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SCAN-CONVERTER DISPLAY

Final Report

(December 1967 through August 1968)

VOLUME I

Technical Description

April 1969

Prepared Under Contract N00019-68-C-0553

for

Naval Air Systems Command

Department of the Navy

Washington, D. C.

by

RCA

Defense Electronic Products

Aerospace Systems Division

Burlington, Massachusetts, 01801

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ABSTRACT

This report consists of two parts, Volume I, the technical description and Volume II, the circuit schematics.

This report describes a scan-converter/cathode ray tube (SC/CRT) aircraft cockpit indicator unit for display of either radar or television data. For the purpose of flight testing this experimental system, the unit was designed and fabricated for installation in A-7 A/B aircraft. The indicator is a direct electrical and mechanical replacement for the direct view storage tube (DVST) indicator currently used in A-7 A/B aircraft.

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SECTION 1

INTRODUCTION

The A-7 aircraft, like a number of other current military aircraft, is equipped to carry and launch the Walleye television-guided weapon. The combat effectiveness of the Walleye, and the combat attrition rate of the aircraft, are both directly affected by the quality of the pilot cockpit television display. The cockpit displays currently installed in operational aircraft do not provide a straight through path from the weapon television camera to a cockpit display which is optimized for television. Instead, the television picture is processed through a direct view storage tube (DVST) to provide a display which is usually optimized for radar. This results in a degradation of A-7/Walleye combat effectiveness for two reasons. First, the less-than-optimum quality of the pilot television display degrades his ability to detect, acquire, and lockon to his target. Second, the resulting short lockon range forces the pilot into unnecessarily long and hazardous exposure to enemy antiaircraft weapons.

1. The Technical Problem

The Walleye television camera operates at the conventional TV scan rate of 30 frames per second-thirty pictures per second. The airborne radar, on the other hand, operates at a scan rate of one per second-one picture per second. The space limitations of a fighter cockpit require that both the TV and radar displays be presented on one instrument. The very difficult technical problem is to provide a cockpit indicator unit which can accommodate the different scan rates of the radar and the TV. To put it another way, the problem is to convert the scan rate of one sensor to the scan rate of the other.

2. Two Alternate Solutions

Two technical approaches are applicable to solution of the military problem.

a. The Direct View Storage Tube (DVST)

The DVST is presently used in the A-7 aircraft. It is a single cathode ray tube with two electron guns and a storage grid for the relatively slow radar picture. With appropriate circuitry, the DVST can show either a television or a radar display. The display can be optimized for either radar or for television, but not for both. Combat experience, supported by engineering test flight, has demonstrated this conclusively.

b. The Scan Converter Tube (SCT)

The second solution is that used by RCA for this application. The SCT is used in combination with a television-type cathode ray display tube of extremely high quality. In this scheme, the Walleye television picture is passed directly to the pilot CRT display tube with no intermediate processing. The relatively slow radar picture is transmitted to the scan converter tube; the SCT converts the radar to television scan rate and passes the converted video to the television display tube. There are two results: the radar display is itself improved, and the Walleye display is very substantially improved.

The CRT-SCT approach was selected over the direct view storage tube (DVST) indicator for the following reasons:

- When the DVST is used to display television, moving images are smeared. The DVST has high brightness only when the image is displayed by the use of the storage mesh and the flood gun. Writing gun brightness is low. When there is only one millisecond to erase the image between frames, the erasure is not complete. The image is partially retained and moving images are therefore smeared.
- The DVST tends to have poor grey shade discrimination at the high writing speeds necessary for TV display. In addition, the DVST tends to display any particular desired grey shade non-uniformly over its display area. Both phenomena are caused by the very small DVST writing gun grid voltage change between beam cutoff and saturation at high writing speeds and by non-uniformities in the storage grid.
- The DVST faceplate brightness cannot be changed. It must be done by optical means such as a Polaroid filter. The flood gun electron beam must be collimated,

meaning that when the beam passes through the storage grid, the electron paths must be parallel and perpendicular to the screen. This is accomplished by a series of electrical lenses. Any change in the potentials of the tube elements degrades the collimation, and hence the uniformity of the picture.

- It is possible to build a DVST system that will display TV in a reasonable fashion, but this DVST indicator will not display radar properly because the maximum storage time is too short.

RCA has chosen to use a CRT for the display tube because there is no better way to display TV pictures. No collimation is required and it is easy to adjust and control brightness. Ten grey shades can be displayed. The SCT is then used to obtain the required storage time for the radar displays.

SECTION 2

SCAN CONVERTER DISPLAY

The scan converter display (SCD), designed by RCA to interface with the AN/APQ-116 on the A-7 aircraft is a direct replacement for the APQ-116/IP-799 direct view storage tube (DVST) indicator.

Front and rear views of the SCD are shown in Figures 1 and 2 respectively.

The SCD model has dimensions which exactly match the present indicator; it displays Walleye TV video, and all the modes of the AN/APQ-116 radar. The design is also completely compatible with the sweep generator of the APQ-116 radar. This one-box approach to the design of the display permits the RCA SCD model to be interchangeable with the present DVST indicator harnessing and sweep generator.

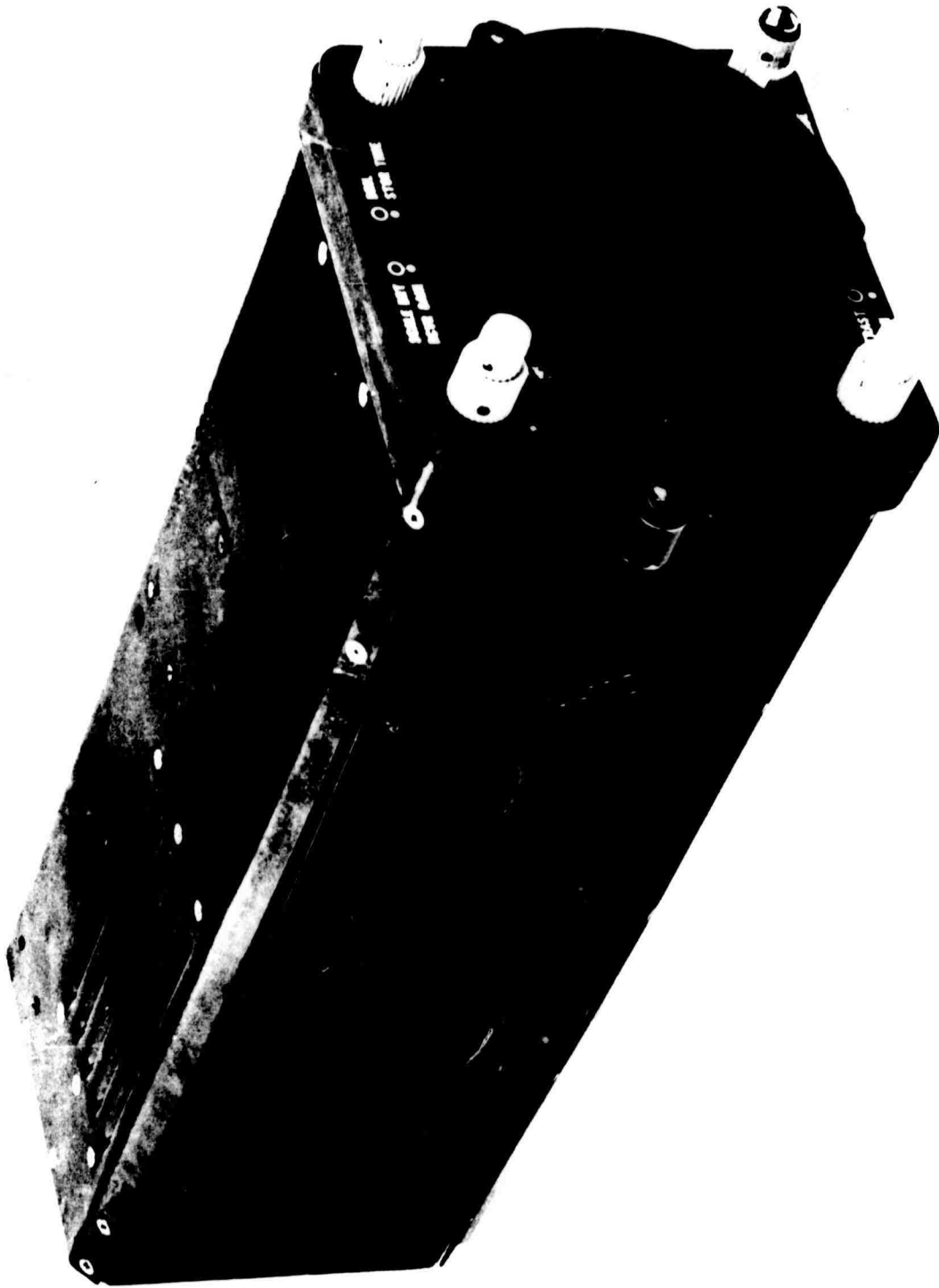


Figure 1. Scan Converter Display (Front View)

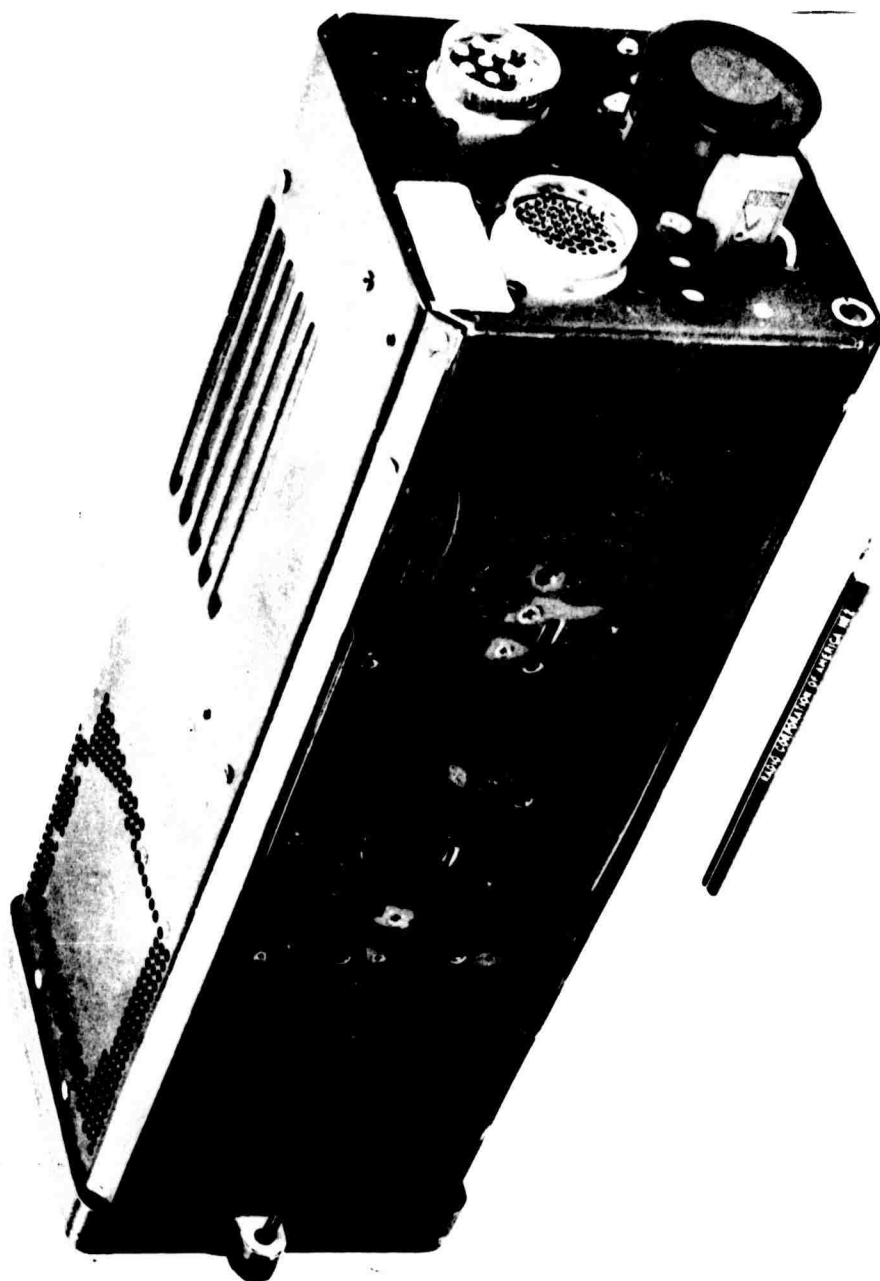


Figure 2. Scan Converter Display (Rear View)

SECTION 3

SPECIFIC ASPECTS

To package the RCA subminiature scan converter, with a high brightness cathode ray tube and all of the associated electronics, in the same volume occupied by the present DVST indicator, RCA has developed the following items:

A specially designed high resolution minimum-volume scan converter tube package (C22021) consisting of an RCA subminiature scan converter tube, deflection yokes, focus coil, and magnetic shield. A drawing of this configuration is shown in Figure 3.

A microelectronic synchronizer for synchronizing the output of the scan converter with the CRT display.

A low-noise hybrid microelectronic preamplifier consisting of a field effect transistor input stage followed by a transistor amplifier. The equivalent input noise for this preamplifier is less than 1.6 nanoamps. A version of this preamp is presently being used in a recently developed portable RCA color camera in use by the National Broadcasting Company.

A hybrid low-noise microelectronic video output driver for driving the CRT.

Hybrid microelectronic sweep safety and unblank circuits which provide loss-of-sweep protection for both the scan converter and the CRT.

High efficiency sweep deflection drivers, based upon advanced RCA concept, which perform all of the functions provided by the present DVST indicator deflection circuits but which require less volume and less power.

SECTION 4

SYSTEM DESCRIPTION

A scan converter display unit (SCD) consists of a scan converter tube (SCT), a cathode ray tube (CRT) and associated electronics. It displays the television image from the Walleye weapon or the radar image for the various modes generated by the AN/APQ-116 forward looking radar. The radar video is processed through the SCT so that it may be displayed as a TV picture on the CRT. The Walleye TV video is directly displayed on the CRT. System performance and other characteristics are given in Figure 4. A simplified block diagram is shown in Figure 5. Circuit schematics are contained in a separate document, Volume II of this Engineering Report.

3. Display Tube Description

The display tube is a five inch round CRT having a 70° deflection angle. It is a high brightness tube, having a faceplate output of 800 ft lamberts at an anode voltage of 15KV with a beam current of approximately 300 microamps. The tube uses high voltage electrostatic focussing to facilitate high resolution at high brightness. Spot size is limited to less than 0.005 inch and the tube is capable of greater than 800 TV line resolution at 800 ft-lamberts brightness. A limited acceptance angle (Micromesh) filter or a polarizing filter can be used over the CRT face to improve the contrast of the CRT under high ambient lighting conditions.

On a clear bright day, typical cockpit ambient light is 3,000 foot-candles. It can be shown by mathematical analysis that the RCA SCD indicator with Micromesh filter is capable of providing a brightness ratio of 12.1:1. This is more than adequate to provide eight shades of grey on a bright day. Ten grey shades can be observed in less severe ambient light conditions.

4. Scan Converter Tube Description

The scan converter tube shown in Figure 6 is used to obtain the required storage time for display of the radar information. The SCT is a device with two axially aligned electron guns

Cathode Ray Tube		5 inch round
Scan Converter Tube		Subminiature (2 in. diameter x 10 in. long)
Indicator Unit		
Size		5.6 in x 5.6 in x 15.75 in
Weight		23 lb approx
Power		
Blower		35 watts
Circuits		150 watts
Total		185 watts
Display		
Format		4-inch round
TV		525 lines at 60 fields/sec
Radar		875 lines at 60 fields/sec
Interlace		2 fields/frame
Brightness (CRT Face Plate)		800 ft-lamberts
Limiting Resolution		
TV	Horiz	600 TV lines
	Vert	350 TV lines
Radar	Horiz	550 TV lines
	Vert	580 TV lines
Grey Shades of Contrast		
TV	8-10	{ In $\sqrt{2}$ steps at max brightness
Radar	6	
Display positional linearity		
TV		$\pm 2\%$
Radar		$\pm 2\%$

Figure 4. Scan Coverter Indicator Unit Characteristics

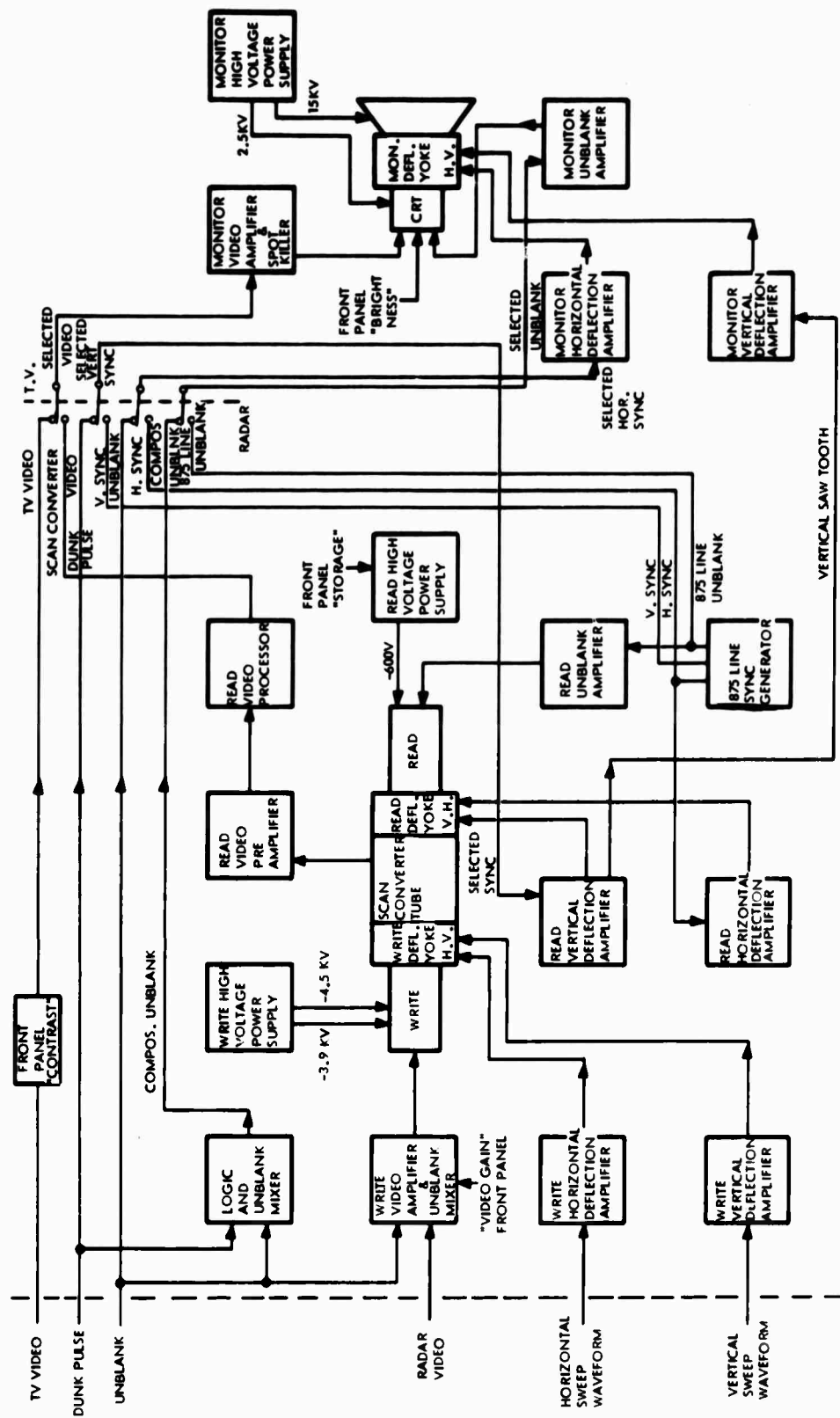


Figure 5. Scan Converter Display Block Diagram

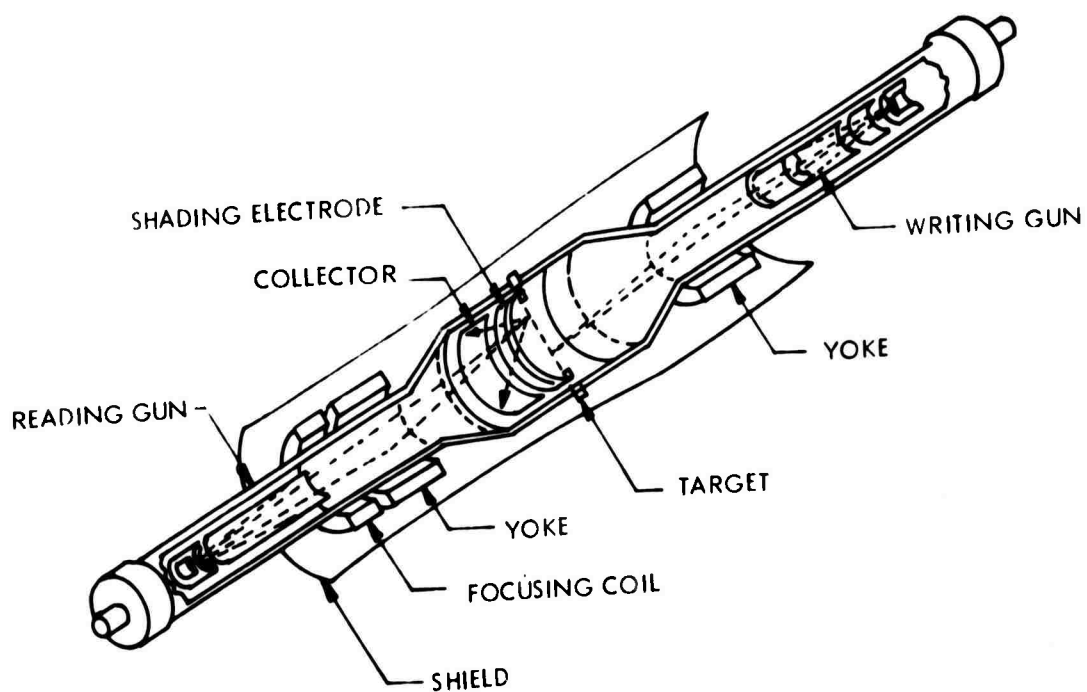
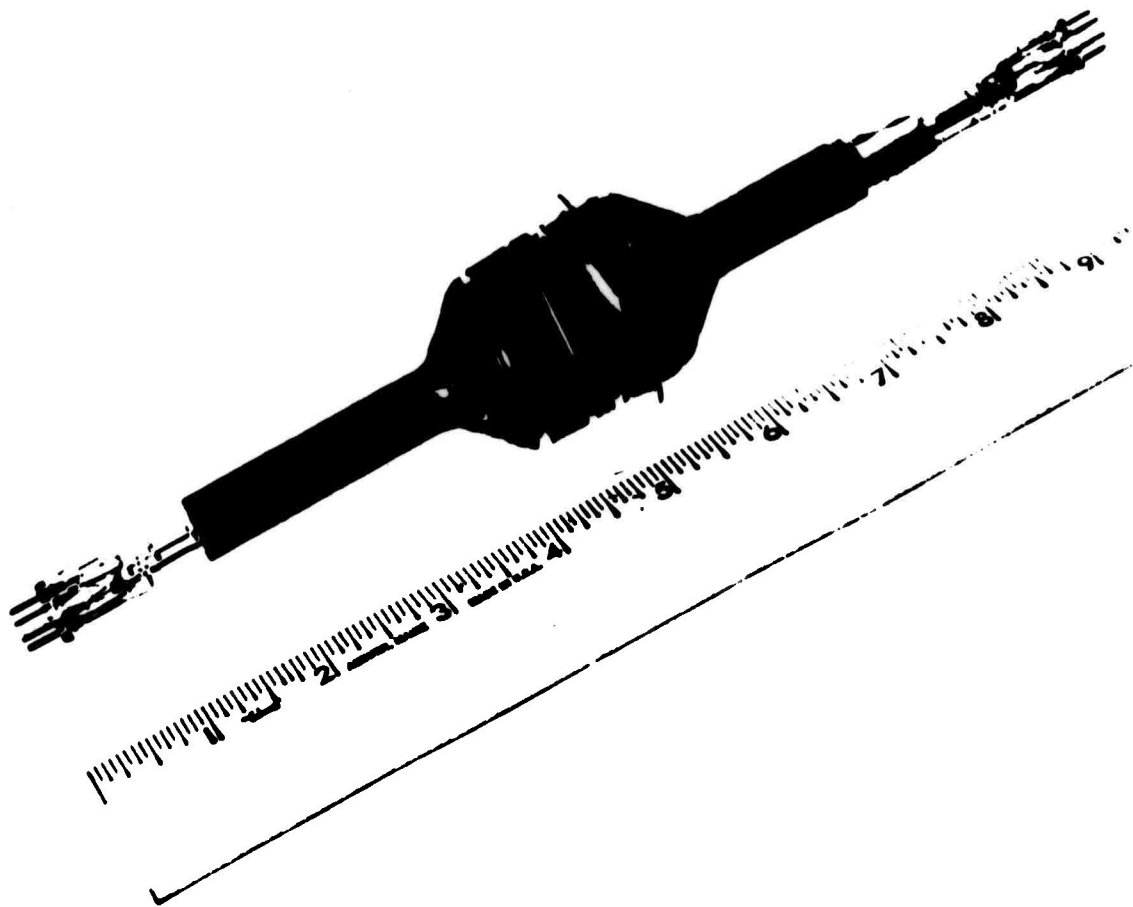


Figure 6. Scan Converter Indicator Unit
Scan Converter Tube

directing electron beams at a dielectric target. Radar information is written on the target by the write gun, and write video and deflection circuits.

An electron beam generated by the read electron gun is swept across the target by the read deflection circuits. The display format is a raster of 875 horizontal lines at 30 frames per second interlaced. As the read beam is swept across the target electrical signals are generated according to the written pattern; the TV monitor accepts this signal to display the radar image on the CRT. Many frames of TV are presented before the written picture is erased. Storage time is directly related to the read beam current and is adjustable.

The SCT used in the SCD is a subminiature electron bombardment induced conductivity (EBIC) SCT. It is the RCA type C22021 similar to the C22012. This SCT was specifically designed for use with airborne forward looking sensors. The size and tube parameters have been optimized for the present application. Because of its small size and simplicity of construction, the SCT is a highly reliable, rugged device. It is easy to adjust and maintain because there is no requirement for collimation of either electron gun beam.

5. Electronic Circuitry Description

a. Scan Converter Write Electronics

- The write video amplifier performs the function of amplifying the incoming video signal and driving the write electron gun. It sums the template video, radar video, and compensated unblanking waveforms.
- The write horizontal and vertical deflection amplifiers are highly stable dc current feedback amplifiers. Their function is to deflect the electron beam as required by the various radar modes to follow the repetitive sweep waveforms. Included in these circuits is a sweep safety circuit which protects the SCT from damage resulting from a loss of sweep. It ensures that the write electron gun remains blanked if the write deflection circuit signals are outside of limits.

- The write high voltage power supply produces the potentials required for the SCT write electron gun. It consists of a 5000 (negative) volt power supply and a 600 volt power supply which is referenced at the high negative voltage. Its dc to dc converter is a high frequency type so that the transformers and filtering components are not excessively bulky and weighty. The supply employs active regulation.
- b. Scan Converter Read Electronics
- The read video preamplifier is a hybrid microelectronic circuit preamplifier which amplifies and processes the video signal from the output of the SCT. The SCT acts like a current source producing peak signal currents typically from 0.1 to 1.0 microampere.
 - The video processor amplifies the preamplifier output to the signal amplitude required by the CRT video amplifier. It contains aperture correction and pedestal insertion circuits.
 - The read horizontal and vertical deflection amplifiers are highly stable current feedback amplifiers. Linear sawtooth waveforms are generated in the circuits and synchronized by the sync generator. In the TV mode the vertical sawtooth is synchronized by the dunk pulse. The vertical sawtooth waveform is also used to drive the monitor (CRT) vertical deflection amplifiers. Linearity correction is not required in the read deflection amplifiers because both write and read sides of the SCT produce identical nonlinearities, resulting in a linear transformation. The vertical deflection operates at 60 Hz and the horizontal deflection at 26.25 kHz. A hybrid microelectronic circuit is used as a sweep safety which blanks the read electron gun if the deflection circuits or sync generator fail.
 - The read high voltage power supply produces the potentials required for the SCT electron gun. Its dc to dc converter is a high frequency type, enabling transformer and filter components to be small and light weight. Active regulation is used. The control grid to cathode bias potential is adjusted by means of an external storage potentiometer.
 - The sync generator consists of a printed circuit card containing a crystal controlled oscillator and microelectronic countdown circuits. It provides sync and unblank signals for the 875 line 30 frame/sec raster.

- The low voltage power supply generates those required voltages which are not received from the radar sweep generator unit. This supply operates from 115V 3 phase, 400 Hz power.
- c. Monitor (CRT) Electronics
- The monitor video amplifier is a hybrid microelectronic circuit which drives the CRT cathode. The input video signal is selected by means of a relay from the read video or TV video. Dc restoration is included to maintain desired absolute brightness on the CRT. A spot killer circuit is included to prevent phosphor burns on the CRT whenever power to the unit is shut off.
 - The monitor vertical deflection circuit is a linearity corrected current feedback amplifier. Its function is to convert the sawtooth waveform coming from the read vertical deflection circuit to a sawtooth current in the deflection yoke.
 - The monitor horizontal deflection circuit is a parallel efficiency switching circuit with linearity correction. Sync signals come from the sync generator at 26.26 kHz during radar operation and from the Walleye unblanking signal at 15.75 kHz in the TV mode. Sweep safety is provided to blank the CRT if the vertical and horizontal sweeps are not within limits.
 - The monitor high voltage power supply generates the voltage for the CRT. Its dc to dc converter is a high frequency type and it employs active regulation.
 - The monitor unblank circuit drives the control grid of the CRT. It accepts a selected unblanking signal from a relay. In TV the dunk pulse is anded with the unblanking signal to provide a composite unblanking signal from the logic network. In the radar mode unblanking comes from the sync generator.

SECTION 5

ELECTRONIC CIRCUITRY DETAILED DESCRIPTION

The schematics referred to in the following descriptions are contained in Volume II. A detailed block diagram is given in Figure 7 of this Volume I.

6. Scan Converter Write Electronics

a. Write Video Amplifier, Buffers and Logic A6

Refer to Figure 7, and schematic diagram 1889411. The write video amplifier, buffer, and logic circuit is a PC card in the PC basket assembly. The write video amplifier consists of a video selection network, a clamp switch, a summing amplifier and an output driver amplifier. Radar video or template video is selected through a diode logic network CR8 and CR10 and is superimposed on the unblank waveform in the summing amplifier Q3, Q5. The output amplifier Q6, Q7, Q8 and Q9 is used to drive large voltage pulses into a capacitive load of the write bias network.

Undisplayed radar video is blanked out by the clamp signal in the clamp switch, Q2. The ECM/AGR signal is applied to the clamp switch to block out unwanted noise from the video signal during the ECM or AGR modes. A sweep safety signal is applied to a switch Q4 in the summing amplifier to blank the write side of the scan converter in the event of a failure in the write vertical or horizontal sweeps.

The dunk pulse is applied through a level shifter and buffers Z1A, Z2 to a pulse width discriminator Z3, Z1 whose output is connected to the sweep safety and clamp switches, Q2, Q4. In the TV mode the pulse width discriminator thus blanks the write side of the SCT. The buffered dunk pulse is used as a vertical sync pulse for the read vertical sweep generator in the TV mode. The buffered unblank pulse is anded with the buffered dunk pulse in the logic Z4 to produce a composite unblank pulse for the monitor CRT in the TV mode. In the TV mode, the buffered unblank pulse is used as a sync signal for the monitor horizontal deflection circuit. Mode switching is accomplished by relay K1.

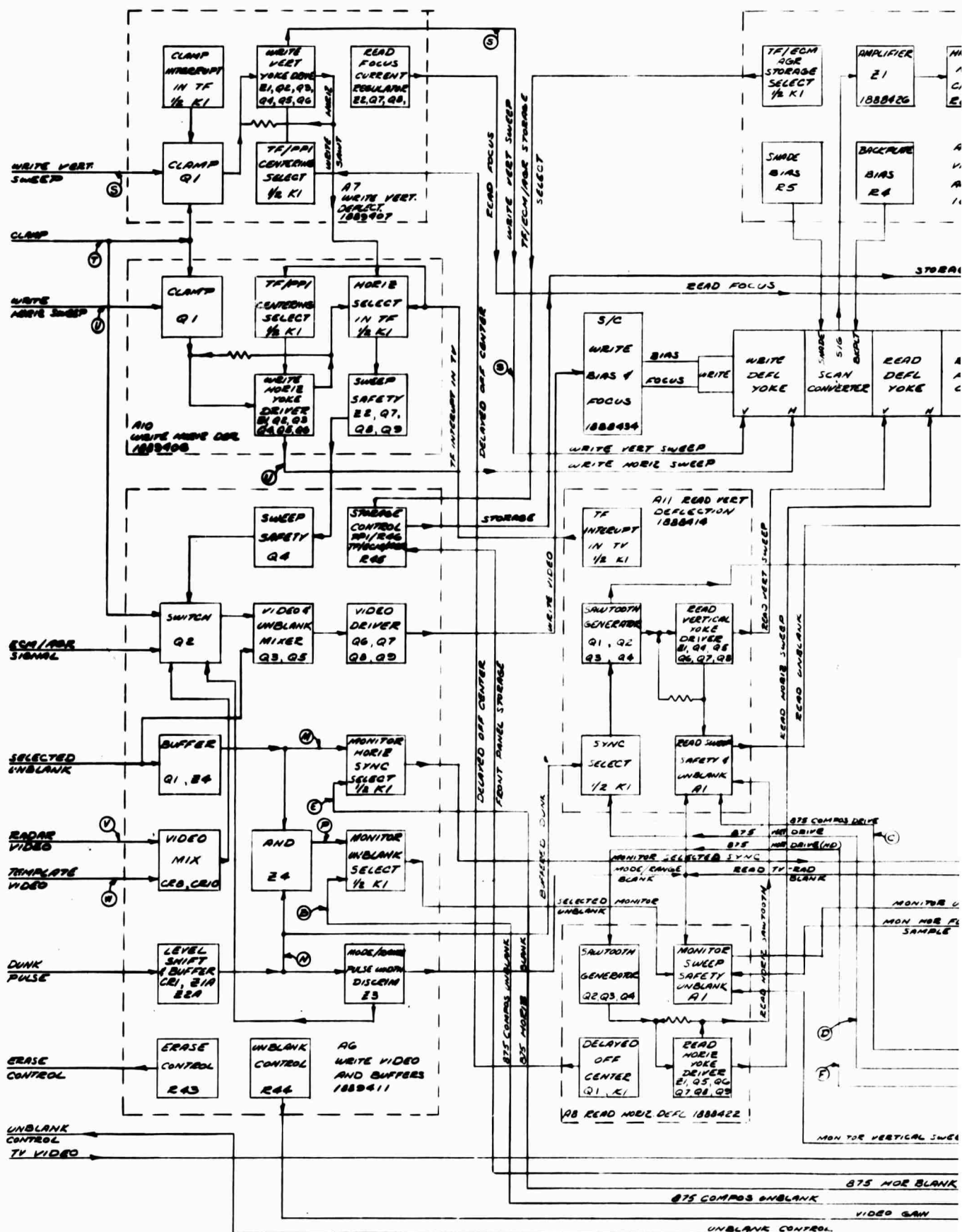
R3 adjusts the level of the radar video, R5 adjusts the level of the template video, and R8 adjusts the level of the unblank pulse into the summing amplifier. R46, a potentiometer in series with the front panel storage control, is used to program the read power supply which controls the read G1 to cathode bias, hence storage. In the TF mode a shorter storage time is necessary and R45 is applied in parallel to R46, by means of a relay in the video pre-amplifier module. R43 controls the erase pulse amplitude in the radar sweep generator unit. R44 in conjunction with the video gain potentiometer on the front panel controls the unblank pedestal amplitude in the sweep generator unit. Since the amplitude of the pedestal controls the amount of information which is written into the SC, the read output video amplitude will vary as the pedestal amplitude is varied.

b. Write Horizontal Deflection Driver and Sweep Safety A10

Refer to Figure 7 and schematic 1889406. The write horizontal deflection circuit is a PC board located in the PC basket assembly. The write horizontal sweep waveform is capacitively coupled to a differential amplifier Z1 through a dc restorer switch Q1 actuated by the clamp signal. The output of the differential amplifier is fed through emitter followers Q3 and Q4 to a push-pull deflection yoke driver, Q5 and Q6. The deflection circuit is highly stable due to current feedback through R16 and R17. Centering, selected by relay K1 for either TF or PPI, is applied to the differential amplifier. A sample of the output quiescent current is fed to differential amplifier Q2 which controls the operating point in Z1 and is adjustable by R11. The sweep safety circuit consists of a high gain amplifier Z2 whose output is a pulse when the vertical sawtooth is applied to the input. The pulse output is used to keep capacitor C14 discharged over a period of time by means of Q7. In the absence of this pulse, Q7 remains off and the capacitor C14 is allowed to charge, causing the following stage Q8 and Q9 to produce a positive output to energize the sweep safety switch on the write video board. In the TF mode, the horizontal sawtooth is substituted for the vertical sawtooth at the input by means of relay K1. Relay K1 is energized in the TF mode, but interrupted if TV is present. R14 adjusts TF horizontal centering; R15 adjusts PPI horizontal centering.

c. Write Vertical Deflection and Read Focus Current Regulator A7

Refer to Figure 7 and schematic 1889407. The write vertical deflection circuit is a PC card located in the PC basket assembly. The description of the write vertical deflection



NOTE: CIRCLED LETTERS ♂ REFER TO WAVEFORMS SHOWN IN FIGURES 8, 9, AND 10

circuit is identical to that for the write horizontal with the following exceptions: Relay K1 if energized in the TF mode, is not interrupted in the TV mode. Dc restorer switch Q1 is disabled in the TF mode by relay K1 due to the fact that the vertical sweep is a 3Hz sinusoidal waveform.

The read focus current regulator, located on this board, is a constant current source supplying a constant current to the read focus coil. Z2 is a voltage source for the base of Q7. The emitter of Q8 is essentially a constant voltage, therefore the current through the emitter, essentially the same as that through the collector, is adjusted by the emitter resistance R48.

d. Write Bias A2

Refer to Figure 7 and schematic 1888434. The write bias circuit is a potted module whose adjustments are accessible through the rear wall of the display unit.

The write bias is essentially a highly filtered resistor voltage divider, supplying the proper voltage from the 5000 volt power supply to the various electrodes. The term bias refers to the control-grid to cathode potential, which is adjustable by means of potentiometer, R2. A diode resistor network CR3, R6 provides dc restoration to the unblanking signal applied to the grid.

The anode to cathode voltage is supplied by a separate floating 600 volt power supply. The voltage on the focus electrode G3 is adjusted by means of a potentiometer R4 in the divider string.

7. Scan Converter Read Electronics

a. Read Horizontal Deflection and Monitor Sweep Safety A8

The read horizontal deflection circuit is a PC card located in the PC basket assembly. Refer to Figure 7 and the circuit schematic diagram 1888422. The read horizontal deflection amplifier is a highly stable, current feedback amplifier. A linear sawtooth waveform is generated by the sawtooth generator Q2, Q3 and Q4 and fed to a differential

amplifier Z1 driving a push-pull output deflection yoke driver stage Q7 and Q8 through emitter followers Q5 and Q6. The horizontal sawtooth generator accepts sync pulses from the sync generator, through switch Q3. R6 is a size adjustment.

Current feedback is supplied through R16 and R18 to the differential amplifier input of Z1. Centering is provided by R19. A high degree of dc stability is obtained by sampling the output quiescent current. This sample is fed back to program the quiescent operating point of amplifier Z1 through Q5. R23 adjusts the operating point.

When the high voltages are first turned on after the initial delay, a surge in writing strength may occur. A momentary off-centering voltage is applied to the write vertical deflection circuit during this surge through relay K1. This is to prevent damage to the SCT.

The monitor sweep safety and unblank circuit is located on this board. The description is identical to that for the read sweep safety located on the read vertical deflection board.

b. Read Vertical Deflection and Read Sweep Safety A11

The read vertical deflection circuit is a PC card located in the PC basket assembly. Refer to Figure 7 and schematic diagram 1888414. The description of the read vertical deflection circuit is identical to that for the horizontal, with the following exceptions: Q1, Q2, Q3, and Q4 constitute a free running sawtooth generator, Q1 being an unjunction transistor. R3, having the same location as R6 in the horizontal circuit is a free-running frequency adjustment. R10 is the read vertical size adjust and R9 is the monitor vertical size adjust. Relay K1 interrupts the action of K1 on the write vertical circuit during TV, and selects the vertical sync signal to the read vertical sawtooth generator. In radar mode, the synchronizer vertical drive is selected. In TV mode the buffered dunk pulse is selected.

c. Read Sweep Safety and Unblank

The read sweep safety and unblank circuit is located on this board. See Figure 7 and schematic drawing 1888428. It is a hybrid microelectronic module. The sweep safety and unblank circuit accepts mode-range blanking, composite sync, and horizontal and vertical sense signals. The circuit unblanks the control grid of the SCT read gun (or

monitor CRT) during active line time. The grid is blanked (unblank signal is inhibited) during horizontal and vertical retrace, whenever either sweep fails, and during mode or range change.

d. Read Video Preamplifier and Gain Control A5

Refer to Figure 7 and schematic 1888443, 1888426. The video preamplifier is a hybrid circuit mounted in the SCT penthouse. The scan converter video output is fed to a hybrid amplifier Z1 and then to a high peaking network C11, C12, R8 which compensates for the gain-frequency characteristics of the SCT video output. Amplifier Z2 restores the gain lost in the high peaker network. Its output is fed through gain control R13 to the output emitter follower Q1. Relay K1 switches R15 gain control into the circuit during TF, ECM, or AGR modes. One half of the relay K1 is used to change the storage control resistor on the write video board during TF, ECM or AGR as described in paragraph 6a. Included on this circuit are bias adjustments for the backplate (R4) and shading electrodes (R5) which control the background and persistence uniformity in conjunction with G3.

e. Read Bias A3

The read bias circuit is a potted module mounted near the SCT read end. See Figure 7 and schematic 1888425. The read bias circuit is essentially an RC filtering network for the cathode and G1 electrodes. The unblank signal is fed through a decoupling capacitor C3 and diode dc restorer CR3, R5 to the grid. The G3 electrode is a uniformity adjustment acting in conjunction with the shading electrode, its bias potential is determined by a potentiometer, R6. The G1 to cathode potential is controlled by the read power supply.

f. Sync Generator A12

Refer to Figure 7 and schematic 1888435. The sync generator consists of a crystal controlled oscillator Y1, Q1, Q2, countdown modules Z1 through Z26, to produce the proper synchronizing, blanking and unblanking pulses for a raster of 875 lines per frame, 30 frame per second at 2:1 interlace. During a mode change from radar to TV, momentary blanking pulses are generated by means of K1, Q3 and Q4.

8. Monitor Electronics

a. Video Processor A9A1

The video processor is an enclosed assembly mounted at the read end of the SCT. See Figure 7 and schematic diagram 1888444.

The output video from the read video preamplifier is applied through an aperture correction circuit to amplifier Z1. The amplifier output is fed through emitter follower Q2, through a clamp switch Q1 to a video and blanking mixer Z2. Pedestal insertion is provided by R15 and CR2. R1 is an aperture gain control adjusting the input to the delay line. Horizontal drive pulses from the sync generator are used to drive the clamp switch Q1. Q1 provides dc restoration for C8. Composite blank pulses from the sync generator are mixed with the video in Z2 through CR1. The output radar video and the TV video from the front panel contrast control are applied to contacts on the video select relay K1. In the TV mode, the TV video from contrast is selected and in radar mode the SCT video is selected. The selected video is fed to the monitor video amplifier through emitter follower Q3.

b. Monitor Video Amplifier and Spot Killer A9A2

The video amplifier and spot killer is a circuit mounted in the same assembly with the video processor. See Figure 7 and schematic diagrams 1887421 and 1888429.

The monitor video amplifier is a hybrid circuit which drives the CRT cathode. Its input is the selected video from the video processor. Dc restoration is included through CR1 (schematic 1888429) to maintain absolute brightness at the desired level on the CRT. The spot killer circuit Q1 (schematic 1887421) applies the potential on charged capacitors mounted on the write vertical deflection board to the cathode of the CRT to keep the CRT blanked when the power is turned off. This is provided to prevent phosphor burns on the CRT. During switching from radar to TV a blanking pulse is provided through Q1.

c. Monitor Vertical Deflection Amplifier A14

The vertical deflection amplifier is an enclosed assembly mounted below the CRT. See Figure 7 and schematic 1888433.

The vertical deflection circuit is a linearity corrected current feedback amplifier. The sawtooth input from the read vertical deflection circuit is capacitively coupled to a resistor-diode network R7, CR6 and CR7 which shapes the waveform for compensation against flat face distortion in the CRT.

The corrected sawtooth is then applied to one side of a differential amplifier, Q1, feedback is applied to the other side. The output of the differential amplifier is fed to a complementary output power amplifier Q2 through Q7. During the flyback period the large pulse produced by the yoke inductance is absorbed by the insertion of a large negative voltage by a boost circuit, Q8 through Q11 and C6. Power required to drive the yoke is thus conserved.

A sample of the output current waveshape is supplied to the sweep safety circuit located on the read horizontal deflection board.

d. Monitor Horizontal Deflection Driver A13

The horizontal deflection driver is an enclosed assembly mounted above the CRT. See Figure 7 and schematic 1888427. The monitor horizontal deflection circuit is a parallel efficiency switching circuit with linearity correction. It generates an S corrected, linear ramp current through the monitor horizontal yoke. A negative going, selected sync pulse from the sync selector on the write video board, is used to synchronize a free running multivibrator Z1 through pulse amplifier Q1. The multivibrator generates a pulse of the proper duty cycle for the driver stage Q2. The driver stage drives a transformer T1 to generate the proper turn-on and turn-off currents to the output switching transistor, Q3. A change in mode from radar (875 lines) to TV (525 lines) is accomplished by paired relays K1, K2 which change the timing capacitor C2 on the multivibrator and the supply voltage to the output stage. The output stage incorporates a boost voltage network T2, CR6, CR7, C10 to reduce the supply voltage requirement. Q5 is a differential amplifier used as a sawtooth generator with C16. Q6 through Q9 is a complimentary power output stage driving T3. Q4 is a switch, and is part of the sawtooth generator. R32 and R33 adjust the peak to peak sawtooth signal. R32 is selected in parallel with R33 during the radar mode. R10 adjusts the free-running frequency of the multivibrator. R17 is a width adjustment for the raster in the radar mode. R18 is a width adjustment in the TV mode.

The sawtooth generator output is applied to a transformer T3 in series with the yoke to correct for nonlinearities in the deflection current resulting from circuit resistance. A sample of the flyback voltage is supplied to the sweep safety circuit on the read horizontal deflection board.

e. Monitor Sweep Safety and Unblank

See Figure 7, schematic 1888428. The description of the monitor sweep safety and unblank circuit, located on the read horizontal deflection board, is identical to the description of the read sweep safety and unblank.

f. Monitor Bias A4

See Figure 7, schematic 1887426. The monitor bias supplies the proper voltage to the focus electrode through a potentiometer (R4) and resistor voltage divider (R5 and R6). It supplies the voltage from the front panel brightness control to the control grid G1 and applies the unblank signal through a capacitor C1 and diode dc restorer CR3, to the control grid. The front panel brightness control is connected in series with +100 Vdc.

9. Waveforms and Timing Diagrams

Refer to Figures 8, 9, and 10, with cross reference to Figure 7.

a. Composite Blank and Unblank

The waveforms shown as (A) and (B) are produced by the sync generator. (A) is labelled composite blank and is composed of a string of positive going pulses, a composite of vertical and horizontal blanking pulses. (B) is labelled composite unblank. It is simultaneous to the composite blank but opposite in polarity. Since interlaced scanning is used, there are two fields to each frame. In the first field, vertical scanning begins at the start of one horizontal line and ends in the center of a horizontal line, the second consecutive field scan begins in the center of a horizontal line and ends at the end of another, such that interlace is achieved.

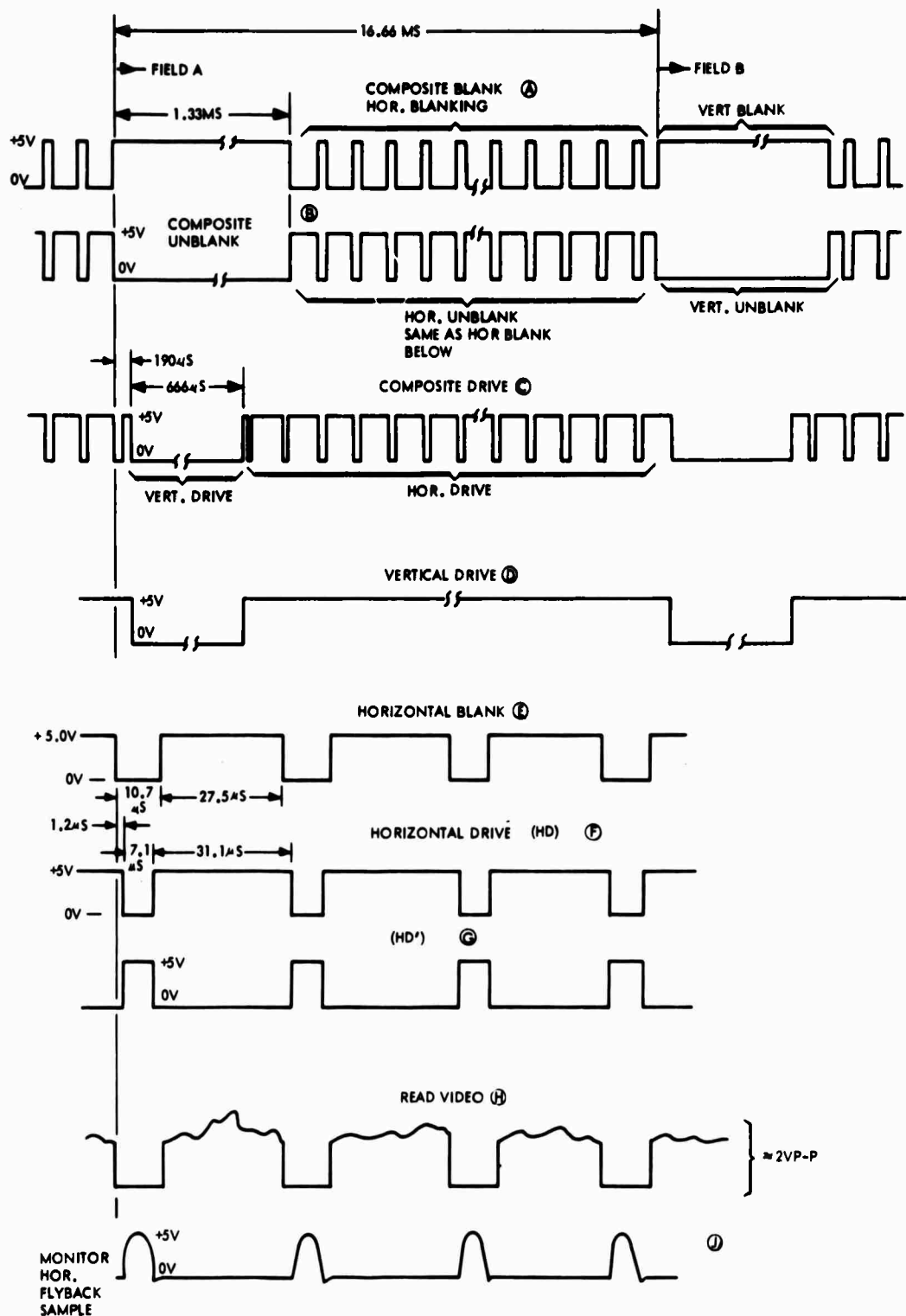


Figure 8. Waveforms and Timing Diagram

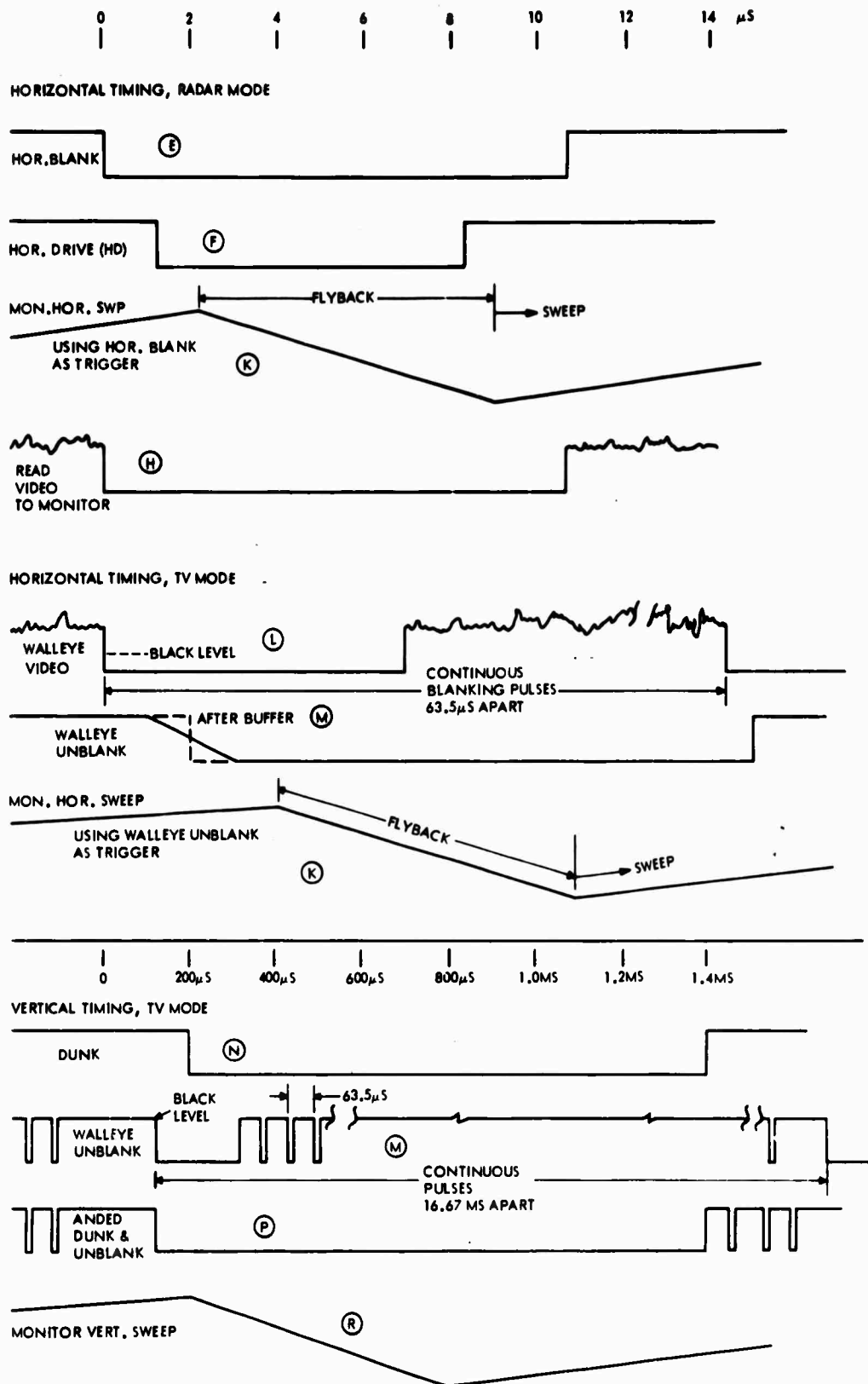


Figure 9. Waveforms and Timing Diagram

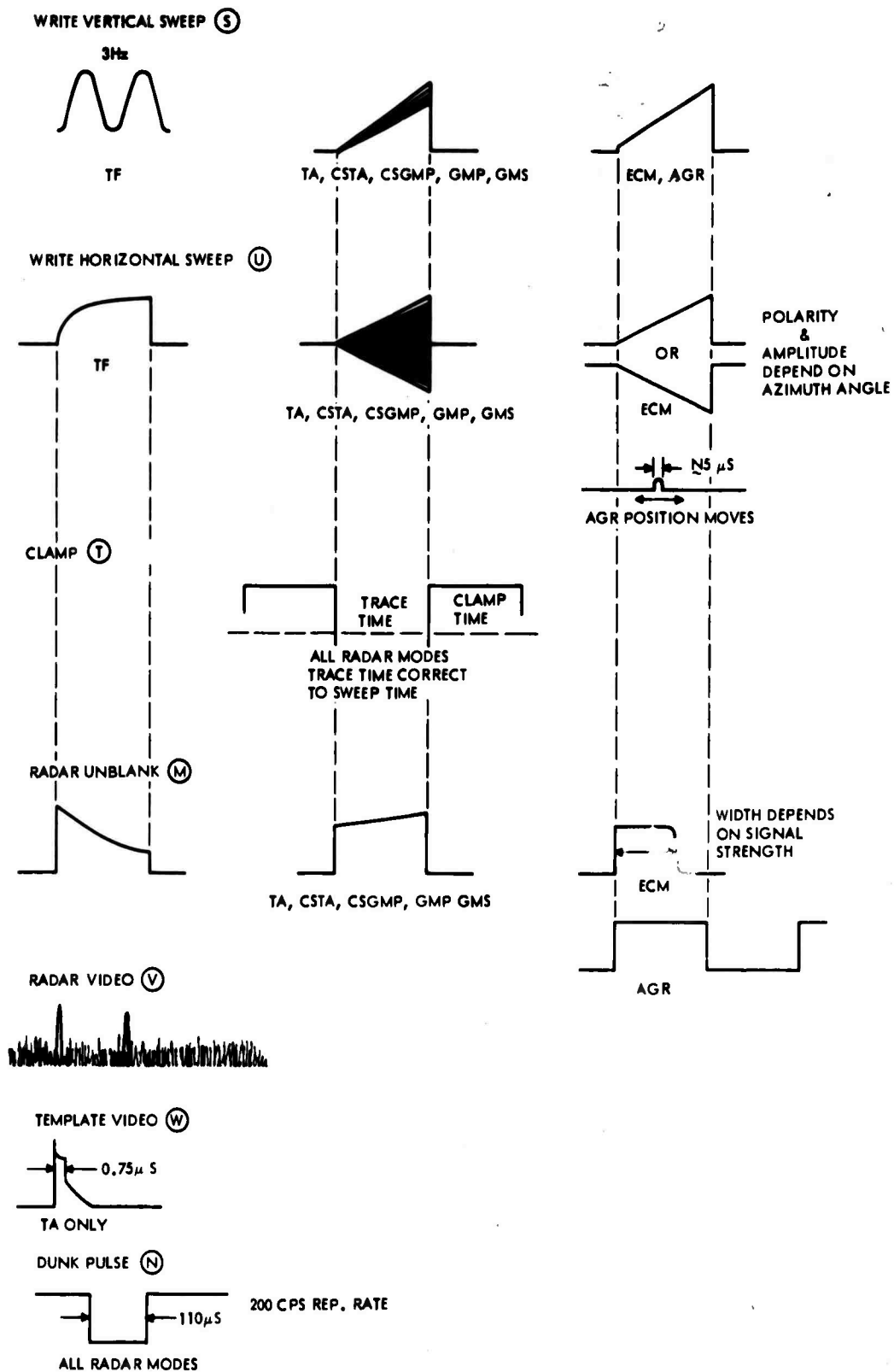


Figure 10. Waveforms and Timing Diagram

b. Composite Drive

Waveform (C) is labelled composite drive. It consists of a train of negative going pulses, composed of vertical and horizontal drive pulses. Composite drive is synchronous with composite blanking, but pulse widths are narrower.

c. Vertical Drive

Waveform (D) is the vertical drive waveform produced by the sync generator. It is negative going and simultaneous to the composite drive waveform. Vertical drive begins approximately $190\ \mu\text{s}$ after the start of the vertical blanking period and ends $474\ \mu\text{s}$ before the end of the vertical blanking period.

d. Horizontal Blank

Waveform (E) is the horizontal blank waveform produced by the sync generator. It consists of a string of negative going pulses simultaneous to the composite blank waveforms.

e. Horizontal Drive (HD and HD')

Horizontal drive (HD) waveform (F) is simultaneous to the horizontal blank waveform except that pulse widths are narrower. The start of the horizontal drive begins $1.2\ \mu\text{s}$ after the start of horizontal blank and ends $2.4\ \mu\text{s}$ before the end of horizontal blank. Horizontal drive (HD') is simultaneous, but opposite in polarity.

f. Read Video

Waveform (H) is an example of the typical read video waveform from the video processor, where blanking is applied.

g. Horizontal Flyback Sample

Waveform (J) is a typical sample of the monitor horizontal flyback voltage which is a half-sine wave, $6\ \mu\text{s}$ pulse, occurring simultaneous to the horizontal blanking pulse; each flyback pulse begins approximately $2\ \mu\text{s}$ after the start of horizontal blank.

h. Timing Relationships

In Figure 9, waveforms (E) (F) (K) and (H) are expanded to scale to show the exact time relationships during the horizontal retrace period of the 875 line or radar mode. Waveforms (L), (M), and (K) are expanded to scale to show the same relationships in the TV mode. Waveforms (N), (M), (P) and (R) are expanded to scale to show the exact time relationships of the dunk, unblank, and monitor vertical waveforms.

i. Input Radar Waveforms

(1) Write Vertical Sweep

Waveform (S) is the radar or write vertical sweep. In the TF mode it is a 3 Hz sinusoidal waveform. In all other modes it is a sawtooth waveshape occurring at radar repetition rate, envelope modulated by a repetitive segment of a sinewave corresponding to antenna azimuth scanning rate. In the ECM and AGR modes the vertical sweep is an unmodulated sawtooth, since the antenna is not scanning the azimuth direction.

(2) Write Horizontal Sweep

Waveform (U) is the radar or write horizontal sweep. In the TF mode the sweep is a repetitive hyperbolic waveform occurring at 3600 Hz. This presents range information on a logarithmic scale horizontally. In TA, CSTA, GSMP, GMS modes the write horizontal sweep is a sawtooth waveform at radar repetition rate, envelope modulated by a sine wave corresponding to azimuth position and scanning rate. In the ECM modes the horizontal sweep can be a positive or negative sawtooth or 0 amplitude. Amplitude depends on the pointing direction of the antenna. In the AGR mode the horizontal sweep is a pip at 3600 Hz repetition rate. Its position with respect to the start of the vertical sweep is a function of the range gate.

(3) Clamp

Waveform (T) is the clamp signal. It is used as an enable pulse for the other radar waveforms.

(4) Unblank

Waveform (M) is the unblank pulse waveform. In the TF mode the pulse has a negative slope. This is because video information written on the storage surface requires greater writing energy at the start of the sweep, where the sweep is moving very rapidly. During sector scan presentation, the storage surface tends to integrate video information near the origin due to a greater information density, therefore the unblank has a positive slope for compensation. In the ECM mode the image is a bright line pointing to an azimuth direction and whose length depends on signal strength; therefore the unblank waveform is a 200 Hz pulse whose width is proportional to signal strength. In the AGR mode the displayed image is a vertical line, the full display diameter, therefore the unblank pulse is a square pulse.

(5) Radar Video

Radar video (V) is a continuous signal consisting of noise at radar repetition rate so a reflected radar signal occurs as a pulse delayed from the origin by a time period corresponding to the range.

(6) Template Video

Waveform (W) or template video is computer generated and is present in TF mode only.

(7) Radar Dunk Pulse

Waveform (N) is the radar dunk pulse. It occurs at 200 Hz and occurs during the time of each cycle when the display is not presented.

10. Miscellaneous Circuitry

In addition to the electronic circuitry modules described by paragraphs 6 through 8, there are additional circuits shown on the interconnection diagram 1889419.

The blower takes power from the 115V 400 Hz 3 phase power input. It takes cockpit ambient air from the rear of the SCD and moves it through the unit where it cools the surfaces of the electronics modules, and is expelled through strategically placed holes in the sides near the viewing screen end of the SCD.

The low voltage power supply, drawing 1885406, takes power from the 115V 400 Hz 3 phase power input. It provides line and load regulated dc outputs as follows:

+100V	100 mA
+ 20V	2 amp
- 6V	100 mA

The S/C write power supply, drawing 1885403, uses +40 Vdc for an input. It provides a negative 5000V at 200 microamps, and a floating 600V which is insulated for 10kV. Active regulation is used. Limitations of the scan converter require a high degree of filtering. Short circuit protection is included, as well as input polarity reversal protection.

The S/C read power supply, drawing 1885402, uses +40V for an input. Its output is -600V at 1 mA and floating 100V at 0.5 mA. The positive terminal of the 100V supply is connected internally to the negative 600V terminal. The 100V supply is programmable by means of external resistances. This provides a method of controlling the read grid-to-cathode bias voltage, or beam current. Both voltages are highly filtered and employ active regulation.

The monitor high voltage power supply, drawing 1885404, uses +40V for an input. It is a highly filtered, actively regulated supply, providing the following outputs:

+15000 VDC	500 μ A	
+ 3000 VDC	150 μ A	Adjustable by external resistor
+ 650 VDC	200 μ A	
- 120 VDC	5 mA	

The 6 volt dc regulator, drawing 1886411, is used to supply a highly filtered, regulated voltage to the read preamplifier. The preamplifier being a high gain amplifier, is sensitive to power supply ripple and voltage variations. Input to the regulator is the three phase rectified 6 Vdc from the radar sweep generator module. This input is filtered by a 2 mA choke L2 and a 250 μ F capacitor C2. The 6V regulator uses the +20 Vdc as a reference supply.

Other circuits using 6 Vdc, are not as sensitive to voltage changes, therefore 6 Vdc is supplied from the input 6V through the filter L2 and C2 and R9. CR2 is a 7 volt zener diode for transient protection.

The 40 Vdc input to the high voltage power supplies is controlled by relay K1. Relay K1 is actuated by the 115V, 400 Hz delayed input. The +40V input to the monitor high voltage power supply goes through safety relay K2. Should the low voltages fail or become short circuited, relay K2 is de-energized causing the high voltage power supply to be shut off to prevent phosphor burns and other damage.

SECTION 6

PHYSICAL DESIGN

11. General Description

To facilitate rapid field replacement, the SCD was configured for exact interchangeability with the AN/APQ-116 radar DVST indicator, per Revision L of TI drawing 525022 (Indicator, Multiple Displays, IP-799/APQ-116, Outline Dimensions). The control layout of the DVST indicator was essentially duplicated in configuration and front panel location. Pertinent physical data describing the SCD appears in Figure 4. SCD packaging design has employed individual electronic subassemblies housed within an EMI-tight, stressed-skin enclosure, construction of which was dip-brazed and heat-treated aluminum alloy for improved EMI integrity and structural capability. Interior access is by means of full-length top and bottom covers. This design was found to provide excellent utilization of internal volume as well as high strength and low weight. Circuit components and structures were designed to contribute strength and rigidity within the overall assembly context rather than on an individual basis. This technique, applied to inter-subassembly relationships as well, has provided a high degree of weight control in the SCD, allowing the design weight requirement to be met. A top view of the indicator with the top removed is shown in Figure 11. The power supplies and CRT deflection circuits are packaged in easily removed subassemblies; the bulk of the circuits are packaged on 6 printed circuit cards for ease of maintenance. A bottom view of the indicator is shown in Figure 12; the scan converter tube is shown removed to show the interwiring and the scan converter and its associated electronics.

a. Electronic Subassemblies

Electrical functional areas of the indicator have been organized and packaged within the following discrete subassemblies:

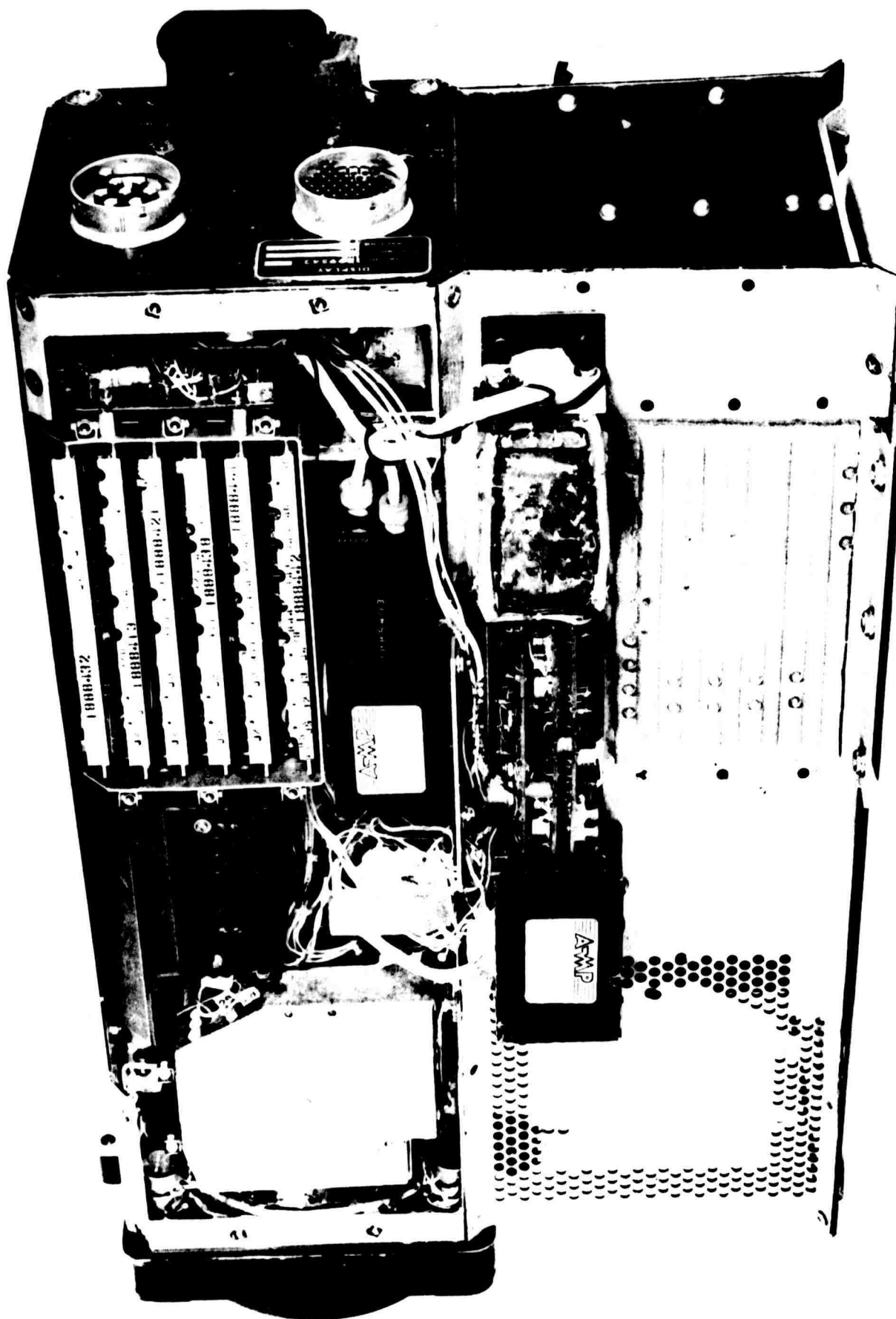


Figure 11. Scan Converter Display (Top View)

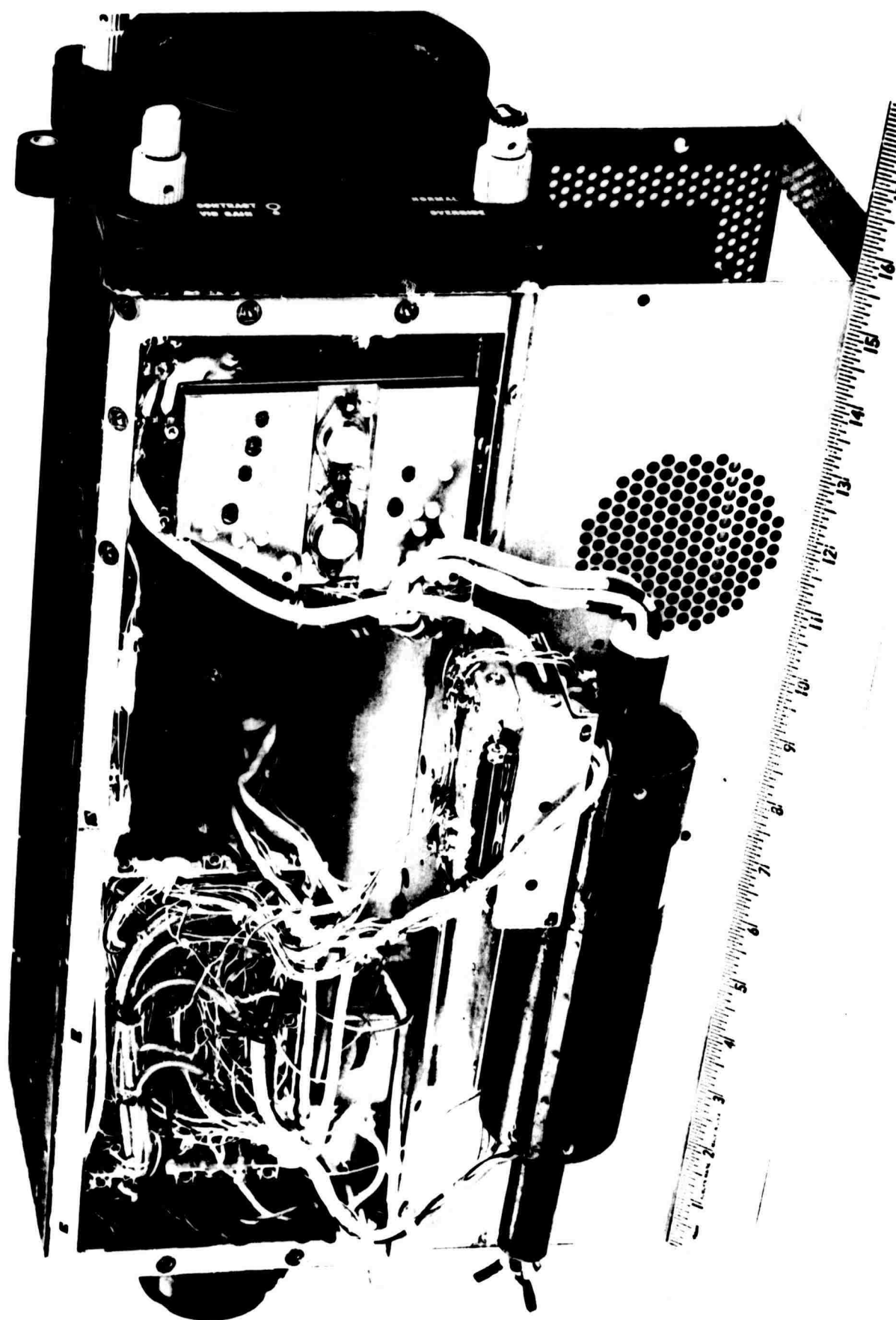


Figure 12. Scan Converter Display (Bottom View)

- CRT subassembly
- Horizontal deflection subassembly
- Vertical deflection subassembly
- Scan converter/video preamplifier subassembly
- Printed circuit enclosure, containing six printed circuit cards (scan converter read/write drive circuits, timing and protection circuits).
- Power supply assemblies
 - (a) Scan converter read
 - (b) Scan converter write
 - (c) Scan converter filament isolation transformer
 - (d) High voltage
 - (e) Low voltage
- Edge-lighted cursor/indicator panel

The above subassemblies have been configured to maximize ease of servicing and/or replacement. A combination of discrete components, integrated circuits, and hybrid circuits have been used to achieve minimum production cost consistent with the extreme packaging density required. Conventional double-sided printed circuit boards are employed for their inherently lower production cost, higher reliability and greater repairability.

b. Cooling

Indicator cooling is accomplished by a rear-mounted high-performance Rotron Aximax blower which induces movement of cockpit ambient air through the indicator from the front, discharging through the blower in the rear of the display. Entry holes are provided in the indicator skin to apportion and distribute cooling air; location of these entry holes is determined from a careful thermal analysis. Conservative design and proper derating of circuit components further assure that the required reliability and operating life goals are met or exceeded.

c. Environmental Considerations

Extensive pre-delivery environmental testing has established the SCD capability in meeting the requirements of Mil-E-5400F (Class I equipment), as well as the additional environmental

requirements imposed by the SCD design specification (see Appendix A, this report). Numerous techniques were employed to assure compliance with the above so as to provide immunity of the SCD to the effects of humidity condensation, shock, vibration and other pertinent environmental hazards.

d. Maintainability

Every effort has been made in the equipment design to provide a high degree of maintainability. Modular construction of major electrical subassemblies has reduced the repair time required to restore operation in the event of malfunction. Where feasible, plug-in printed circuit modules are provided with test points and test connectors in locations throughout the indicator to further improve maintainability.

e. Indicator Controls and Accessories

As previously stated, the SCD viewing area and controls have been placed at the front of the unit. This design precondition required also that the SCD indicator controls be identical to those of the DVST indicator in their effect upon the displayed image. An additional front panel control, to locally dim range light intensity during night flight, has been provided. Past performance of the DVST indicator has shown that pilots were sometimes annoyed by the intensity of the range indicator lights whose intensity has heretofore been non-adjustable.

Because of vast differences in ambient brightness found in the SCD operating environment, it was essential to provide optical filtering for image contrast enhancement. Filter combinations consisting of Polaroid circular polarizers in neutral density or variable red, and/or a proprietary filter of the limited acceptance angle type, mounted immediately to the front of the CRT faceplate, are provided. The specific combination required may be specified as a user option.

SECTION 7

PERFORMANCE

Detailed performance data is contained in the document "Final Acceptance Test Procedure for Scan Converter Display", dated 15 August 1968. Test results are summarized in Table 7-1 below.

Table 7-1. SCD Electrical Performance Results

Test	Requirements	Results
Brightness	Minimum 800 Ft-Lamberts	>800 Ft-Lambert
Limiting Resolution		
TV Horiz	600 TV Lines	623 TV Lines
Vert	350 TV Lines	350 TV Lines
Radar Horiz	550 TV Lines	570 TV Lines
Vert	580 TV Lines	580 TV Lines
Grey Shades of Contrast		
TV	Min 8	> 8
Radar	Min 6	6
Display Linearity		
TV Horiz	±2% Max	0.87% Max
Vert	±2% Max	1.7% Max
Radar Horiz	±2% Max	1.13% Max
Vert	±2% Max	1.87% Max

SECTION 8

CONCLUSION

As Table 7-1 indicates, all design requirements of this development effort have been met or exceeded.

Visual comparison of the scan converter display unit with the DVST indicator has led to the following RCA observations:

- (1) The SCD display image appears more uniform than the DVST image. That is, no evidence of portholing or background mottling appeared on either the radar or the TV images of the SCD.**
- (2) Television images are indeed better with the SCD than with the DVST with regards to both smearing and grey scale content .**
- (3) TV images displayed on the DVST are not completely erased, resulting in a TV image being visible when radar information is displayed. This sticking is absent with the SCD indicator.**
- (4) Radar images on the SCD equal or exceed the best images on the DVST indicator.**

In general, this development effort has demonstrated the following:

- The scan converter/CRT technique is feasible for fighter aircraft application, especially if the sub-miniature tube is used for low-volume requirements.**
- The SC/CRT can provide high brightness, high contrast, and high resolution, all simultaneously.**
- The SC/CRT principle offers a potential solution to many problems in the use of multiple sensors. The techniques can be extended to the multiple use of such sensors as radar, television, low light level television, forward-looking IR, line-scanning IR, side-looking radar, laser target designators, and laser illuminators.**

SECTION 9

RECOMMENDATIONS

As a result of the Conclusions described in Section 8 above, RCA offers the following recommendations for future activities.

- (1) Begin action to provide scan converter displays for all tactical aircraft which employ the Walleye or other TV-guided weapons. The cost would appear to be justified by the substantially improved combat effectiveness of the Walleye. Cost effectiveness appears to be excellent because in quantity production, the cost of a scan converter display for a single aircraft is roughly the same as the cost of the Walleye weapons carried on a single mission.
- (2) Continue research and development efforts in the area of scan converter displays. Attention should be given to such features as the following:
 - (a) Moving window techniques for use with line scanning radar or IR sensors.
 - (b) The capability of picture freeze for time periods on the order of minutes.
 - (c) Superposition of data from multiple sensors.
 - (d) Scale expansion.
 - (e) Format conversion for sensors which operate at TV frame rates but in a format different from the TV raster.
 - (f) Digital techniques.

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13. ABSTRACT This report describes a scan converter CRT cockpit indicator unit (IPX/-APQ-116) for the A7 A/B aircraft for display of radar information from the present AN/APQ-116 Radar and TV information from the Walleye missile. The indicator is a direct replacement both mechanically and electrically for the present A7 direct view storage tube indicator (IP799/APQ-116).		

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
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