This causes a drop in the plate voltage of V7B, which is in synchronism with the input pulse. The drop is coupled to V7A, and the tubes assume their original condition (V7B conducting, V7A cut off). The drop in voltage at the plate of V7B is used in the generation of a 4.5-microsecond gate in Z5 and V8A. The duration of the second half-cycle is controlled by the discharge of C30 through R35.

j. Delay Network Z5 and Amplifier V8A. During the portion of the multivibrator cycle when V7B is cut off, the capacitor in delay network Z5 charges through crystal CR6 and resistor R38. The potential at terminal 3 of Z5 thus rises gradually, and the inductance of Z5 is effectively short-circuited. When, because of the regenerative action of the multivibrator circuit, V7B is driven into conduction, and the potential at the plate of V7B drops rapidly so that the potential drop at terminal 3 of Z5 is transmitted almost entirely to terminal 2 of Z5. Since terminal 2 is near ground potential while the capacitor is charging, it must now assume a negative potential equal in magnitude to the potential drop at terminal 3 during the switching action. The series-resonant circuit composed of the capacitance and inductance of Z5 starts to oscillate. The potential at terminal 2 rises sinusoidally until it reaches a potential slightly positive with respect to ground, at which time CR6 conducts and grid current flows in V8A. This short-circuits the inductor in Z5 and further oscillations are damped. The components in the delay network are selected so that amplifier V8A is held cut off for 4.5 microseconds by the negative quarter-cycle of oscillation. A positive square wave (where leading edge is coincident with one of the calibrator pips at the output of V5) appears at the plate of V8A. This signal is applied to gating circuit V6B, where it is used to gate the next succeeding pip.

k. Gating Circuit V6B. The output of V5 is differentiated by C28 and R46, and the pulses which result are applied to V6B. A positive potential from voltage-divider R43-R44 is applied to the cathode of V6B and holds it cut off. Neither the amplitude of the input from V8A nor the amplitude of the input from V5 is great enough to overcome the cut-off bias. When the positive output of V8A and a positive pulse from V5 are coincident, the combined amplitude overcomes the bias and a positive pip appears at the cathode V6B. Since the gate from V8A occurs at about 1,000 cps, an output is obtained from V6B at the same rate. The positive pulse is coupled through C35 and is used to trigger blocking oscillator V8B.

l. Blocking Oscillator V8B. Between pulses, V8B is held cut off by the negative potential developed by voltage divider R59-R60. The positive pulse from the cathode of V8A overcomes this bias. Current flow through the plate winding of T1 causes a negative pulse to appear at the plate of V8B. A positive voltage is induced across the grid winding and is applied to the grid of the block oscillator. The plate current increases because of the increasing potential at the grid. This regenerative action causes the plate current to rise rapidly to saturation. During this action grid current is drawn, and capacitors C35 and C36 become charged. When the blocking oscillator reaches saturation, plate current ceases to increase and the magnetic field about the plate winding of T1 no longer expands. Thus, no voltage will be induced in the grid winding of T1. This drop in potential at the grid results in a decrease in plate current. Since a magnetic field is a function of current, the field about the plate winding will collapse because of the decrease in plate current through the winding. This collapsing field induces a voltage across the grid winding of reverse polarity, driving the grid in a negative direction. The stage is driven rapidly below cutoff and plate current ceases. The negative charge on capacitor C36 is applied to the grid of V8B, driving V8B far below cutoff. The capacitor then discharges to the potential developed by R59-R60. The signal at the plate of V8B is inverted by T1. The outputs at J4 and J5 are the calibrator sync pulses. The calibrator sync pulses are positive 0.25-microsecond pulses which occur at a rate of about 1,000 cps. These pulses are used in the range unit assemblies of both the missile and target radar during range calibration.

37. Range Calibration Control Circuitry

a. Target Range System (Sh 32, Sh 38A.1, and fig. 8-1.1). In order to perform range calibration, certain relays must be operated to cause the calibrator sync pulses and the 500-yard markers to be applied to the circuits of the range system. These relays are controlled by ZERO-NORMAL-RANGE CALIBRATE switch S3 and TEST-OPERATE switch S12. These switches are located at the target console. To perform range calibration, S3 must be in the RANGE CALIBRATE position and S12 must be in the TEST position. In addition, the target range system must be in aided-manual or manual operation. When these conditions exist, relay K16 in the target console control drawer is energized. Current flows from the minus 28-volt supply (through K16) contacts of MAN-AID relay K17, S3 and S12 to ground. When K16 is energized, the output from the stator of the 2,000-yard CALIBRATE synchro control transformer in the range unit assembly is applied to terminal 7 (Sh 32) of the target range coupling unit. This synchro produces a null every 2,000 yards and will drive the range servomotor until it is positioned at its nearest null point. The range SLEW switch may then be used to roughly position the range system. Fine positioning will be provided by the 2,000-yard CALIBRATE SYNCHRO which will drive the range to multiples of 2,000 yards. With S12 still in TEST, S3 in RANGE CALIBRATE, and the range system in manual or aided-manual, relay K1 in the range mark generator in the range unit assembly will be energized. This substitutes the calibrator sync pulses for the preknock pulses. The calibrator sync pulses are applied from J5 of range unit assembly to range phantastron V6 in the range mark generator and to the main gate generator in the timing wave generator. This causes the tracking range mark at the output of the range unit assembly to be synchronized with the outputs of the range calibrator. The tracking range mark is used in the generation of the 35-yard range gate in the range error detector. This causes the range gate to occur in synchronism with the outputs of the range calibrator. S3 and S12 also energize relay K1 in the range error detector. When

K1 is energized, the 500-yard markers are amplified by V13A, V14, and V15, and are used as video signals to cause the range error channel to produce d-c range error signals which may be read on the RANGE ERROR meters in the radar range and receiver cabinet when the switch between the meters is in the METER position. The 500-yard markers are not applied to the video and notch mixer because of the action of K1. Therefore, the 500-yard markers are not displayed on the tracking indicators. The markers are also applied to the ATC channel of the range error detector. The outputs of the ATC channel and the range error channel are used to cause the ATC unit to extinguish the COAST light when one of the 500-yard markers is in the range gate. This is necessary because there is no other means of determining whether the range gate is exactly centered on a 500-yard marker or completely off since they are not displayed on the tracking indicators.

b. Missile Range System (Sh 38B.1). The missile range system is prepared for calibration in much the same manner as the target range system. The system must be in manual or aided-manual operation so that relay K12 is energized. ZERO-NORMAL-RANGE CALIBRATE switch S5 on the missile control drawer must be in the RANGE CALIBRATE position, and TEST-OPERATE switch S1 must be in the TEST position. This will energize relay K11 in the missile console control drawer, relay K1 in the range mark generator, and relay K1 in the missile range error detector. Relay K11 in the control drawer connects the voltage from the 2,000-yard CALIBRATE synchro to the missile range coupling unit. Relay K1 on the range mark generator applies the missile 500-yard markers to the video amplifier in the range error detector. The range error output of the missile range error detector may be read on the missile RANGE ERROR meter in the radar range and receiver cabinet. The ATC outputs of the missile range error detector will extinguish the COAST light on the missile console when a 500-yard marker is coincident with the range gate.

PART TWO

TARGET TRACKING RADAR PRESENTATION SYSTEM

CHAPTER 10

INTRODUCTION

38. General

The target radar presentation system provides visible indication of video signals in three coordinates—azimuth, elevation, and range. This information is used in manual or aided tracking of a target and supplies helpful information during automatic tracking. The PPI and PI indicators are not considered a part of the target presentation system; however, since these indicators are located in the target console, a brief discussion of their presentation will be included in this text. Their detailed functional operation and circuit analysis may be found in TM 9-5000-9, "Acquisition Radar Circuitry," paragraph 13 and chapter 6. There are two PPI (Plan Position Indicator) indicators in the Nike system, one in the battery control console and the other in the target console. The two scopes present the same image from video signals originating in the acquisition radar. The indicators give position of targets in terms of slant range and azimuth. Two range sweeps are provided for each scope, a 60,000-yard range and a 120,000-yard range. The operators of the two indicators may choose either range with a selector switch located on the indicator; however, during operations it is desirable that both the target-tracking radar operator and the acquisition radar operator use the same range. Both scopes present all targets within the area scanned by the acquisition radar; and from these targets, the acquisition operator selects the target to be tracked by the target-tracking radar. The controls provided enable the acquisition radar operator to move the two lines appearing on the scope, the movable range circle and steerable azimuth line. These lines are moved to intersect over the target to be tracked. After the target has been designated, the target operator operates the ACQUIRE switch on his console, and the target radar automatically slews in azimuth and range to the position indicated on the scope by these intersecting lines. The PPI indicators also present an electronic cross whose center indicates the position of the target radar in azimuth and slant range coordinates. Thus, when a target is being tracked by the target radar, the center of the electronic cross will indicate the position of that target. There are two precision indicators in the Nike system, one with each PPI indicator. The indicators show different images. The indicator located in the target console will be discussed in this section. This indicator presents an area around the target being tracked covering a sector of 5,000 yards in range and 30 degrees in azimuth. Two stationary lines appear on this scope, a vertical azimuth line and a horizontal range line. When a target is being acquired, or automatic tracking is being used, this precision indicator is helpful in manual or aided tracking of a target. This presentation is an expanded view of the area appearing around the electronic cross on the PPI indicator.

39. Presentation System Block Discussion

(fig. 7-1.1, Sh 29)

a. The target radar presentation system is made up of three indicator units which provide target azimuth, elevation, and range information for a 5-inch cathode-ray tube in the form of an A-type presentation. This information is used by the corresponding operators seated in front of the indicators at the target console. By their presentation the indicators assist the operators in manual or aided tracking of a target. The three indicators are identical with the following exceptions: their coordinate data dials, the information supplied to them, and the output connections of the video amplifier. These connections are the same for azimuth and elevation but are reversed in the range indicator. The reason for this is explained in paragraph 41c(1) of this text. The three indicators, along with the video error signal panel, comprise the target radar presentation system.

b. The azimuth and elevation operators carry out the tracking operation by observing the polarity and amplitude of the error pips (fig. 10).

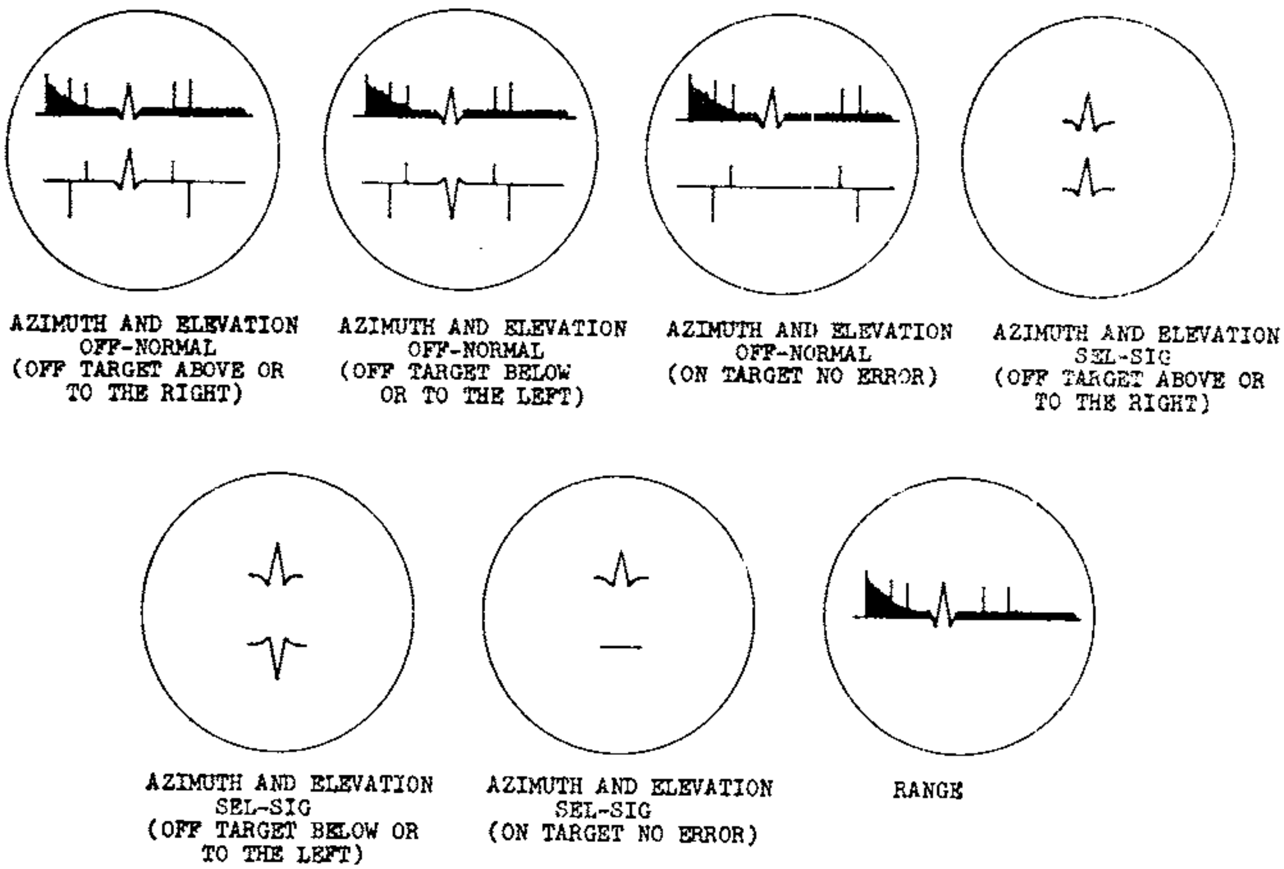

Figure 10. Target-tracking radar scope presentation.

The pips will appear positive for a pointing error above (or to the right) and will appear negative for an error below (or to the left) of the target. The operators position the antenna so as to minimize the amplitude of the pip. The range operator tracks the target by centering the target pip in the movable 100-yard range notch. A 500-yard area of the sweep in which the 100-yard notch is centered is expanded for more accurate centering of the target pip. The 500-yard expanded sweep and the sum video and notch appear on all three indicators. The sweep length can be varied continuously from 20,000 to 100,000 yards, while the 500-yard expanded section occupies a constantly proportional space on the total sweep length.

c. The IMAGE SPACING switch on the front of each indicator is kept in the OFF or NORM (normal position). The SEL SIG (selected signal) position was used on earlier type indicators to eliminate confusion caused by unwanted signals overlapping the signal being tracked. With the IMAGE

SPACING switch in the SEL SIG position, the sweep on the indicator will be unblanked only during the period of the 500-yard expanded portion.

d. A coarse and fine coordinate dial appears on the front of each of the tracking indicators. The azimuth and elevation dials are calibrated in mils, with the coarse dial reading from 0 to 64 in hundreds of mils and the fine dial reading from 0 to 100 mils. The range dials are calibrated in yards so that the coarse dial reads from 0 to 100 in thousands of yards and the fine dial reads from 0 to 1,000 yards.

e. The cabling of the signal inputs to the indicators is so arranged that they can be used as test oscilloscopes in conjunction with the test amplifier and the test probe. These two units and their usage may be found in TM 9–5000–12, Chapter 1, Section III.

f. Figure 7–1.1 is a block diagram of the target presentation system. From observation of this figure, it can be seen that all three indicators are identical units, although different information is supplied to each unit, resulting in a different presentation for each.

CHAPTER 11

TRACKING INDICATOR UNIT AND VIDEO ERROR SIGNAL UNIT

40. Block Diagram Discussion

a. General (fig. 7–1.1). The track indicator unit consists of a video amplifier, a sweep generator, cathode-ray tube, associated controls, and, though not illustrated here, a coarse and fine synchro receiver. The inputs to the range indicator are: the preknock pulse from the target synchronizer, the three-microsecond expansion pulse from the range error detector, and the sum video and notch, also from the range error detector. For the azimuth and elevation indicators, the inputs are: the preknock pulse, the three-microsecond expansion pulse, the video error signal, and the sum video and notch from the video error signal unit (these appear alternately), and the 500-cps sweep-switching square wave, also from the video error signal unit.

b. Sweep Channel (fig. 7–3.1). The preknock pulse triggers the one-shot multivibrator circuit consisting of tubes V1 and V2 in the sweep generator unit. The output of the multivibrator is a square wave whose negative portion has a duration of 658 microseconds. This period is equivalent to 100,000 yards of range, plus the 24-microsecond delay between the preknock and sync pulse. The negative square wave cuts off switching tube V3A, permitting sweep capacitors C3 and C11 to discharge through constant current pentode V6. This discharge voltage, applied through cathode follower V3B and sweep amplifier V4 to the horizontal deflection plates of the cathode-ray tube, produces a left-to-right sweep. The 3-microsecond pulse, amplified by expansion pulse amplifier V5, increases the conductivity of discharge pentode V6, which increases the discharge rate of sweep capacitors C3 and C11 for 3 microseconds, expanding a portion of the sweep representing 500 yards.

c. Unblanking Amplifier (fig. 7–5.1). In the OFF or NORM positions of switch S1, unblanking is obtained for the full 658 microseconds by applying the negative square wave from the multivibrator in the sweep generator to the unblanking amplifier unit. In the SEL SIG position of the switch, the beam is unblanked only during the period of the 3-microsecond expansion pulse, thus only a 500-yard sector will be shown on the indicator. Clamper V2 in the unblanking amplifier unit maintains the control grid of the cathode-ray tube at a constant reference level.

d. Video Amplifier (fig. 7–10.1).

(1) When used with the range indicator, the sum video and notch are amplified by tube V1 and applied through cathode follower V2A and push-pull amplifiers V3–V4 to the vertical deflection plates of the cathode-ray tube.

(2) For the azimuth and elevation indicators, the input at jack J1 is the sum video and notch and the error signal. These two signals appear alternately; that is, after one preknock pulse the sum video and notch will appear; after the next preknock pulse the error video will appear, and so on. These signals are from the video error signal panel. The input at P1–3 is a 500-cps symmetrical square wave and is applied to the paraphase amplifier V4. This signal will cause alternate sweeps to be displaced vertically on the indicator. The upper of the two baselines thus established will have the sum video and notch superimposed on it. The error signal will appear on the lower baseline directly below the sum video.

e. Coordinate Data Synchros and Dials (Sh 36). The dials and synchros are located on the lower center of each indicator. Observing from the front of the indicator, the fine synchro is on the left and the coarse synchro is on the right. Each is driven by an associated synchro trasnmitter in the corresponding data unit.

f. Video Error Signal Panel (fig. 7–8.1). Although not a part of the tracking indicators, a discussion of the video error signal panel will be undertaken at this point inasmuch as its outputs are used only in the target presentation system. The unit is located on the same slide with and immediately behind, the test amplifier. This unit has as its inputs the sum video and notch, the preknock pulse, and both the azimuth and elevation error signals. Its function in regard to the azimuth indicators is identical to that effecting the elevation indicators with the exception of the tubes employed, so only the azimuth channel will be discussed. The preknock pulse is amplified and inverted by tube V1A and applied to the bistable multivibrator V3 through the pulse injectors V2A and V2B. The output of the multivibrator is a 500-cps square wave. This square wave is applied through tube V1B to the azimuth and elevation indicators (as in paragraph 40d(2), above) and to the unblanking amplifier. It is also applied from tube V3 to the gated mixer V5 through the action of tube V4. One alternation will cut off tube V5A and at the same time permit V5B to conduct. During this condition, tube V5B will invert and amplify the azimuth error signal. During the next alternation, tube V5A will conduct and V5B will be cut off. The video and notch applied to tube V5A will then be inverted and amplified. These two signals appearing alternately across the common plate load of tube V5 will be applied to the video amplifier of the indicator through cathode follower V6 and jack J4.

41. Indicator Detailed Schematic Analysis

a. Sweep generator (fig. 7–3.1).

(1) *General.* The sweep generator consists of a one-shot multivibrator V1 and V2, a switch tube V3A, a sweep capacitor discharge pentode, V6, sweep capacitors C3 and C11, a cathode follower V3B, expansion pulse amplifier V5, and a cathode-coupled push-pull sweep amplifier V4. The sweep generator provides a horizontal sweep which is continuously variable from 170 to 658 microseconds, with a constant 3-microsecond (500-yard) expanded portion to the indicator. The sweep generator also provides a 658-microsecond negative square wave for the unblanking amplifier to unblank the indicator during the sweep. This unit is located on the indicator chassis.

(2) *Multivibrator* (figs. 7–4.1 and 11). Figure 11 is a simplified schematic of the one-shot multivibrator V1–V2. This multivibrator puts out a negative pulse for each triggering pulse applied to it. Initially, the grid of V1B is held at approximately zero potential, with respect to its cathode, by the biased diode V2A, and the resulting current through the common cathode resistor R8 holds V1A cut off. The plate of V1A is directly connected to the control grid of cathode follower V2B. As a result, this tube conducts heavily and the potential of the cathode of V2B is slightly higher than the supply voltage to V1A. The positive preknock pulse from jack J1 is applied to the grid of V1A and causes this tube to conduct. The resulting drop in voltage at the plate is coupled to the grid of V1B through cathode follower V2B and capacitors C1 and C10. This action cuts off V1B, which further reinforces the conduction of V1A by reducing the positive voltage at the top of resistor R8. This action is almost instantaneous, and the result is that V1A conducts and V1B is cut off. The potential at the grid of V1B will then begin to go positive at a rate determined primarily by the discharge of capacitors C1 and C10 through resistors R9 and R10. When the grid voltage of V1B rises a sufficient amount to allow the tube to conduct, the current of V1B through the common cathode resistor R8 causes a voltage drop which makes the cathode potential positive with respect to the grid of tube V1A. V1A conducts less and its plate voltage rises. This action, in turn, drives the grid of V1B further positive until it draws grid current through R9 and R10. Thus, the multivibrator has returned to initial condition with V1A cut off and V1B conducting. Tube V2B is substituted for the normal connection of capacitors C1 and C10 between the grid of V1B and the plate of V1A, shown dotted in figure 12. This arrangement is provided for the purpose of decreasing the recovery

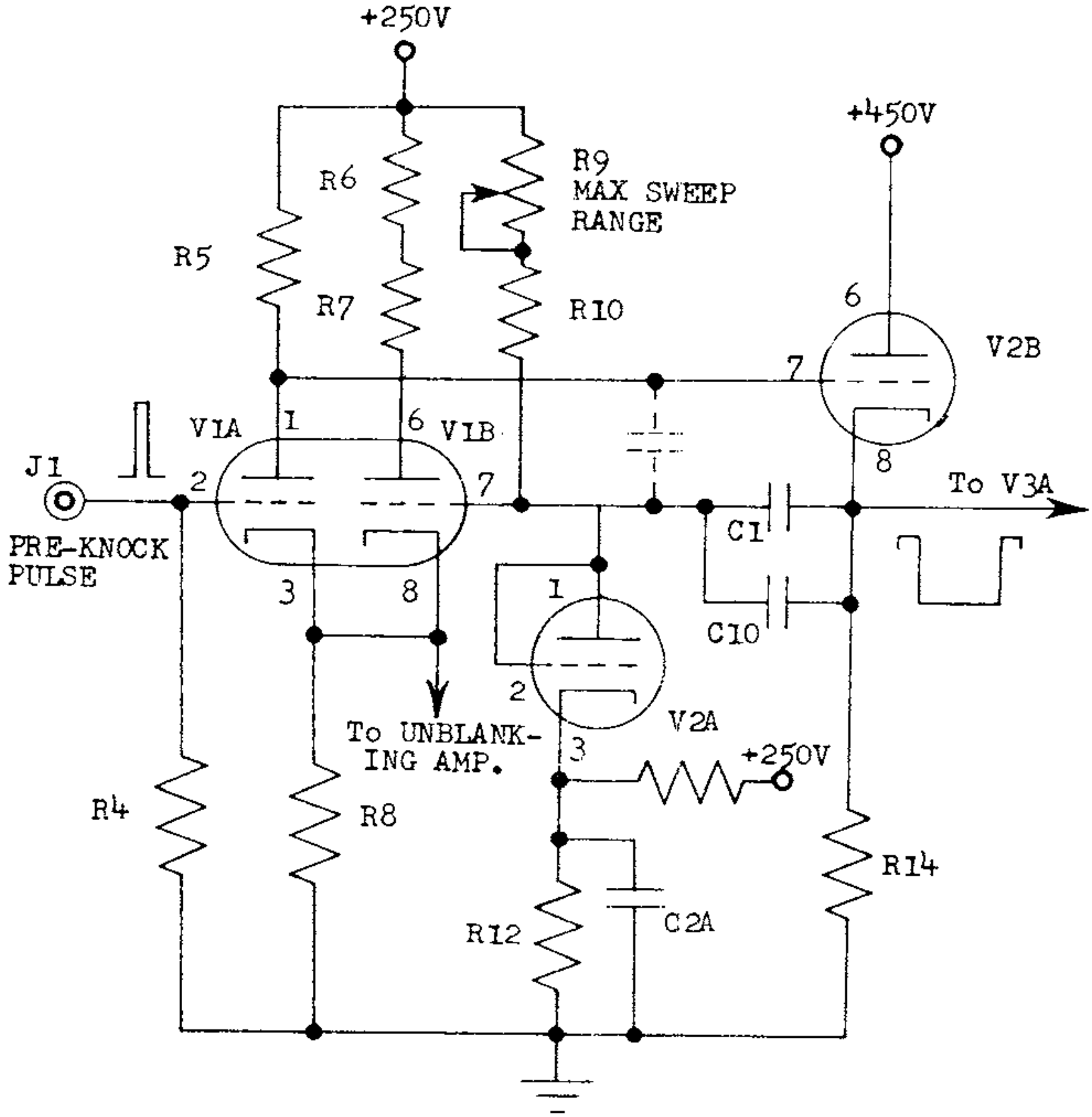

Figure 11. Track sweep generator multivibrator, simplified diagram.

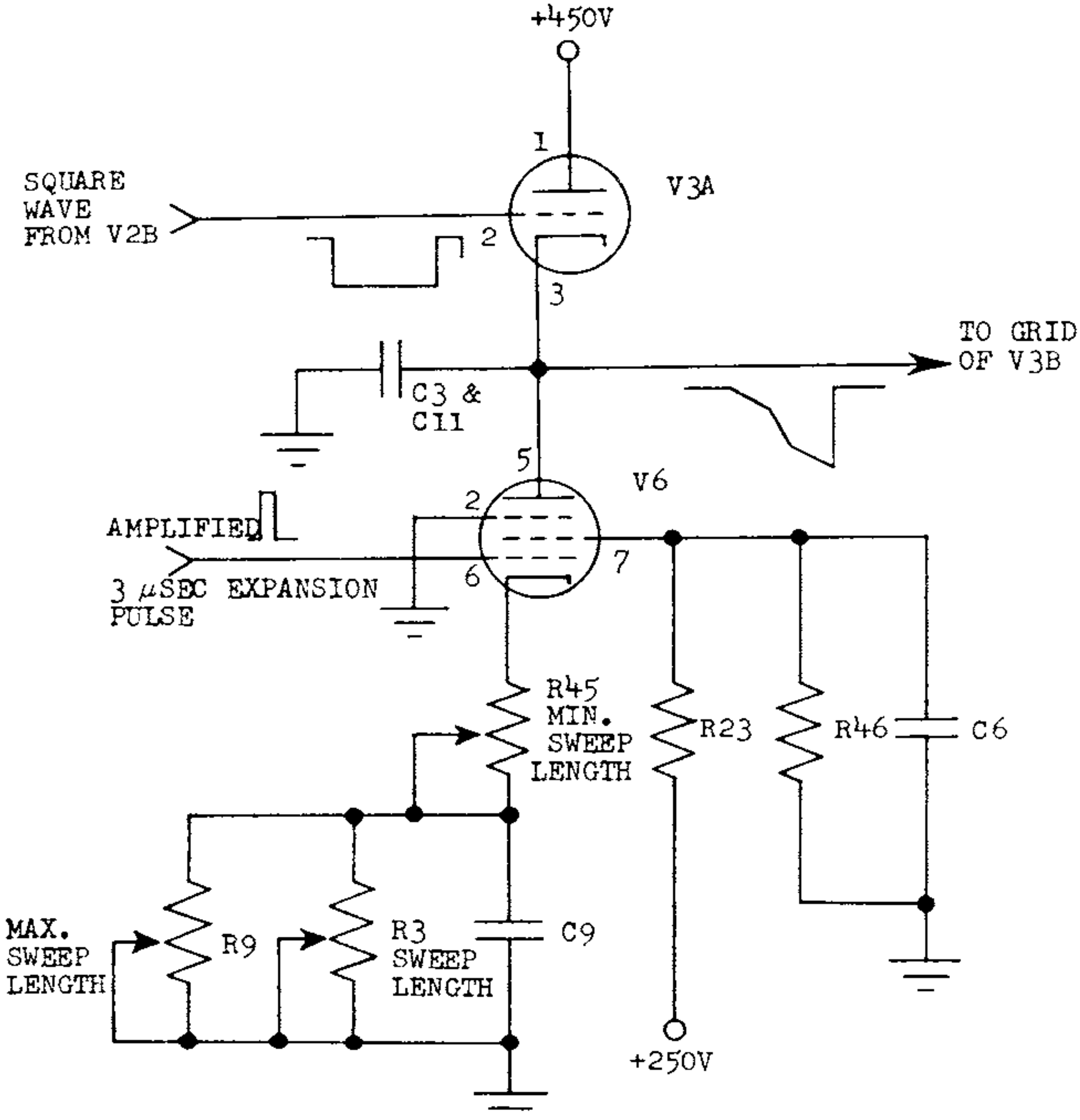

Figure 12. Track sweep generator sweep circuit, simplified diagram.

time of the multivibrator with a low resistance charge path for C1 and C10 from ground through C2A and V2A to the negative side of C1 and C10, and from the positive sides of C1 and C10 through V2B to plus 450-volt supply. Tube V2A replaces the normal grid-to-ground resistance of V1B, and tube V2B bypasses resistor R5, the plate load of V1A. To prevent tube V1 from operating as a free-running multivibrator, V2A is biased by a voltage divider consisting of resistors R11 and R12 so that the grid of V1B can rise to the same positive potential as its cathode. This assures enough plate current in V1B to produce sufficient voltage drop across common cathode resistor R8 to keep V1A cut off. MAX SWEEP RANGE potentiometer R9 controls the discharge rate of capacitors C1 and C10 by varying the resistance in their discharge path. Adjustment of potentiometer R9 determines the time at which the switching action of the multivibrator will occur. It can thus be seen that the setting of potentiometer R9 determines the duration of negative portion of the output signal.

(3) *Sweep circuit* (figs. 7-4.1 and 12). The 658-microsecond pulse appearing at the cathode (pin 8) of tube V2B is coupled to the grid (pin 2) of switch tube V3A. This pulse will cut V3A off and open the charge path of sweep capacitors C3 and C11. (Refer to Fig. 12.) This causes capacitors C3 and C11 to start discharging through tube V6. V6 is a constant current pentode used to cause a linear discharge of capacitors C3 and C11. The discharge voltage of C3 and C11 appears as a negative sawtooth at the grid of cathode follower V3B. The speed at which these capacitors discharge, and consequently the rate or change of the sweep voltage, depends upon the resistance in their discharge path. This is essentially the cathode-to-plate resistance of tube V6 which is determined by the screen grid voltage, the control grid voltage, and the amount of cathode degeneration. The screen voltage is fixed by a voltage divider consisting of resistors R23 and R46. In the cathode circuit of tube V6 is front-panel-control SWEEP LENGTH potentiometer R3. When potentiometer R3 is set at its minimum value, the cathode bias of the stage will be minimum, and the plate-to-cathode resistance of tube V6 will be minimum. Consequently, the sweep capacitors are able to discharge faster, resulting in a faster sweep on the indicator from 20,000 to 100,000 yards, respectively. The 500-yard expanded portion of the sweep results from the 3-microsecond negative pulse applied to the control grid of pulse amplifier V5 from jack J2. Tube V5 amplifies and inverts this pulse, after which it is applied to the control grid of the constant current pentode V6. Therefore, the effective resistance of V6 is lowered during the period of the expansion pulse, and the rate of discharge of the sweep capacitors is accelerated for the period of the pulse. This results in a step in the sweep voltage. (Refer to Fig. 13.) From the foregoing discussion, it would seem that the 3-microsecond expanded portion of the sweep will appear five times as long on the 20,000-yard sweep as it will on the 100,000-yard sweep. In order for this expanded section to remain a constant portion of the sweep length as the time of the sweep is increased, it is necessary to increase the rate of sweep with the increase of sweep range. The range is increased by increasing the cathode resistance of V6 with potentiometer R3. Degeneration occurs across cathode resistor R45 because it is not bypassed. As the resistance of R3 is increased, a smaller portion of the self-bias is developed across resistor R45, and the degeneration of R45, with respect to the signal on the control grid is decreased. On the other hand, potentiometer R3 is bypassed by capacitor C9, consequently, as the range is increased (resistance of R3 increased), the amount of degeneration to the 3-microsecond pulse is not changed. The expanded sweep length is thus maintained constant as the range is varied. MIN SWEEP LENGTH potentiometer R45 is a screwdriver adjustment whose setting determines the 20,000-yard sweep length when SWEEP LENGTH potentiometer R3 is at minimum setting. The limit to which sweep capacitors C3 and C11 discharge is further determined by the amplitude of the square wave from the multivibrator

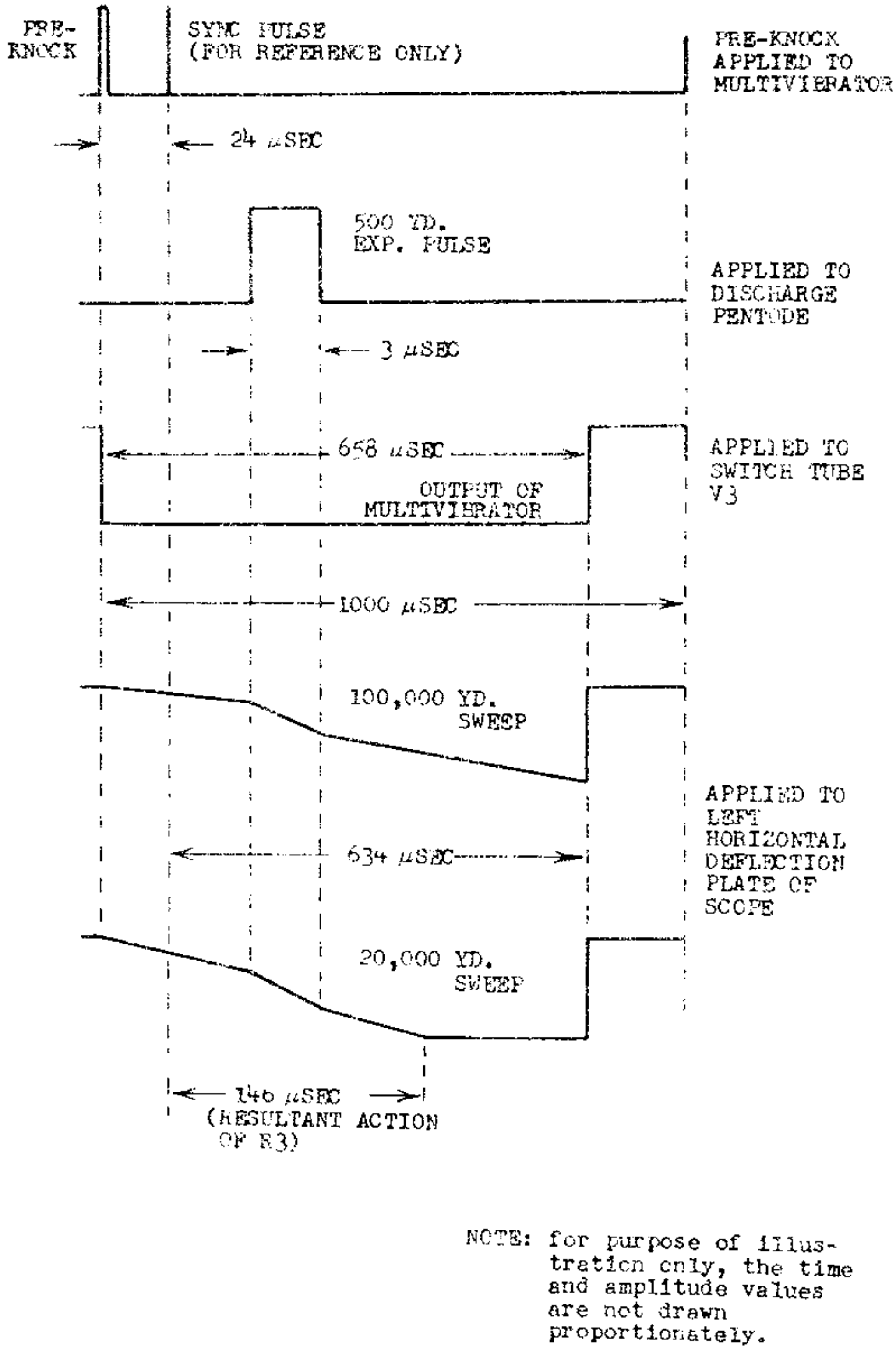

Figure 13. Track sweep generator waveform.

which cuts off the switch tube V3A. As capacitors C3 and C11 discharge, the cathode voltage of V3A is lowered until the grid-to-cathode voltage permits conduction. The point at which capacitors C3 and C11 cease to discharge is determined by how much negative grid voltage on V3A must be overcome. Inductance L1 in the plate circuit of V5 causes overshooting at the beginning of the 3-microsecond pulse to compensate for the opposite curvature introduced by the sweep amplifier tube V4. Crystal CR1 damps out any oscillations that may occur across L1. Crystal CR2 prevents any positive signals from appearing at the grid of V5. EXP WIDTH ADJ potentiometer R42 varies the screen voltage of V5 and, thus, amplification of the stage. If the arm of potentiometer R42 is moved toward terminal 3, the screen voltage rises and the amplification of the stage is increased. As the amplification of the pulse is increased, the 500-yard section of the sweep is further expanded on the scope. Turning potentiometer R42 the opposite direction will cause the expanded sweep to become narrower. Switches S1 and S2 are used to remove C10 and C11 from the circuit in order to produce a sweep of shorter duration when the indicator is used with the missile-tracking radar.

(4) *Sweep amplifier* (fig. 7–4). The sweep voltage is applied from the plate of tube V6 to the grid of tube V3B. From the cathode of V3B, the sweep voltage is applied through capacitor C4 and resistors R17 and R18 to the grid (pin 2) of V4. From the plate (pin 1) of this section of V4, the positive-going sweep voltage is directly coupled to the right horizontal deflection plate of the cathode-ray tube. Cathode coupling of the two sections of tube V4 produces a negative-going voltage at the other plate (pin 9) of V4. This voltage is directly coupled to the left horizontal plate of the cathode-ray tube. If CENT potentiometer R18 varies the grid bias of V4A by tapping off a varying amount of the positive cathode voltage developed by cathode follower V3B. If the arm of the potentiometer is moved toward terminal 1, the voltage on the grid of V4A rises, the current through V4A increases, the average plate potential of V4A decreases, and the voltage at the plate (pin 9) of V4B decreases. Thus, the sweep on the cathode-ray tube is displaced to the left.

(5) *Astigmatism correction* (fig. 7–13.1). ASTIGMATISM potentiometer R33, connected from plus 250 volts to ground, varies the potential on the second anode of the cathode-ray tube. This action eliminates the defocusing effect appearing in one deflection plane and not the other by adjusting the static potential difference between the deflection plates and the second anode.

b. Unblanking Amplifier (figs. 7–5.1 and 7–6.1). The unblanking amplifier provides unblanking of the horizontal sweep of the indicator for the period of the sweep. When IMAGE SPACING switch is in the OFF or NORM position, the sweep is unblanked for the full sweep. When the switch is in the SEL SIG position, the sweep is unblanked only during the 3-microsecond expanded portion. When the IMAGE SPACING switch S1 is in the NORM or OFF position, S1B connects the negative signal from the cathode of the multivibrator in the sweep generator to both grids of tube V1 in the unblanking amplifier. The positive output at the plate of tube V1 is coupled through capacitors C2 and C3 to the control grid of the cathode-ray tube. The positive portion of this signal at the plate of V1 will permit conduction of the cathode-ray tube, and the negative portion, which occurs during retrace, will cut off the cathode-ray tube. When switch S1 is in the SEL SIG position, the 3-microsecond expansion pulse is applied to tube V1, with resultant unblanking only during the period of the pulse. Tube V2 clamps the negative extremity of the output to a voltage determined by the setting of the INTENSITY potentiometer R14. (See fig. 7–13.1.)

c. Tracking Video Amplifier.

(1) *General* (fig. 7–10.1). The video amplifier amplifies and applies the sum video and notch and the image spacing signal to the vertical deflection plates of the indicator. When this unit is used in the range indicator, only the video and notch are applied to it through jack J1. This

signal comes from the range error detector. When used with the azimuth or elevation indicator, it has applied alternately at jack J1 the video and notch and the error signal. The image spacing signal is applied at P1-1. These signals come from the video error signal panel. The connections from E1-A and E1-B to the vertical deflection plates of the cathode-ray tube are reversed when this unit is used with the azimuth or elevation indicator. This is done because the sum video and notch are inverted in the video error signal panel. This unit is located on the indicator chassis.

(2) *Video amplifier V1 and cathode-follower V2A* (fig. 7-11.1). The video and notch (or the error signal alternately) is applied through jack J1, capacitor C1, and resistor R3 to the control grid of tube V1. This tube is a class "A" amplifier. The inductor L1 in the plate circuit, along with the unbypassed cathode resistance, improves the video response of the circuit. The signals developed at the plate are coupled through capacitor C3 to the grid of the cathode-follower V2A. VIDEO GAIN potentiometer R6 controls the amount of degeneration in the cathode circuit of V1 and, thus, the gain of the stage. Resistor R1 and capacitor C2 form a decoupling network, while resistor R3 is a parasitic suppressor. V CENT potentiometer R9 in the grid circuit of tube V2A controls its static grid voltage and, thus, the cathode voltage. The cathode of V2A, in turn, is directly coupled to the control grid of V3. A given level of grid voltage for V3 will control its static plate potential and, since the plate of this tube is connected directly to one of the vertical deflection plates, the setting of R9 will determine the vertical centering of the trace on the scope.

(3) *Vertical amplifiers V3 and V4* (fig. 7-11.1). Tube V3 amplifies and inverts the signals supplied to it by V2A. These are then applied to the lower deflection plate of the indicator. Assume that a positive signal appears at the control grid of V3. The signal at the plate of V3 would then be negative while the signal appearing at the cathode will be positive. This signal at the cathode of V3 is directly coupled to the cathode of V4, causing a positive signal to be developed at the plate of V4. The plate of V4 is connected to the upper vertical deflection plate of the cathode-ray tube. Therefore, the signals appearing at the deflection plates are 180 degrees out of phase. When used with the elevation or azimuth indicator, the 500-cps image spacing signal is applied through P1-3, across VERT SPACING potentiometer R31, through resistors R30 and R17 to the control grid of tube V4. This signal is a square wave, each alternation having a period of 1,000 microseconds. From the preceding discussion, it can be seen that this square wave will be applied to the deflection plates. One alternation of the image spacing signal will occur with each horizontal sweep, causing alternate sweeps to be displaced vertically. The video and notch will be superimposed on the upper baseline and the error video on the lower baseline. VERT SPACING potentiometer R31 controls the amplitude of the image spacing signal applied to the grid of V4 and thus the distance between the two baselines. Resistors R29 and R30 form a voltage divider that will determine the static grid voltage of V4. Inductors L2 and L3 provide high frequency compensation for V3 and V4.

42. Video Error Signal Panel

a. General (fig. 7-8.1). The video error signal panel provides a switching arrangement of the elevation and azimuth error signals and the sum video and notch for presentation on the indicators. This switching enables the azimuth and elevation operators to track a target manually or aided by observing the indicators, as explained in paragraph *39b*. The unit has four inputs, preknock from the target synchronizer, sum video and notch from the range error detector, and the azimuth and elevation error signals from the respective angle error detectors. The unit has three outputs, the image spacing signal, the sum video and notch and azimuth error video, and the sum video and notch and the elevation error video. (Refer to Sh 29 for signal distribution.)

b. Multivibrator and Switching (fig. 7-9.1). The positive preknock pulse enters at jack J1. It is coupled through capacitor C1, developed across resistor R2, and applied to the control grid of tube V1A through parasitic suppressor resistor R1. The pulse is amplified and inverted by tube V1A and then coupled through capacitor C3 to the cathodes of the pulse-selector tubes V2A and V2B. This negative pulse is applied to the grids of tube V3 through capacitors C5 and C6. Tube V3 and associated components form a bistable multivibrator; that is, a multivibrator that requires two triggering pulses to complete one cycle of operation. When voltage is first applied to the plates of V3A and V3B, one tube will conduct slightly more than the other since no two tubes have exactly the same characteristics. This action, typical of multivibrators, causes one tube to conduct heavily and the other to be cut off. Assume, in this initial condition, tube V3A is conducting and V3B is cut off. The current drawn through cathode resistor R13 by V3A is sufficient to cause a voltage drop across resistor R13 large enough to keep V3B cut off since R13 is the common cathode resistor for both V3A and V3B. The multivibrator will remain in this condition until a triggering pulse is applied through diodes V2A and V2B. The preknock pulse is applied to both of these diodes. The diode connected to V3A, in this case diode V2A, is biased so that its plate is sufficiently negative with respect to its cathode that the trigger pulse cannot pass. V2B can conduct, however, and the negative trigger is applied to the grid of V3A. The decreased conduction of V3A causes its plate voltage to rise. This rise is coupled to the grid of V3B through capacitor C5. This voltage causes V3B to conduct and its plate voltage to decrease. The decrease in plate voltage is coupled through capacitor C6 to the grid of tube V3A. This negative voltage further reduces the conduction of V3A. Therefore, there is a cumulative, almost instantaneous, action present, which results in tube V3A being cut off and V3B conducting heavily. The conduction of tube V3B is sufficient to cause a voltage drop across resistor R13 that will keep V3A cut off. Since the preknock pulse occurs at 1,000-microsecond intervals, the period of a full cycle of the square wave appearing at either plate of tube V3 will be 2,000 microseconds. The output square wave from the plate of V3B, taken from the junction of resistors R9 and R10, is 180 degrees out of phase with that taken from the plate of V3A (the junction of resistors R7 and R8). The output of tube V3A is applied through capacitors C14 and C16 to the grids of the azimuth and elevation gate generators V4A and V8A, respectively. The output of V3B is coupled through capacitors C15 and C17 to the grids of V4B and V8B, respectively, and is also coupled through capacitor C8 to the grid of cathode follower V1B. Tube V1B is referred to as the switching cathode follower since it applies to the indicators, the square wave of which accomplishes the switching action in the presentation scheme of the indicators. The output of tube V1B is applied to the video amplifiers of both the azimuth and the elevation indicators.

c. Sum Video and Notch and Azimuth Error Video Switching. The azimuth angle error video signals in the form of video pulses, which are variable in amplitude and which may be either positive or negative in polarity, appear at jack J2. These pulses are applied through capacitor C9 to the control grid (pin 2) of tube V7A. This tube inverts the pulses without changing their amplitude and applies them through capacitor C12 to the control grid (pin 7) of tube V5B. The negative sum video and the positive notch appearing at jack J6 is applied through capacitor C18 to the control grid (pin 2) of tube V5A. It was established earlier that the square wave appearing on the grid of tube V4A is 180 degrees out of phase with that appearing on the grid of V4B. The negative excursion of the square wave appearing on the grid of V4A will cut off 4VA. The negative portion of the square wave applied to the grid of V4B will produce the same result. Therefore, when V4A conducts, V4B will be cut off, and vice versa. Since resistor R51 is a common cathode resistor for both V4A and V5B when V4A conducts, the current drawn through resistor R51 will produce a voltage drop that is sufficient to cut off V5B. During this same time, tube V4B is cut off and draws no current through resistor R49. Therefore, tube V5A is allowed to conduct. Conversely, when V4B conducts, V4A is cut off, thus permitting V5B to conduct and cutting off V5A. Thus, there is a gating action present which alternately allows conduction of V5A and V5B. Since the plates of both V5A and V5B share a common plate resistor (R48), only one output comes from tube V5, and it can be called a gated mixer. By the alternate conduction of the two sections of tube V5, the signals appearing at the control grid of tube V6 will alternately be sum video and notch and azimuth error video, occurring 1,000 microseconds apart. As the antenna azimuth error increases, the amplitude of either the positive or the negative error pulses will increase accordingly. The two sections of cathode follower V6 are connected in parallel to meet the power requirements of the circuit. The two sections of the tube V6 cause a quiescent current of approximately 50 milliamperes so as to permit a maximum of plus or minus two volts output to the coaxial cable. This results in a 15- to 85-milliampere conduction of the tube which keeps the operating characteristic of the stage linear.

d. Elevation Error Video and Sum Video and Notch Switching. The operation of the elevation channel is identical to that of the azimuth channel previously discussed, and reference to identical circuits will suffice for an explanation. The elevation error pulses from the elevation angle error detector enter at jack J3 and are coupled through capacitor C13 to the control grid (pin 7) of tube V7B. Tube V7B inverts the pulses without changing the amplitude and applies them through capacitor C31 to the control grid of V9B. The sum video and notch are applied to the control grid of V9A through capacitor C19. Here the elevation and the sum video are mixed as in the azimuth channel. The signals appearing at the common plate load resistor R63 are applied through capacitor C29 to the grids of cathode follower V10. The output, taken at the cathode of V10, is applied to the video amplifier in the elevation indicator. BALANCE potentiometers R36 and R43 in the cathode circuits of tube V4 and V8, respectively, should be set for approximately midrange. They no longer serve as a balancing function in the modified video error signal panel.

U. S. GOVERNMENT PRINTING OFFICE 1956 O-401349

TM 9-5000-19—NIKE I SYSTEMS; TARGET TRACKING RADAR RANGE AND PRESENTATION, CIRCUITRY (U)—1956

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