

## CHAPTER 5

# INDICATORS

In this chapter, we will discuss the various types of indicators in use today. These indicators range from the heading indicators to the newest heads-up display (HUD) tactical displays. Every effort was made to include as many different platforms as possible.

### HEADING INDICATORS

**Learning Objective:** *Identify the types of heading indicators and their primary functions.*

The two heading indicators that we will be discussing are the horizontal situation indicator (HSI) and the bearing-distance-heading indicator (BDHI). Both of these indicators are used on many different types of aircraft. The information displayed by these indicators comes from the various navigational systems on the aircraft. The HSI displays more information than the BDHI.

### HORIZONTAL SITUATION INDICATOR

The HSI system we will discuss is the system in use on the P3-C aircraft. The HSI group provides the pilot, copilot, and NAV/COMM operator with a visual display of aircraft course, bearing, heading, and distance to a selected point.

#### System Components

The HSI group consists of three ID-1540/A indicators and three control boxes. The three control boxes are the pilot's control, copilot's control, and the NAV/COMMs control. The three ID-1540/As are interchangeable between the three stations, but the control boxes are not.

**ID-1540/A HORIZONTAL SITUATION INDICATOR.**— The ID-1540/A indicator (fig. 5-1) is a multipurpose aircraft situation indicator. It keeps the pilot, copilot, and the NAV/COMM operator informed of the aircraft's situation at any given moment. Refer to figure 5-1 while reading the following text.

1. The lubber line is the reference line for reading the aircraft's heading on the compass card.

2. Bearing pointer 1 points to the bearing of the selected navigational point.

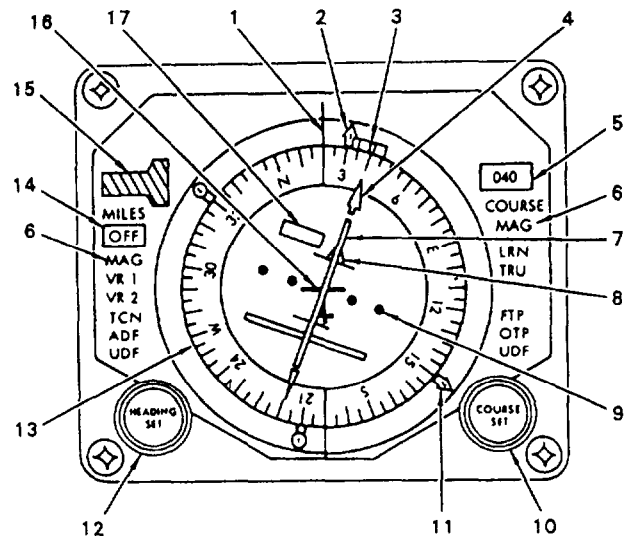
3. The heading marker indicates the desired heading as set by the HEADING SET knob.

4. The course arrow indicates the course set by the COURSE SET knob in the radio navigation mode. This arrow indicates the course set by the computer in the tactical navigational mode.

5. The COURSE indicator displays, in degrees, a digital readout of the course arrow setting.

6. The mode lights indicate the operating mode selected on the HSI control box for that station.

7. The course deviation bar indicates deviation relative to the course arrow position for VOR or



- |                          |                       |
|--------------------------|-----------------------|
| 1. Lubber line           | 10. COURSE SET knob   |
| 2. Bearing pointer 1     | 11. Bearing pointer 2 |
| 3. Heading marker        | 12. HEADING SET knob  |
| 4. Course arrow          | 13. Compass card      |
| 5. COURSE indicator      | 14. OFF flag          |
| 6. Mode lights           | 15. MILES counter     |
| 7. Course deviation bar  | 16. Aircraft symbol   |
| 8. To-From arrows        | 17. NAV flag          |
| 9. Course deviation dots |                       |

Figure 5-1.-ID-1540/A horizontal situation indicator.

TACAN signals. When localizer signals are being used, the deviation is relative to the localizer.

8. The To-From arrows indicate whether the selected course is going toward or away from the selected beacon station.

9. The course deviation dots indicate course deviation in degrees relative to the course deviation bar position.

10. The COURSE SET knob allows the operator to set both the course arrow to a desired course and the COURSE indicator to the desired course readout when in any mode other than TAC NAV.

11. The bearing pointer 2 indicates the bearing to a selected navigational point.

12. The HEADING SET knob allows the operator to set the heading mark to any desired heading.

13. The compass card indicates the aircraft compass heading when read against the lubber line.

14. The OFF flag will appear whenever there is a power failure.

15. The MILES counter displays a digital readout of distance, in nautical miles, to a selected TACAN station.

16. The aircraft symbol indicates the lubber line, which, in turn, indicates aircraft heading.

17. The NAV flag will appear if the signal input from the selected TACAN or VOR becomes unreliable.

**A280 PILOT HSI CONTROL.**— The A280 (fig. 5-2) controls the inputs to the pilot's HSI. This unit allows the pilot to select inputs from the different navigational aids. Refer to figure 5-2 when reading the following text.

1. The HDG selector switch selects the heading signal source for display on the HSI compass card. The pilot can select either inertial navigation system 1 (INS-1) or inertial navigation system 2 (INS-2).

2. The ATTD selector switch selects the source of pitch and roll signals for the flight directory indicator (FDI) sphere. The signals will either come from the INS-1 or from the vertical gyro (STBY GYRO).

3. The COURSE HSI-FDS selector switch selects the source of course signals for display on the HSI. The signals include the course deviation and

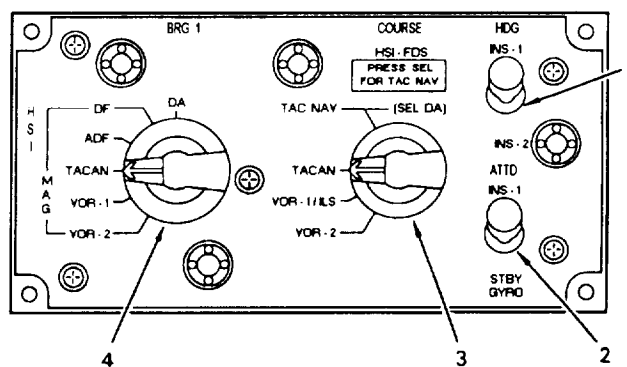
To-From signals to position the course deviation bar and the To-From arrows. They will come from the VOR-2 NAV converter (VOR-2), the VOR-1 NAV converter (VOR-1/ILS), the TACAN R/T (TACAN), and the central computer TAC NAV) when the BRG 1 switch is in the DA position.

4. The BRG 1 switch selects the source of the bearing signal to be displayed on the pilot's, copilot's, and NAV/COMM's HSIs bearing pointer 1. This switch controls all three HSIs. The bearing sources available are the VOR-2 NAV converter (VOR 2), VOR-1 NAV converter (VOR 1), TACAN R/T (TACAN), ADF receiver (ADF), or UHF direction finder group (DF). In the DA position, the drift angle supplied by the Doppler radar or the central computer is sent to the bearing pointer 1.

**A279 COPILOT HSI CONTROL.**— The A279 control box (fig. 5-3) controls the inputs to the copilot's HSI. It allows the copilot to select the navigational aid. Refer to figure 5-3 when reading the following text.

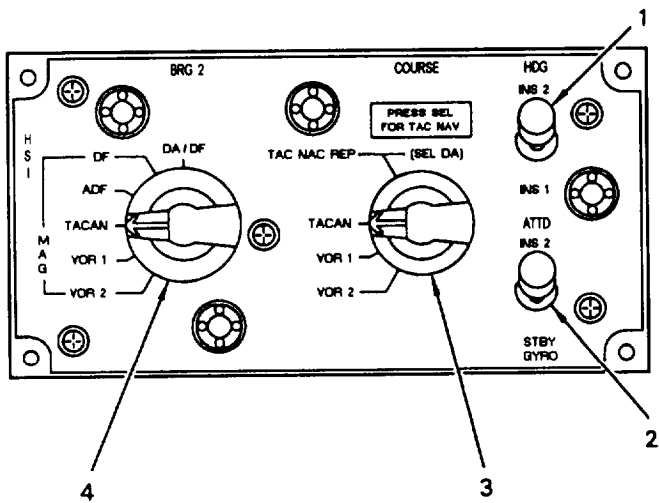
1. The HDG selector switch selects the source of heading information supplied to the HSI compass card. Either INS-2 or INS-1 is available.

2. The ATTD selector switch selects the source of pitch and roll signals for display on the FDI sphere. The source can be either the INS-2 or the vertical gyro (STBY GYRO).



1. HDG selector switch
2. ATTD selector switch
3. COURSE HSI-FDS selector switch
4. BRG 1 switch

Figure 5-2.-A280 pilot HSI control.



1. HDG selector switch
2. ATTD selector switch
3. COURSE selector switch
4. BRG 2 selector switch

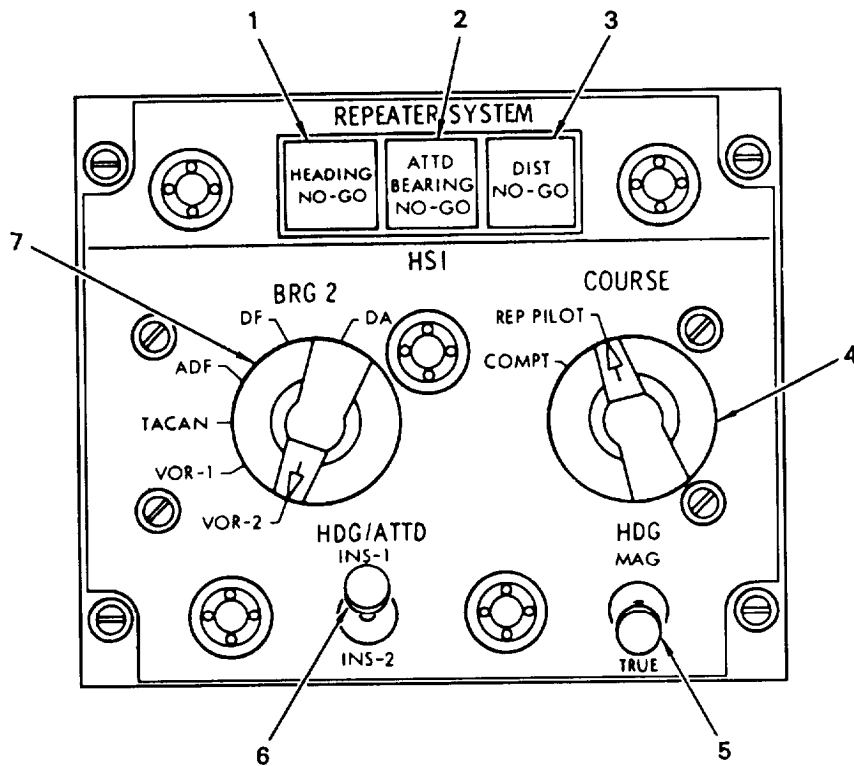
Figure 5-3.-A279 copilot HSI control.

3. The COURSE selector switch selects the source of course signals for display on the HSI. The sources available for selection are VOR-2, VOR-1, or TACAN. Selecting the TAC NAV REP position will slave the copilot's HSI to the pilot's, provided the BRG 2 switch is in the DA/DF position.

4. The BRG 2 selector switch selects the source of the bearing signal for display on both the pilot's and copilot's bearing pointer 2. The sources available for selection are VOR-2, VOR-1, TACAN, ADF, or DF. The DA/DF position will provide drift angle information, if in radio navigation mode, or DF signals, if in the tactical navigational mode.

**A309 NAV/COMM HSI CONTROL BOX.—**

The A309 control box (fig. 5-4) allows the NAV/COMM operator to select the inputs to the HSI at the NAV/COMM station. It also indicates certain system malfunctions. Refer to figure 5-4 when reading the following text.



- |                                 |                          |
|---------------------------------|--------------------------|
| 1. HEADING NO-GO indicator      | 5. HDG switch            |
| 2. ATTD BEARING NO-GO indicator | 6. HDG/ATTD switch       |
| 3. DIST NO-GO indicator         | 7. BRG 2 selector switch |
| 4. COURSE selector switch       |                          |

Figure 5-4.-A309 NAV/COMM HSI control box.

1. The HEADING NO-GO indicator illuminates when there is a failure with the heading function in the central repeater system (CRS).
2. The ATTD BEARING NO-GO indicator illuminates when there is a failure with the attitude bearing function in the central repeater system.
3. The DIST NO-GO indicator is not used in the P3-C.
4. The COURSE selector switch selects the course data for display on the HSI. The course data is either set by the computer (COMP) or by the pilot's control box (REP PILOT).
5. The HDG switch selects either magnetic (MAG) or true (TRUE) heading signal inputs to be displayed on the NAV/COMM HSI.
6. The HDG/ATTD switch selects either INS-1 or INS-2 to be the source for the heading data signal to be displayed.
7. The BRG 2 selector switch selects the source for the information to be displayed on the NAV/COMM HSI bearing pointer 2. The sources available for selection are VOR-2, VOR-1, TACAN, ADF, DF, or DA. In the DA position, drift angle supplied by the Doppler radar or the central computer is displayed.

### System Description

The HSI system functions as a selectable display for the navigational systems on the aircraft.

When the TACAN, VOR-1, or VOR-2 system is selected, the corresponding system will provide radial bearing and bearing information, NAV flag, course deviation, and To-From signals to the HSI. The bearing signal will position the bearing pointer 1 or bearing pointer 2, as selected. The radial bearing information is resolved with the course set by the COURSE SET knob. The resultant signal is returned to the TACAN, VOR-1, or VOR-2 to be used to develop the course deviation and To-From signals. These signals are returned to the HSI, where the course deviation signal displaces the course deviation bar. The To-From signal will drive the To-From arrow in the proper direction. If the flag input signal becomes unreliable during a radio navigation mode, the NAV flag appears on the HSI. When TACAN is selected, the distance signal from the TACAN will position the dials of the distance counters to reflect the distance to or from the TACAN station.

The UHF-DF/OTPI and the ADF systems will supply bearing information when selected. This information is routed to either the bearing pointer 1 or bearing pointer 2, as selected.

Magnetic and true heading information is supplied to the HSI compass card by the INS-1 and INS-2, as selected. Magnetic heading is normally used to position the compass card. When a tactical mode is selected, magnetic heading information is switched out of the circuit, and the compass card will be driven by the true heading information.

### BEARING-DISTANCE-HEADING INDICATOR

The bearing-distance-heading indicator (BDHI) (fig. 5-5) may be used with the various navigational systems, and it provides information according to the mode selected. Some aircraft may have more than one BDHI, with separate select switches for each instrument. The distance counter numerals may be in a vertical row or horizontal, as shown in figure 5-5.

#### Indicator Parts

This section will explain the various parts of the BDHI. Refer to figure 5-5 while reading the following text.

The lubber index is a fixed reference mark that allows the operator to read the heading from the

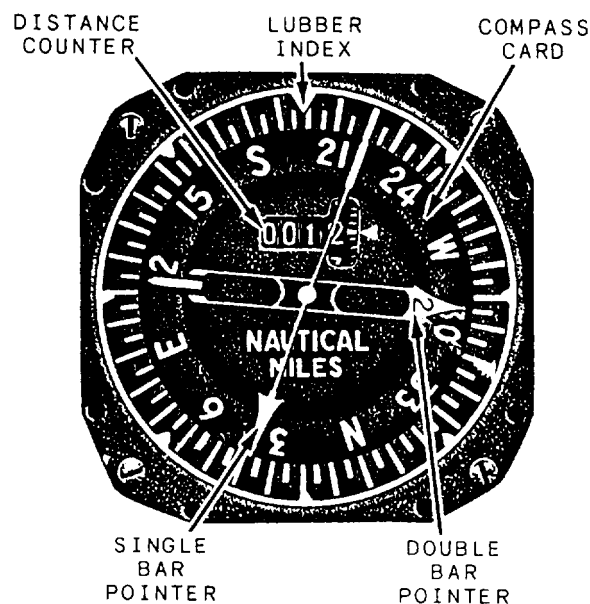


Figure 5-5. Bearing-distance-heading indicator.

compass card. The compass card moves with the heading of the aircraft. The distance counter indicates the distance to the selected station. There are two pointers—a single bar and a double bar. These pointers or bars can indicate (1) bearing to a ground electronic station, (2) bearing to destination, (3) aircraft ground track, (4) aircraft drift angle, or (5) heading error. The available combinations of these indications are limited by the BDHI select switches used in the given aircraft configuration.

### Primary Functions

Electrical signal inputs for the compass card and the pointers come from the synchro transmitters located in the various navigational systems. The compass card will follow the heading of the aircraft and is read at the lubber index. The distance counter may display distance to base, target, or ground station, depending upon the mode selected. It consists of three synchro torque receivers to position the units, tens, and hundred numerals. There is also a 1,000 flag to place the numeral 1 preceding the hundreds numeral, which enables the counter to display distance up to 1,999 nautical miles. The OFF flag covers the distance counter when distance information is not provided or is unreliable.

### HEADS-UP DISPLAY (HUD)

*Learning Objective: Recognize components and functions of a typical Heads-Up Display (HUD) tactical display system.*

Modern aircraft are equipped with instruments and displays to provide the aircrew with up-to-date visual information about the performance of the aircraft. Since the advent of airborne computers, radar, and other state-of-the-art avionics equipment, the concept of visual information has taken on a new meaning. In this age of lasers, high-speed missiles, nuclear submarines, and stealth aircraft, the Navy has had to incorporate new visual display systems, and constantly improve these systems as technology advances. The visual display system, commonly called the “tactical display system” (TDS), is used by the aircrew to search for, attack, and destroy the enemy. The TDS is also used to gather information about the enemy and to allow the aircrew to defend the aircraft when attacked.

The airborne computers are used to gather information from all aircraft sensors and systems. They then perform high-speed solutions and send out continuously updated information to the various tactical display systems on the aircraft. These display systems vary from aircraft to aircraft, and the information displayed depends on the type of mission the aircraft was designed to perform.

The typical HUD TDS is an electro-optical sight system for use only by the pilot. The purpose of the electro-optical display unit is to display attack and flight information directly to the pilot’s field of view. The electro-optical display uses a light source (fig. 5-6) to display

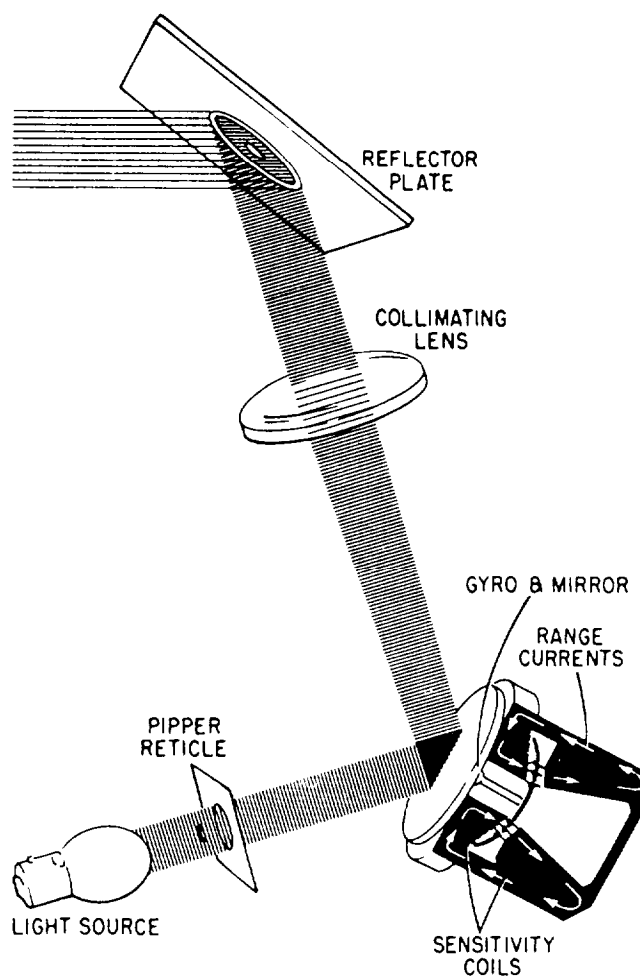


Figure 5-6. Basic principle of a sight unit.

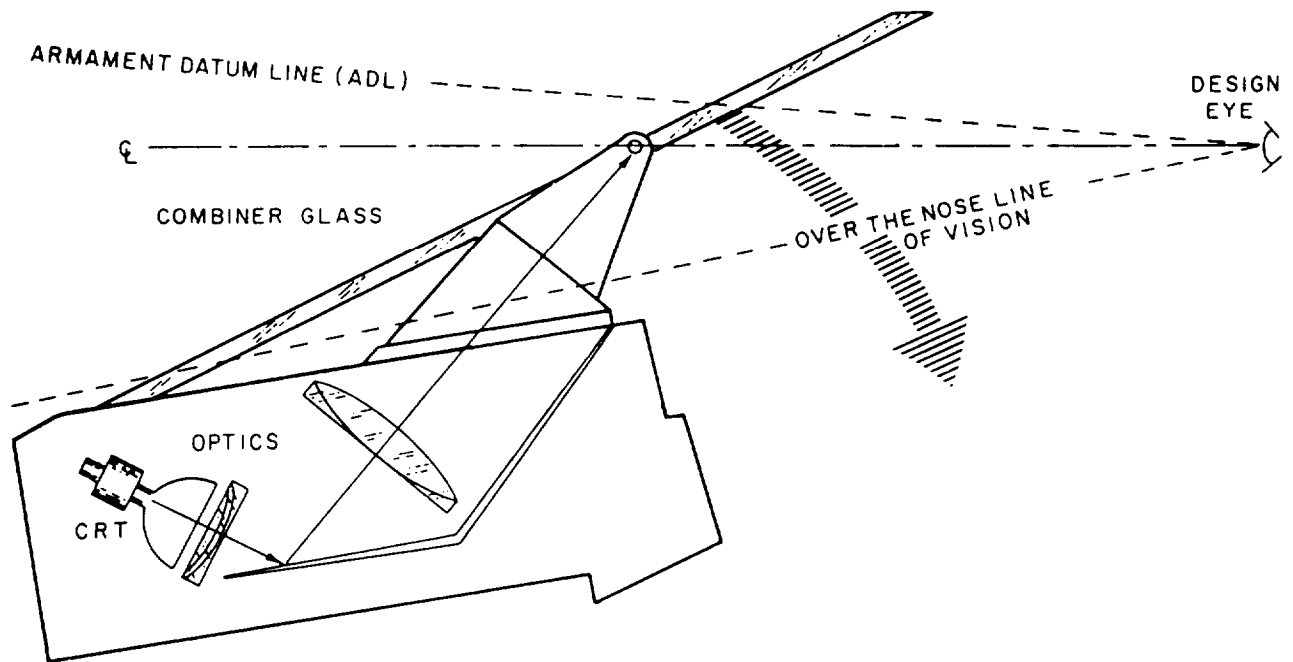


Figure 5-7.-New optical sight with CRT.

the information. Figure 5-7 shows an example of a modern electro-optical sight. This unit or system is known as a heads-up display (HUD).

The HUD receives computed attack and navigational input signals from a tactical computer, aircraft performance data from aircraft flight sensors, and discrete signals from various aircraft systems (fig. 5-8). Information received from these sources is displayed on a transparent mirror (combiner) located directly in front of the pilot at eye level. The HUD processes these signals in the signal data processor. These signals are then applied to the display unit as X (horizontal), Y (vertical), and Z (bright-up) signals that provide the symbols that appear on the combiner. The symbols are focused to infinity and are superimposed over real world objects in line with the aircraft flight path. Certain symbols are positioned on the combiner to correspond with real world object positions relative to the aircraft, even though the real world object may not be visible.

## COMPONENTS

This section will discuss the two major components of a HUD set—the signal data processor and the heads-up display unit.

### Signal Data Processor

Three-phase ac power is applied to six different rectifiers contained in the low-voltage power supply. The ac voltage is rectified by each rectifier, and then regulated to a precise value. Each value of dc supply voltage is distributed for circuit operation through the signal data processor.

**INPUT RECEIVERS.**— Digital data signals are applied to the input receivers on four channels. Data transfer is in serial form, and all four channels are in operation at the same time. Each channel consists of a signal and a signal-return line. Specific input data is applied to each channel as follows:

1. Channel one receives a data word signal and a data word signal return.
2. Channel two receives the data identity signal and a data identity signal return.
3. Channel three receives a data ready signal and a data ready return signal.
4. Channel four receives a data clock signal and a data clock return signal.

Data identity signals are transmitted simultaneously with each data word signal. They identify the data word. The identity signal consists of 20 bits of data, which include the control bit, data identity, and parity bit.

**DIGITAL COMPUTER.**— The digital computer processes the applied digital data in three phases. After the three phases are completed, the entire cycle is repeated. All steps of each phase are performed sequentially according to a prewired program of instruction contained in the program. When electrical power is applied to the digital computer, clock pulses are generated within the clock generator of the program. The clock pulses are distributed by the control logic to the sequence control, input receivers, symbol generator, and processor counter. The processor counter is used to record a specific number of clock pulses so that the demand-next instruction (DNI) pulse is not arbitrarily initiated. However, if a jump signal is received by the function decode, a DNI pulse is initiated. The jump signal may be repeated

until the correct instruction is selected. When the DNI pulse is initiated and is in coincidence with a specific clock pulse in the sequence control, a data request signal is applied to the program of instructions.

**SYMBOL GENERATOR.**— The symbol generator operates in three major modes. The three modes of operation are the line, circle, and analog-to-digital conversion (ADC). Each mode is independently and completely performed before repeating or starting a different mode. The mode to be performed is initiated by the function decode in the digital computer. Correct sequencing of each mode of operation is provided by the timing pulses from the control logic section of the digital computer. The

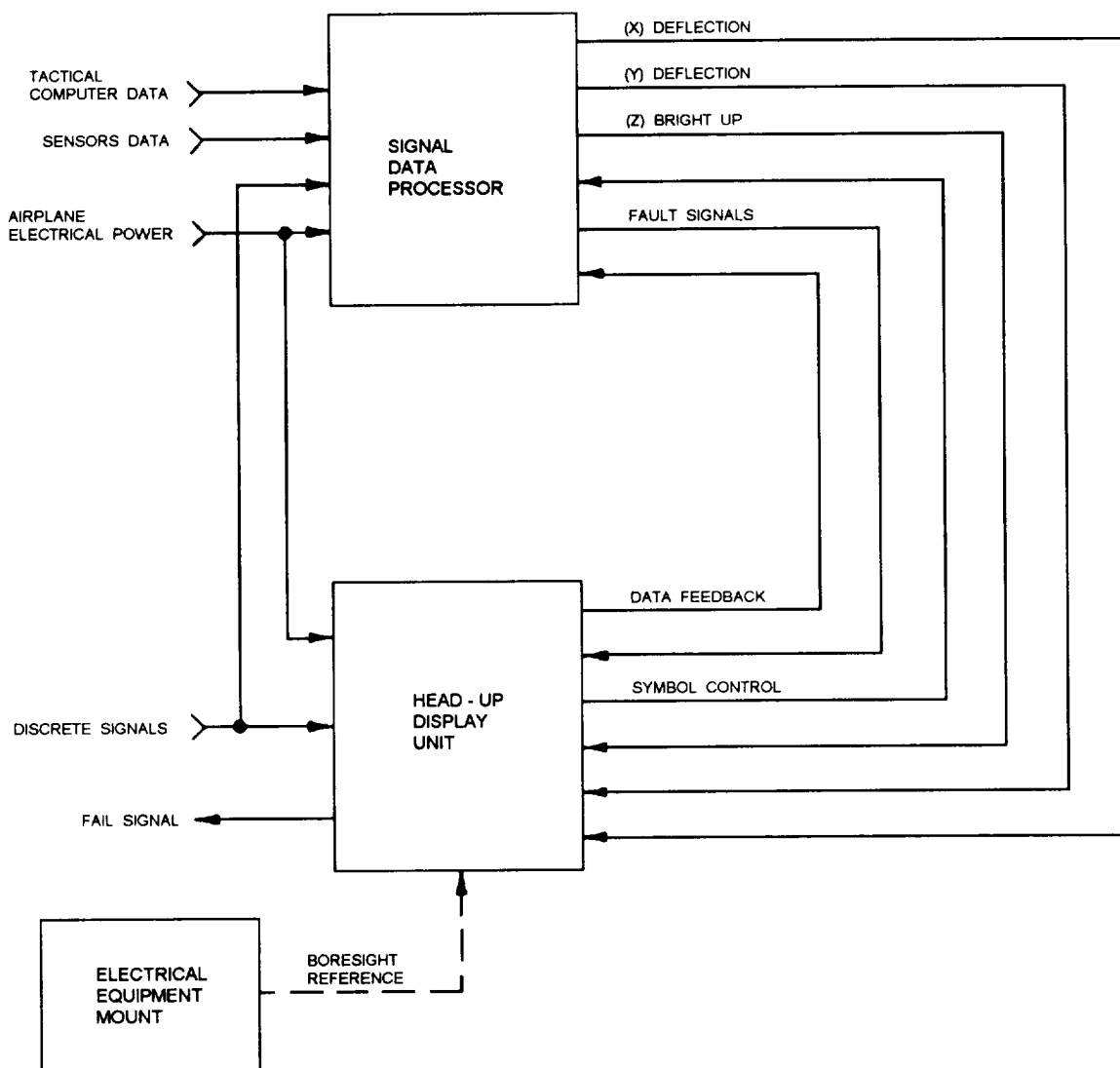


Figure 5-8. Heads-up display set block diagram.

computer's program determines which mode is initiated in the symbol generator.

**Line Mode.**— When a line is to be drawn on the CRT, the line mode signal goes to the input/output buffer of the symbol generator. This signal starts a counter that controls all operations of the generator.

The first operation is to transfer the X 1 data from memory to the X channel deflection register. It is transported through the adder and input/output buffer and control. The X 1 data is the digital equivalent of the analog voltage that drives the beam to the start point (in the horizontal axis) of the line draw.

The second operation is to transfer the Y1 data from memory to the Y channel deflection register. The Y1 data is the digital equivalent of the analog voltage that drives the beam to the start point (in the vertical axis) of the line draw. The digital data in each of the deflection registers immediately converts to an equivalent analog voltage. This conversion takes place in the X and Y channel digital-to-analog converters (DACs). Each DAC holds the X and Y deflection voltage until the input/output buffer and control gates them to the HUD.

The third operation transfers the X2 data from memory to the parameter register. The X2 data is a digital quantity representing the line slope angle cosine.

In the first half of the fourth operation, the X2 data shifts from the parameter register to the X channel rate register. In the second half of this operation, the Y2 data transfers to the parameter register from memory. The Y2 data is the digital quantity representing the line slope angle sine.

In the first half to the fifth operation, the Y2 data shifts from the parameter register to the Y channel rate register. In the second half of this operation, the T data transfers from memory to the parameter register. The T data is a digital quantity representing the length of the line draw (bright-up pulsewidth).

During the sixth and seventh operations, the BITE circuits check all data in the X and Y channel rate registers for correctness. All the data required to draw a specific line is now within the symbol generator. The specific line to be drawn could be a symbol in itself or just part of a symbol.

When all the data to draw a specific line is in the symbol generator (after the seventh operation), the busy signal from the HUD is sampled. If the busy signal is high, the operations stop until the busy signal

is low. The low signal signifies that the HUD is ready to accept the data. At this time, the input/output buffer and control sends a start pulse to the parameter register. This causes it to start down counting. The down counting controls the length of time the bright-up pulse is applied to the HUD. At the same instant, a gating pulse goes to each DAC. This allows an analog voltage to go to the deflection circuits of the HUD. At the same time, the contents of the rate registers either add to or subtract from the respective residue register. This causes generation of either a positive or negative overflow. The overflow drives the deflection register up or down. This causes the start point of the line to move in the direction of the line slope angle. After a preset time delay, a bright-up pulse goes to the HUD. The time delay compensates for the slower response time of the deflection circuits in the HUD. The bright-up pulse continues until the parameter register has down counted to zero. When the parameter register stops counting, the bright-up pulse turns off. At this time the end of the line mode is indicated to the digital computer. The line mode may be repeated as many times as necessary to complete the required symbol.

**Circle Mode.**— When drawing a circle on the CRT, a circle mode signal goes to the input/output buffer and control. The signal starts the operation counter as in the line mode. The data required to draw a circle in a specific location transfers to the symbol generator in the same manner as in the line mode. However, the X2 data is equal to negative one, and the Y2 data is all zeros. The T data set into the parameter register is the digital equivalent of one over the circle radius. Circles are drawn in a counterclockwise direction, starting from the top. The overflow from the residue registers controls the direction and amount of change in each deflection register. However, in the circle mode, the overflow also controls the circle logic to the opposite channel. The circle logic is such that a positive X channel overflow causes the contents of the parameter register to add to the contents of the Y channel rate register. If the X channel overflow is negative, then the contents of the parameter register subtract from the Y channel rate register. The opposite occurs if the overflow from the Y channel residue register is positive. This will cause the contents of the parameter register to subtract from the X channel rate register. If the Y channel overflow is negative, the contents of the parameter register add to the X channel rate register.

This cross-coupling causes the two channels to be interdependent on each other. As the rate of change in



one channel increases, the rate of change in the other decreases. If the circle is large, the rate of change in the analog deflection voltage output is large. If the circle is small, the analog voltage will be small. The rate of change is inversely proportional to the contents of the parameter register, which contains the inverse of the circle radius. This causes the generator to produce a circle with the desired radius.

The bright-up pulse control is from a quadrant counter in the input/output buffer and control. This turns on the bright-up pulse after the electron beam travels halfway around the circle. This delay compensates for the slow response time of the deflection circuits in the HUD. The bright-up pulse stays on until the quadrant counter counts four times. A short time after the fourth count, the bright-up pulse turns off, and the symbol generator busy signal terminates. This completes the circle mode.

**Analog-to-Digital Conversion (ADC) Mode.—** The third mode of symbol generator operation is the analog-to-digital conversion mode. In this mode, the operation of both the X and the Y channels are the same. Therefore, only the X channel operation is described. At the start of the ADC mode, the most significant bit in the parameter register becomes preset to the one level.

The rate and deflection registers are preset to zero and coupled directly to each other. The direct coupling of the two registers provides for duplication of the contents of either register.

The third step gates a specific analog voltage from the X channel input selector to one side of the X channel comparator.

The fourth step gates the digital-to-analog converter (DAC) voltage from the X channel DAC to the other side of the X channel comparator. The DAC voltage represents the contents of the X channel deflection register. If a difference in voltage level exists between the two applied voltages, the comparator has an output applied to the deflection register. The output of the comparator represents the sign of the difference. This output causes the contents of the parameter register to add to or subtract from the contents of the rate register.

On the next operation, the one in the parameter register shifts to the next lower bit location, and the voltage comparison phase repeats. This process continues until the parameter register reaches zero. When at zero, the contents of the rate register (in digital form) are equal to the input selector analog

voltage at the comparator. The next operation transfers the contents of the rate register to memory by way of the data feedback (DFB) lines. In later operations, the remaining analog voltages go to the comparator, and the entire process repeats. The ADC mode continues until all analog voltages are converted to digital data and stored in memory.

### **Heads-Up Display Unit**

Aircraft ac power applied to the low-voltage power supply is rectified, and then divided into seven different dc levels for distribution throughout the display. A transistorized oscillator in the high-voltage power supply receives 24 volts of dc excitation from the low-voltage power supply. The oscillator output is applied to a voltage multiplier and rectifier circuit, which increases the input voltage to 15,000 volts. The 15,000 volts are applied to the CRT anode and a voltage divider within the high-voltage power supply. Outputs from the voltage divider are used to control the oscillator frequency and a comparator output. The comparator senses any differences that may exist between the voltage divider output and a fixed reference voltage. If the high voltage drops below a prescribed level, a fail signal is generated by the comparator and applied to the BITE circuit.

**OPTICAL MODULE.—** The optical module contains the standby reticle, in-range indicator, control panel, autobrilliance sensor, and lens unit. The standby reticle is used only when the HUD is inoperative, and is controlled electrically and mechanically from the control panel. Electrical power used for the operation of the standby reticle is obtained from outside the HUD.

Light emitted from the standby reticle is transmitted through the lens unit to the combiner. The in-range indicator indicates when a range discrete signal is received from the forward-looking radar set. Symbols are represented by light emitted from a CRT located in the video module. As symbols are drawn on the CRT face, the emitted light is received by the lens unit and applied to the combiner. The desired level of brightness is selected from the control panel by adjustment of the voltage level applied to the cathode bias circuit. The autobrilliance sensor is used to detect ambient light changes. Any change in ambient light proportionally changes the output voltage level of the autobrilliance sensor.

**VIDEO MODULE.—** The video module contains the bright-up and autobrilliance amplifiers, cathode

bias circuit, horizontal and vertical deflection coils, and CRT. Symbols are drawn at the rate of 50 times a second on the CRT. The rapidly moving electron beam is generated by the bright-up pulse from the signal data processor. The bright-up pulse is amplified by the bright-up amplifier, and then applied to the CRT grid. The CRT, which is normally biased into cutoff, is turned on, and an electron beam is emitted. The electron beam strikes the CRT face at a position determined by the amount of current flowing in the horizontal and vertical deflection coils. The amount of light (symbol brightness) emitted from the CRT is controlled by the cathode bias circuit. A control voltage from the control panel is applied to the cathode bias circuit, which serves as a reference voltage for the autobrilliance sensor and the CRT cathode. The voltage output from the autobrilliance sensor is amplified by the autobrilliance amplifier. The output is applied to the cathode bias circuit, which changes the amount of bias (brightness) on the CRT. Thus, an optimum CRT contrast is constantly maintained under varying ambient light.

**DEFLECTION MODULE.**— The deflection module contains the X and Y deflection amplifiers, X and Y low amplifiers, X and Y comparators, and one OR gate. The type and location of each symbol on the combiner is determined by X and Y analog voltages applied to the deflection circuits. As the need for a symbol arises, the busy signal from the HUD is sampled by the symbol generator. The busy signal is generated any time current is flowing in either deflection coil. Comparators, connected across each coil, are used to detect when the deflection coil current is equal to zero. As the current in either deflection coil reaches zero, the output from the comparator, connected across the coil, goes low. When both comparator outputs are low, the OR gate output goes low, and the busy signal is removed from the symbol generator input. At the same instant, the symbol generator applies a precise analog voltage to the X and Y deflection amplifiers. The output from the deflection amplifiers causes current to flow in the deflection coils. The current amplitude is precalculated to drive the CRT electron beam to the start point of the symbol to be drawn. A bright-up pulse is then applied to the bright-up amplifier in the video module. At the same instant, the deflection voltage is modulated at a predetermined rate and amplitude by the symbol generator. The modulation is detected by the deflection amplifiers and applied to each deflection coil. A specific part (or all) of a symbol is then drawn on the CRT face in a precise

location. The bright-up pulse continues long enough to draw the prescribed line or circle that makes up the symbol. When the bright-up pulse is removed, the CRT is driven into cutoff until the next bright-up pulse is applied. This process is repeated until all symbols have been displayed on the CRT.

## **BITE Functions**

Both the signal data processor and the heads-up display unit contain built-in test equipment (BITE).

**SIGNAL DATA PROCESSOR.**— The built-in test equipment contained in the signal data processor consists of a clock pulse monitor, data test equipment, raw data test equipment, six low-voltage comparators, a signal data processor fail indicator, and a thermal overload sensor.

**HEADS-UP DISPLAY UNIT.**— The built-in test equipment contained in the HUD unit consists of a high-voltage comparator, seven low-voltage comparators, a bright-up parity circuit, a HUD fail indicator, and a thermal overload sensor.

## **SYMBOLOLOGY**

The symbols that are used with the various modes of operation in the F-14 are listed and described in figure 5-9. These symbols give the pilot important information, such as aircraft attitude, heading, altitude, angle-of-attack, and ground track during flight. Attack information, such as closure rate, range to target, maximum range for weapon launch, minimum range for weapon launch, and boresight reference, is available during air-to-air and air-to-ground operations. Ordnance information, such as number of rounds remaining, the type of weapon selected, and the number of weapons ready for launch, is also available.

## **DECLUTTER**

The system used in the F-14 (AVA-12) has a feature known as declutter. It is used to remove preselected, unwanted symbols from the display during certain modes of operation. This feature is especially important during an air-to-air situation. When the pilot is trying to locate and engage an enemy target, the declutter feature will clear the unnecessary symbols from his/her view.

# SYMBOLGY


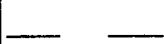
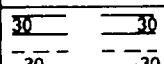
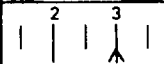
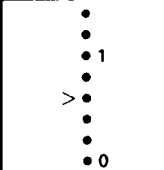
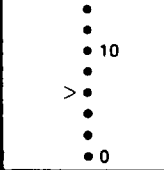
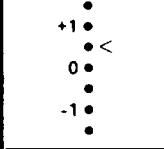
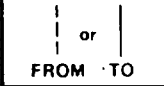

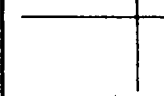
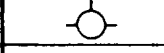
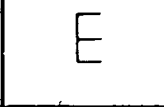
HUD SYMBOL	NAME	FUNCTION
	Aircraft reticle	Depicts own aircraft wings and when lined up with the horizon, the aircraft is in straight and level flight.
	Horizon	This is a demarcation point between ground and sky textures on the VDI. It represents the horizon with respect to the aircraft, and changes orientation with any change in aircraft pitch or roll.
	Pitch lines	Indicates with respect to aircraft reticle pitch attitude. In cruise and A/A mode, HUD pitch lines have a 4:1 compression ratio. Dotted lines indicate a negative pitch. Solid lines indicate positive pitch. Pitch lines above the magnetic heading scale are blanked.
	Magnetic heading (AHRS or WCS via CSDC)	Indicates magnetic heading with respect to index mark.
	Radar Altimeter Scale	Indicates altitude derived from radar altimeter. Scale is from 0 to 1400 feet in 200-foot increments and has a movable pointer. This symbol is only available in the takeoff and landing modes.
	Barometric Altimeter Scale	Indicates altitude derived from the pressure altitude via the CADC. Scale is from 0 to 14,000 feet in 2000-foot increments. This scale is available in A/G and TARPS modes. The altitude is referenced to 29.92 inches Hg.
	Vertical Speed Indicator	Indicates rate of altitude change. Scale is from -1500 to +1500 ft/min in 500-foot increments. This scale appears on the left side of the HUD in takeoff and landing modes.
	TACAN Deviation Bar (TACAN via CSDC)	Indicates difference between bearing to TACAN and selected TACAN radial. Deviation is limited to $\pm 5.625^\circ$ TACAN deviation on the VDI, and $\pm 3^\circ$ TACAN deviation on the HUD. The symbol never leaves field of view. It will limit at edge nearest selected TACAN radial.
	Breakaway	Appears as a flashing symbol at a 3-cycle per second rate in the center of field-of-view when range-to-go-to minimum or safe pullup point is zero. Symbol is commanded by the WCS computer or by D/L, depending on mode of operation.
	Precision course Vector	This symbol consists of two independent vectors (vertical and horizontal), which form a cross pointer. Elevation glide slope information positions the horizontal vectors, whereas the vertical vector is positioned by azimuth glide slope information. This symbol is also used in D/L bombing modes.
	Velocity Vector	Indicates direction of ground track velocity vector (where the aircraft is going, not where it's pointed).
	Angle of attack error (CADC via CSDC)	Its position in relation to aircraft reticle indicates angle-of-attack error. Symbol is positioned by true AOA. Small center horizontal bar indicates zero error. When this symbol is in line with the aircraft reticle, the AOA is 15 units ( $10.31^\circ$ ). If symbol is below aircraft reticle, AOA is too high; above the aircraft reticle indicates AOA is too low. Symbol is displayed in landing mode only.
ORD, G, SW, SP, or PH 0,1,2,3,4,5,6	Armament Ready Legends	ORD - indicates bombs or rockets selected, or bombs and gun selected (A/G GUN switch on ACP set to MIXED) G - indicates gun is selected or gun and bombs are selected (A/G GUN switch on ACP set to OFF). Number under G indicates rounds remaining in hundreds (6, 5, 4, 3, 2, 1, 0). SW, SP or PH - indicates missile type selected (Sidewinder, Sparrow or Phoenix) and the numbers (0 to 6) indicates number of missiles ready for launch.

Figure 5-9. Symbolgy.




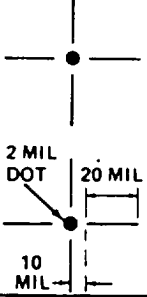
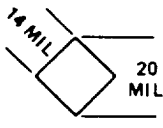
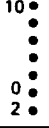
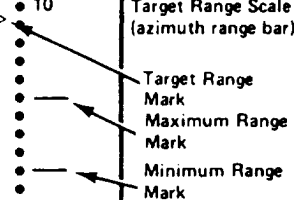



HUD SYMBOL	NAME	FUNCTION
	MASTER ARM switch off	An X symbol through armament ready legend indicates MASTER ARM switch on ACM panel is OFF. Disappears when MASTER ARM switch is set to ON.
	Steering Tee	Provides elevation and azimuth steering in the air-to-air modes when a single target track exists. Type of steering (pursuit, collision, etc.) is dependent on weapon selection and the mode selected on the TID by the RIO. May also provide azimuth steering only on the VDI in TWS. Aircraft steering is accomplished by aligning and maintaining the vertical and horizontal bar of the inverted T with the aircraft reticle center dot. Steering sensitivity on the HUD is 26.5° per inch; on the VDI 25° per inch.
	Boresight Reference	Symbol is a set of crosshairs which is fixed on the HUD and is used to represent the armament data line (ADL) of the aircraft. The reference is located 5.03" above aircraft reticle.
	Moveable Reticle (Impact Point)	Symbol serves as an optical sight for A/A gunnery and for A/G weapons delivery. In A/A gunnery, the symbol is used for lead angle determination. It can be positioned manually using the elevation lead control or automatically by the computer when the pilot selects the gun solution mode. The symbol is so designed that stadiametric ranging techniques can be employed during manual gun firing mode. This symbol in A/G modes indicates instantaneous weapon impact point. This symbol is positioned by the computer in all modes except manual. In the manual mode, it is positioned by the elevation lead control. The computer positions the symbol based on the ballistics of the bomb, wind conditions, and various aircraft parameters. This symbol must overlay the target at the moment of release.
	Target Designator	Indicates radar pointing angle. This symbol is used in all computer A/G modes. It is positioned in this case by the pilot using the TARGET DESIGNATE switch. Once the symbol is over the target, the switch is depressed and the computer knows the slant range to the target. In real-time gunsight mode of air-to-air gun, the target designator is positioned at the 1000-foot bullet solution. In all other weapon modes or with OFF selected, and with a valid sensor angle track on the target, the target designator symbol represents the approximate line of sight to the target. If the target is not within the HUD field of view (FOV) the symbol is positioned at the edge of the FOV in the direction of the target. Limits of designator are 10° in horizontal and vertical.
	Closure Rate	Indicates closing velocity from -200 to +1000 knots between aircraft and target.
	Target Range Scale (azimuth range bar)	Appears on right side of HUD during A/A modes. Scaling is determined by RIO selecting RANGE pushbuttons on the DDD panel. On the VDI, the range scaling is indicated in the lower left corner of the display. Limits are ±35° in horizontal. The symbol appears on the left side of the VDI during A/A modes, except in STT when it will be located at target azimuth. Indicates range to target. Indicates maximum range for weapon launch. Indicates minimum range for weapon launch.
	Upper Solution Cue	Cue is a measure of instantaneous weapon range. It is constrained to motion on the bomb fall line. Displayed with respect to velocity vector to indicate range-to-go to weapon release. When it crosses the velocity vector symbol the computer commands a weapon release.
	Lower Solution Cue	Cue is a measure of maximum range of weapon calculated from instantaneous aircraft position, constrained to motion on the bomb fall line and is used in conjunction with velocity vector to indicate range-to-go-to in range. In range when cue crosses velocity vector and indicates weapon can reach target if pilot executes a pullup. Cue appears after designate.
	Pullup Cue	Cue is a measure of range at which a 4 g pullup is required to clear weapon fragmentation pattern or ground. Positioned directly below velocity vector. Used in conjunction with velocity vector to indicate range to go to minimum safe pullup point, when one crosses the other.

Figure 5-9.-Symboly—Continued.

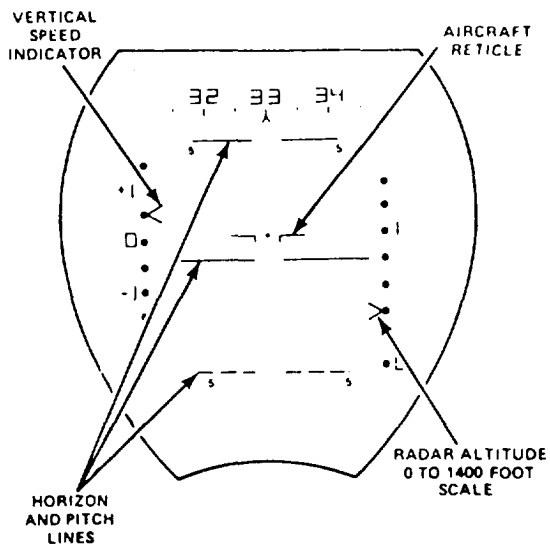


Figure 5-10.-Takeoff mode.

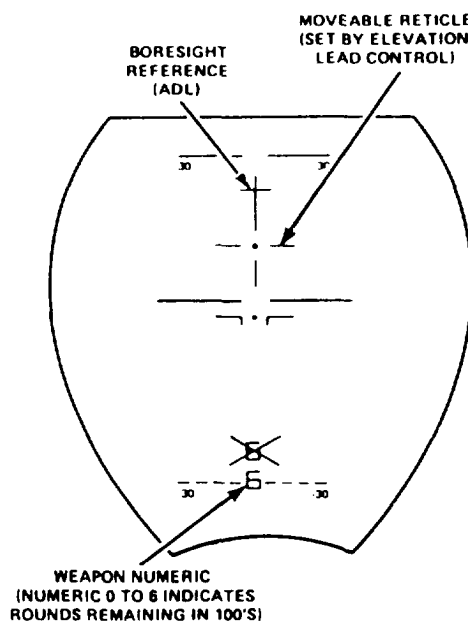


Figure 5-12.-Gun mode.

## MODES OF OPERATION

There are five basic modes of operation. These modes are takeoff, cruise, air-to-air (A/A), air-to-ground (A/G), and landing.

### Takeoff

The takeoff mode is shown in figure 5-10. This mode is used during takeoff and displays vertical speed, altitude, and aircraft attitude.

### Cruise

The cruise mode is shown in figure 5-11. This

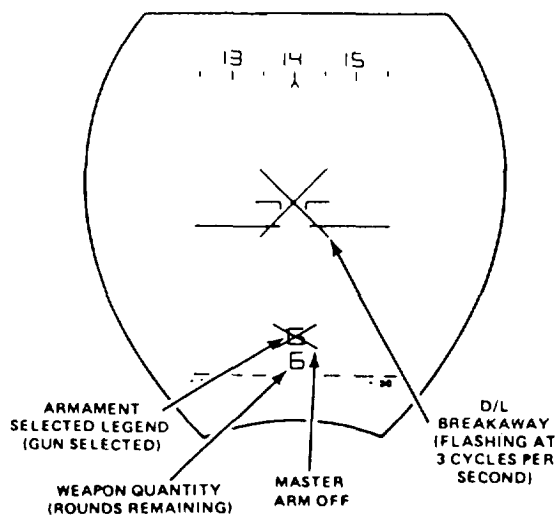


Figure 5-11.-Cruise mode.

another. The display gives the pilot attitude reference, magnetic heading, and various weapon information.

### Air-to-Air

Figures 5-12, 5-13, 5-14, and 5-15 are examples of the air-to-air mode. These displays give the pilot attack data with the various types of A/A weapons selected. In addition to attitude reference, the weapon

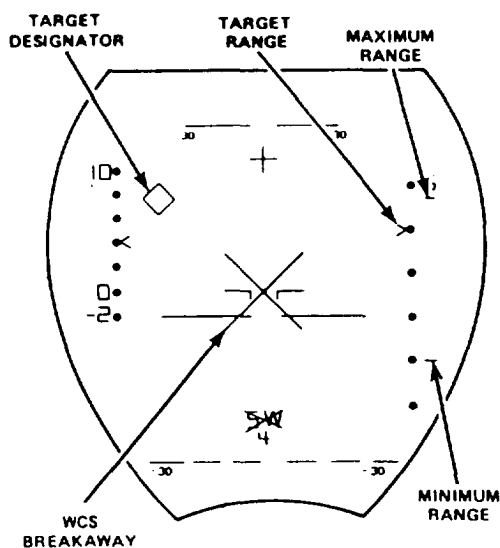


Figure 5-13.-Sidewinder mode.

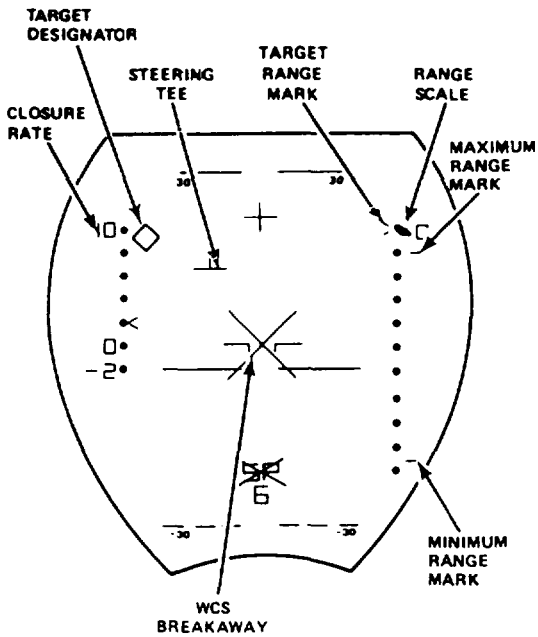


Figure 5-14.-Sparrow mode.

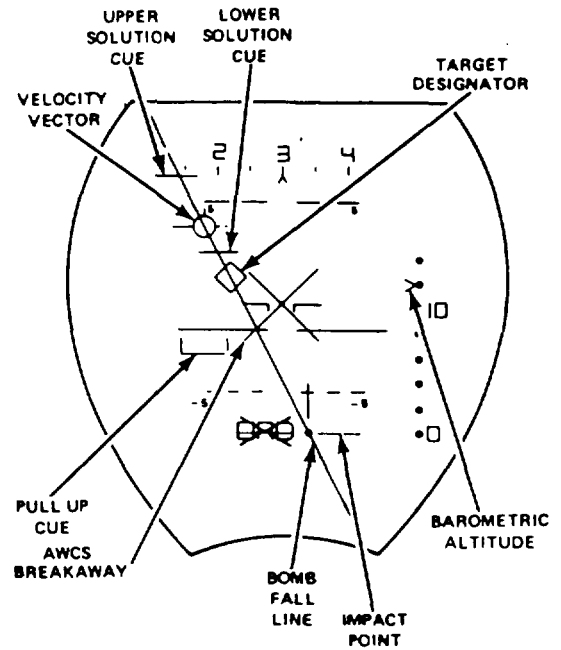


Figure 5-16.-Air-to-ground mode.

along with various types of target information.

### Air-to-Ground

The air-to-ground mode is shown in figure 5-16. This mode is used primarily for the delivery of bombs or other types of A/G weapons. Along with the

navigational information, it shows bomb ballistic and target information.

### Landing

The landing mode is shown in figure 5-17. This display shows the pilot radar altitude, vertical-descent, angle-of-attack, and velocity

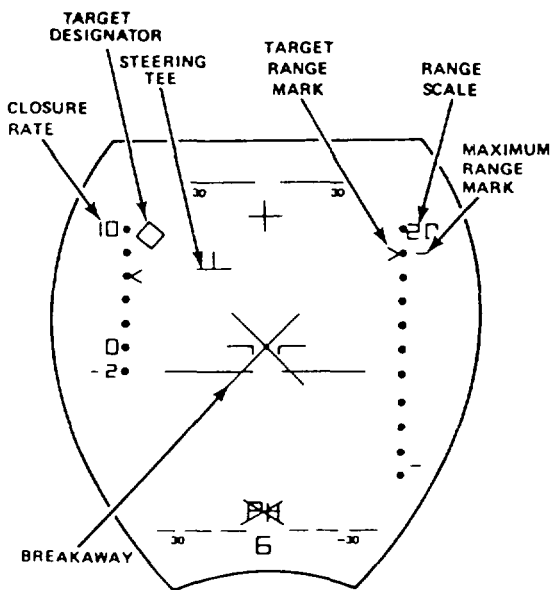


Figure 5-15.-Phoenix mode.

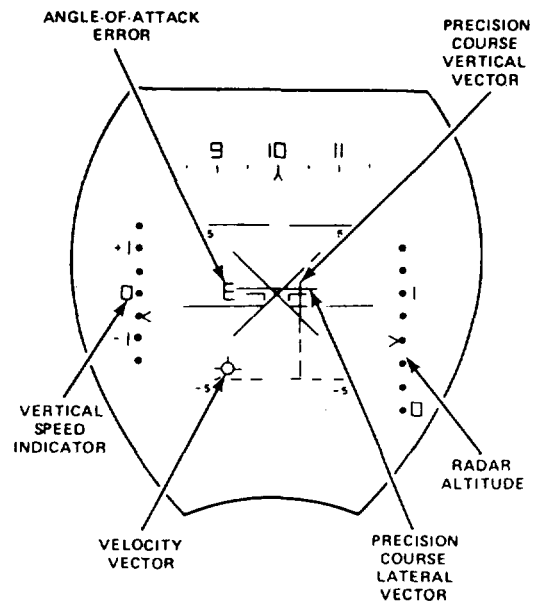


Figure 5-17.-Landing mode.

information. This mode is used when the aircraft is making an approach to an airfield or a carrier until the pilot has visual contact with the field.

### TACTICAL DISPLAY SYSTEM (NON-HUD)

Learning Objective: *Recognize components and functions of a non-HUD tactical display system.*

The AN/ASA-82 TDS is installed on the S-3 aircraft. This system is representative of ASW tactical display systems in use by the Navy.

The AN/ASA-82 consists of five indicators and a digital-to-analog converter. The digital-to-analog converter is commonly called a “display generator unit” (DGU). Three of the indicators are multipurpose displays (MPDs), which, with a few exceptions, can display all pertinent mission data developed within the aircraft. These MPDs are located at the TACCO (tactical coordinator), SENSO (sensor operator), and copilot stations. Because the copilot assists the TACCO during an ASW mission, the copilot station is referred to as the COTAC station. At the SENSO station, there is an additional indicator used to display acoustical data. This is the auxiliary readout unit (ARU). The fifth indicator in the system is located at the pilot’s station. This indicator displays tactical plot data required to maintain aircraft position while the aircrew is searching for or prosecuting a submarine.

### DISPLAY GENERATOR UNIT

The display generator unit generates alphanumeric characters, conics (curved lines), and vectors (straight lines). These graphic symbols are sent to all MPDs and to the pilot’s display. However, the DGU does not send all data types to all displays. The data capabilities of each display will be discussed later in this chapter. The DGU also positions all video data in the proper place on the display. Display data is processed through four processing channels, which are interchangeable, to supply the data for the four crew stations. When a processor channel fails, it is identified and reported to the general-purpose digital computer (GPDC) by the operation of the built-in test equipment at each station.

### PILOT DISPLAY

The pilot display presents the key elements of the TAC (tactical) plot, selected alerts, and peripheral information. The data presented on the display is produced by the GPDC, and is controlled by aircrew members through their integrated control system (INCOS) panels. The basic pilot display format is shown in figure 5-18.

### COPILLOT/COTAC DISPLAY

The copilot/COTAC display provides the video presentations listed below:

- Alerts and cues for the GPDC
- Tableaus containing GPDC-stored data
- Tactical plot (TAC plot) composed of symbols, vectors, and conics
- FLIR (Forward-looking infrared)
- MAD
- BT
- Scan-converted radar
- Test patterns

OUTLINES ARE FOR REFERENCE ONLY AND ARE NOT VISIBLE ON THE DISPLAY

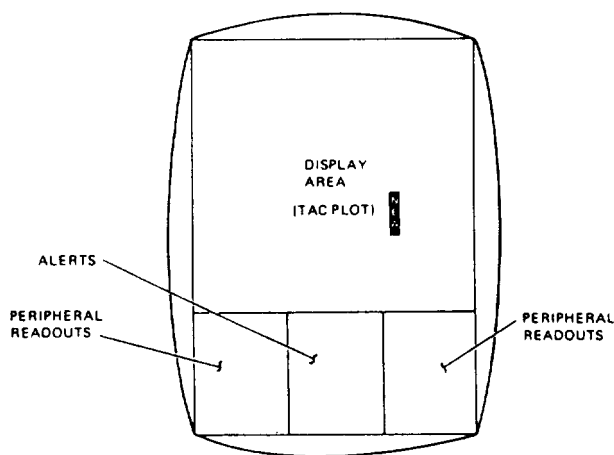


Figure 5-18.-Pilot display format.

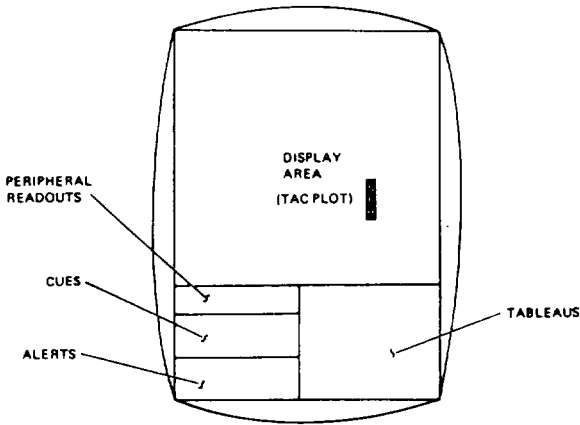


Figure 5-19.-Copilot/COTAC display format.

The basic copilot/COTAC display format is shown in figure 5-19.

### TACCO AND SENSO DISPLAYS

The TACCO display provides the video presentations listed below:

- Alerts and cues from the GPDC
- Tableaus containing GPDC-stored data
- TAC plot composed of symbols, vectors, and conics
- Analog acoustic data from the acoustic data processor (ADP) in the form of frequency, bearing, and range information from active sonobuoys (pingers) and signal strength from passive sonobuoys
- FLIR
- MAD
- BT
- Scan-converted radar
- Raw radar
- Test patterns

The TACCO and SENSO display formats are identical, and are shown in figure 5-20.

### SENSO ARU DISPLAY

The SENSO ARU displays analog acoustic data from passive sonobuoys. This data includes frequency, bearing, and signal strength.

## TACTICAL DISPLAY SYSTEM INTERFACE

As was previously mentioned, the TDS is the primary means used by the GPDC to present information to the operators. As shown in figure 5-21, the GPDC sends commands to the DGU. The DGU interprets them, determines the operating mode, and generates the requested symbols or displays. The DGU also regulates the data flow rates from the FLIR, radar, and the ADP to allow direct interface between these systems and the TACCO, SENSO, and COTAC stations. The pilot's display receives video data from the DGU only. The SENSO ARU interfaces with the ADP only.

## TELEVISION

*Learning Objective: Recognize components and operating fundamentals of a television system.*

Television can be defined as the transmission and reception of visual images by means of electrical signals from one point to another. There are three basic elements in all television systems. These elements are as follows:

- A pickup device to convert an optical image into an electrical signal.
- A means of transmitting that signal from one point to another.
- A reproducing device to convert the electrical signal into an optical image.

Pickup devices, or camera tubes, include image orthicons, image isocons, vidicons, plumbicons, and secondary electron conduction (SEC) tubes.

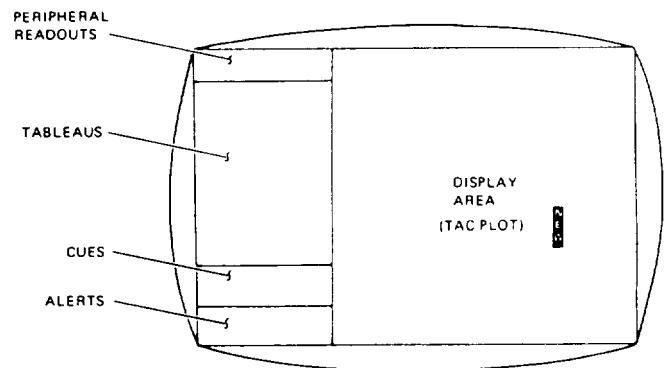


Figure 5-20.-TACCO and SENSO display format.



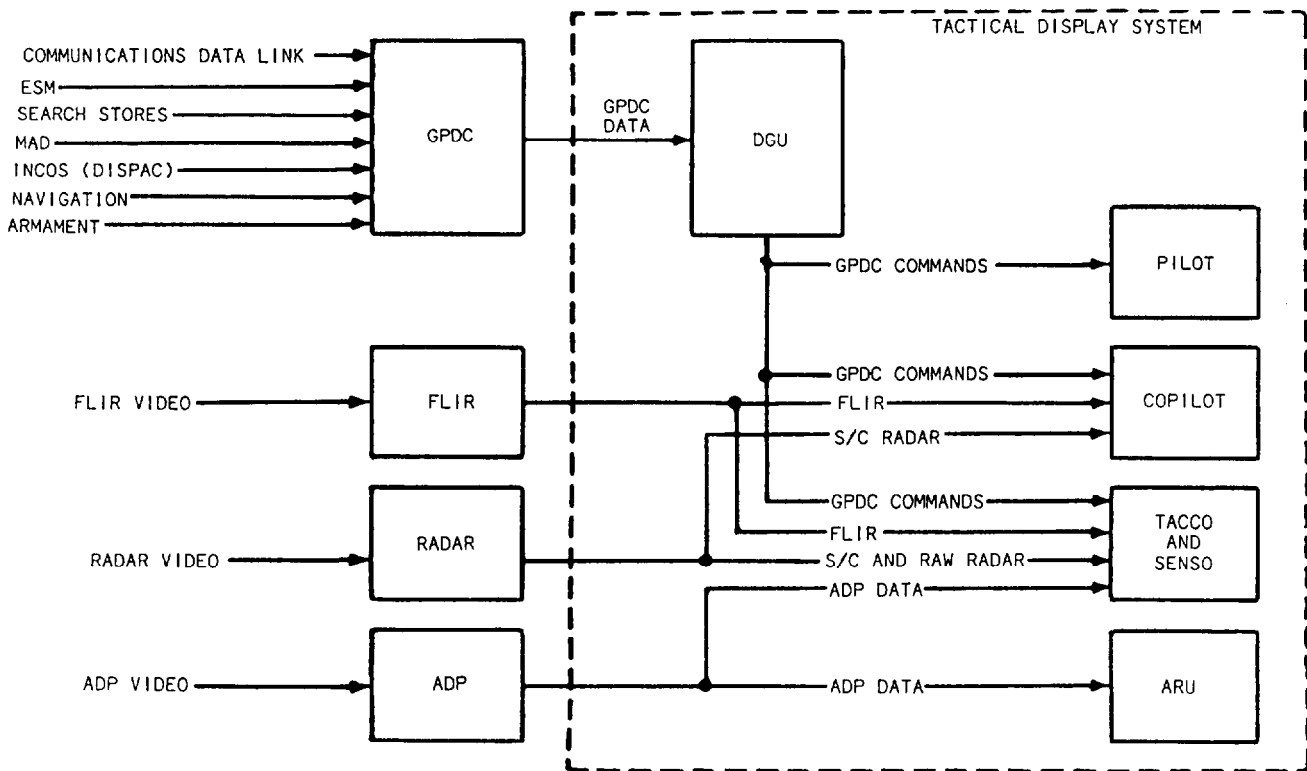


Figure 5-21.-TDS Interface block diagram.

Transmitting devices include coaxial lines, low- or high-power transmitters, or microwave relay links. The reproducing device is a television receiver, a television monitor, or some form of electro-optical projection system.

This chapter will discuss the camera tubes (pickup devices) and picture tubes (reproducing devices). For most uses in aircraft, coaxial cables provide the means for transmitting the video signals from the pickup to reproducing devices.

## TELEVISION FUNDAMENTALS

Television transmission of a picture from one point to another involves a process in which light,

reflected from an object or scene, is converted into electrical impulses of varying magnitude. This process is accomplished by means of synchronized scanning. In synchronized scanning, the picture is examined by the camera and reproduced by the viewing monitor. This is done point-to-point and in a regular pattern. The process is carried out so rapidly that the entire picture is scanned many times each second, and the eye sees it as a single complete image.

The basic television system is shown in figure 5-22. Notice that it consists of a transmitter and a monitor. An image of the scene is focused on the camera pickup device. An electron beam in the device scans the optical image and produces an

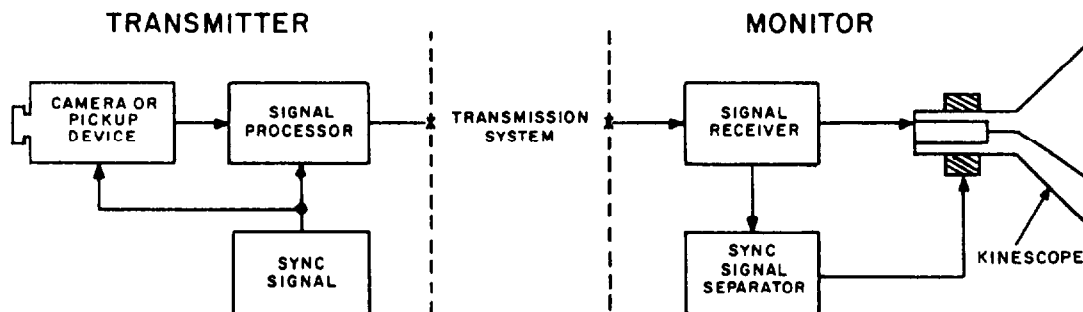


Figure 5-22.-Basic television system.

electrical signal, which varies in amplitude with the amount of light that falls on each point of the image. A synchronizing signal is added to the electrical signal from the camera. The resultant composite video signal is then transmitted to the monitor.

In the monitor, the synchronizing signal causes the beam to scan the picture tube (kinescope) faceplate in synchronism with the camera scanning beam. The intensity of the beam is varied in accordance with the picture signal. The varying beam causes the image to appear on the face of the picture tube.

The time required for one vertical scan of the picture in broadcast television systems in the United States is 1/60 of a second (60 Hz) or a multiple or submultiple thereof. The rate of 60 Hz was chosen because most commercial electrical power sources in the United States operate at a frequency of 60 Hz. Synchronization with the 60-Hz power frequency reduces the visible effects of hum and simplifies the problem of synchronizing film projectors with scanning.

### Scanning

Scanning is the process of breaking up the scene into minute elements, and using these elements in an orderly sequence. Reading a printed page is similar to scanning. You start at the beginning of one line and move to the right, word by word, until you reach the end of the line. Then you jump back to the beginning of the next line and repeat the process until you reach the end of the page. In television, this process is done to the picture.

### Scanning Methods

The number of scanning lines determines the maximum ability of the system to resolve fine detail in the vertical direction. Also, the number of scanning lines is related to the resolution ability in the horizontal direction. Resolution is determined by the number of scanning lines. For a given video bandwidth and frame time, horizontal resolution is inversely proportional to the number of lines. Therefore, as the scanning lines are increased in number, the bandwidth of the system must also be increased in the same ratio to maintain the same resolution in the horizontal direction.

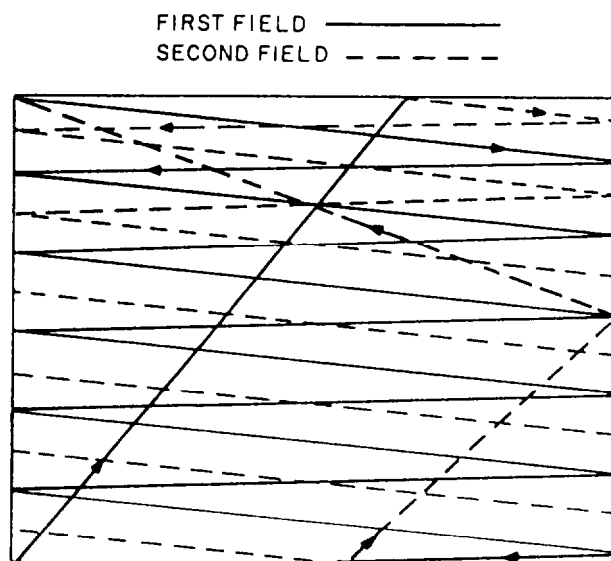
Maintaining approximately equal values of horizontal and vertical resolution is ideal. The bandwidth requirements increase as the square of the

number of lines. The present system of 525 lines was chosen for broadcast television as the most suitable compromise between channel width and picture resolution. This system is also used in many closed-circuit televisions (CCTV).

**NONINTERLACED SCANNING.**— This is the simplest method of scanning. It is also known as sequential or progressive scanning. Noninterlaced scanning uses an electron beam that moves very rapidly from left to right on an essentially horizontal line. It travels slowly from the top to the bottom of the picture. When the electron beam reaches the end of a line, a blanking voltage is applied, which shuts off the beam. The period of time the beam is shut off is known as the horizontal retrace period or flyback time. Similarly, when the beam reaches the bottom of the picture, the beam is again blanked, and returns to the top of the picture. This period of time is known as vertical retrace or flyback time.

**INTERLACED SCANNING.**— An important variation of the scanning method is known as interlaced scanning. It is the method used by broadcast television and most CCTV equipment. With interlaced scanning, it is possible to reduce the video bandwidth by a factor of two without reducing the resolution or seriously increasing flicker.

In the standard two-to-one method of interlacing, alternate lines are seamed consecutively from top to bottom. Then, the remaining alternate lines are seamed. This principle is shown in figure 5-23. In



this type of scanning, each of the two groups of alternate lines is called a field, and the frame is made up of two fields. Interlacing is accomplished by making the total number of lines in a frame an odd integer. Thus, the number of lines in each of the fields is an even number plus one-half line. This results in consecutive fields that are displaced in space with respect to each other by one-half of a line. The total number of lines is 525, the total lines per field is 262 1/2, the vertical scanning frequency is 60 Hz, the number of frames per second is 30, and the horizontal scanning frequency is 15,750 Hz (60 x 262 1/2).

### Television Signals

The standard television signal consists of the following four elements:

1. The picture information
2. The picture blanking pulses
3. The picture average dc component
4. The picture synchronizing pulses

These four elements are discussed in the following text.

**PICTURE INFORMATION.**— The picture information is the basic part of the signal. It is a series of waves and pulses generated during active scanning of the camera tube. As the scanning line travels across the tube, it is amplitude modulated in proportion to the brightness variation in the scene it is scanning. For commercial television, the amplitude variations are such that the maximum video amplitude produces black, and the minimum amplitude produces white. Ordinarily, the maximum and minimum video

amplitude values represent 75 and 15 percent of the maximum carrier voltage, respectively.

**PICTURE BLANKING PULSES.**— To prevent undesirable signals from entering the picture during retrace time, blanking pulses are applied to the scanning beams in both the camera tube and the receiver picture tube (kinescope). Camera blanking pulses are used only in the pickup device. They serve only to close the scanning aperture on the camera tube during retrace periods, and never actually appear in the final signal sent to the receiver. In some systems, the same pulse that triggers the seaming circuit and blanks the kinescope also closes the camera aperture.

The function of the kinescope blanking pulses is to suppress the scanning beam in the kinescope during both vertical and horizontal flyback times. The kinescope blanking pulses are simple rectangular pulses, somewhat wider than the corresponding camera blanking pulses. They have a duration slightly longer than the actual retrace time. The reason for the slightly longer blanking time is to trim up the edges of the picture and to provide a clean, noise-free period during flyback. Figure 5-24 shows a complete video signal that contains pulses for the removal of visible lines during horizontal retrace periods only. The horizontal pulses recur at intervals of 1/15,750 of a second. At the bottom of the picture, they are replaced by vertical blanking pulses. These are similar to the horizontal pulses, except they are of much longer duration (approximately 15 scanning lines) and have a recurrence of 1/60 of a second.

Note that the blanking pulses (and synchronizing pulses) are added at a relatively high-level point in the transmitter because they are considered to be

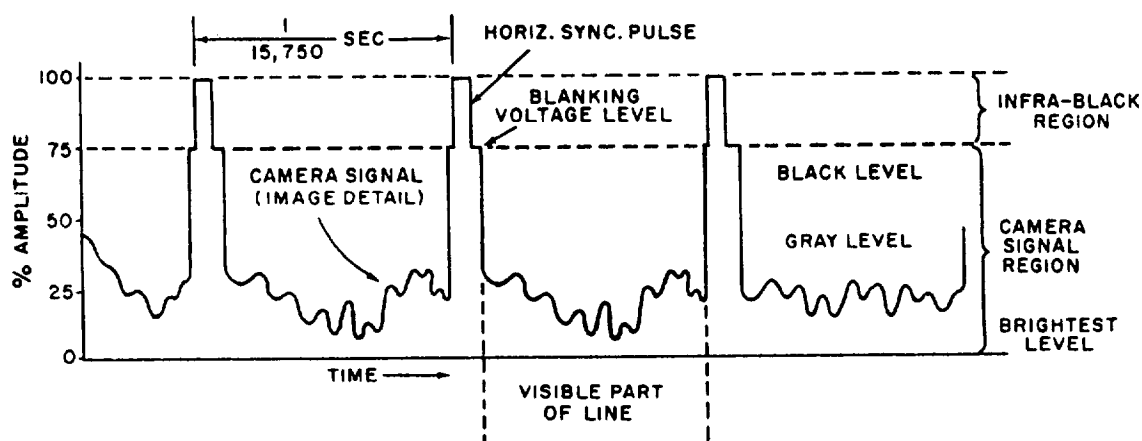


Figure 5-24.-The complete video signal for three scanned lines.

noise-free at that level. The importance of noise-free blanking and synchronizing pulses should be emphasized. They determine the stability of the viewed picture or the degree to which a picture remains locked-in on the picture tube, even under the most adverse transmission conditions. This is important when considering the use of television signals for close-circuit applications. The extreme environmental conditions that may be encountered can seriously degrade the picture signal. This makes it difficult to synchronize or lock-in a picture unless the original blanking-to-picture and signal-to-noise ratios are high.

**PICTURE AVERAGE DC COMPONENT.**— If a television picture is to be transmitted successfully with the necessary fidelity, it needs the dc component of the picture signal. This component is a result of slow changes in light intensity. The loss of the dc component occurs in ac or capacitive coupling circuits. The loss is evidenced by the picture signal tending to adjust itself about its own ac axis. The dc component is returned to the video signal by means of a dc restorer or inserter circuit.

**PICTURE SYNCHRONIZING PULSES.**— Synchronizing the scanning beams in the camera and the receiver must be exact at all times to provide a viewable picture. To accomplish this, synchronizing information is provided by electrical pulses in the retrace intervals between successive lines and between successive pictures (fig. 5-24). The retrace periods should be as short as circuit considerations will allow. These periods are in areas where synchronization pulses may be inserted without interfering with the picture.

Synchronizing pulses are generated in the equipment that controls the timing of the scanning beam in the pickup device. They become a part of the complete signal that is transmitted to the receiver. In this manner, scanning operations at both ends of the system are always in step with each other. In general, synchronizing signals should provide positive synchronization of both horizontal and vertical sweep circuits. They should be separable by simple electronic circuits to recover the vertical and horizontal components of the composite sync signal. They should be able to be combined with the picture and blanking signals to produce a standard composite television signal.

Most television systems produce synchronizing information that conforms to the basic requirements of synchronization. Figure 5-24 shows how the

synchronizing signal waveform is added to the picture information and blanking signals to form a complete composite picture signal ready to be transmitted. Note that the duration of the horizontal sync pulses is considerably shorter than that of the blanking pulses. Vertical sync pulses are rectangular, but they are of much shorter duration than the horizontal pulses. Thus, they provide the necessary means for frequency discrimination.

Synchronization presents a difficult problem as more failures occur from the loss of proper interlacing. Discrepancies in either timing or amplitude of the vertical scanning of alternate fields cause displacement in space of the interlaced fields. The result is nonuniform spacing of the scanning lines. This reduces the vertical resolution and makes the line structure of the picture visible at normal viewing distance. The effect is usually known as "pairing."

Another series of pulses is added before and after the vertical sync pulses to prevent the pairing problem and to maintain continuous horizontal synchronizing information throughout the vertical synchronization and blanking interval. These are equalizing pulses (fig. 5-25). The time between the last horizontal sync pulse and the first equalizing pulse changes from a full horizontal line interval to one-half of a horizontal line interval every other field. This is caused by the ratio between 15,750 Hz and 60 Hz. The ratio produces the necessary difference between fields to provide interlaced scanning. Since the horizontal oscillator is adjusted to the frequency of the horizontal sync pulses, it is triggered only by every other equalizing pulse or serration of the vertical sync pulse.

## Other Systems

Commercial broadcasting and many closed-circuit installations adhere closely to the synchronization signal specifications just discussed. There are some noncommercial and closed-circuit installations that use less rigorous sync signal specifications. We will now discuss four categories of these signals.

**RANDOM INTERLACE, NO SPECIAL SYNC PULSES.**— The random interlace is the simplest television method. It provides no special sync pulses and no fixed relationship between the horizontal and vertical scanning raster. Synchronization information at the monitor is obtained from the horizontal and vertical blanking pulses contained in the video signal. Figure 5-26, view A, shows this type of video signal. Usually at the camera control

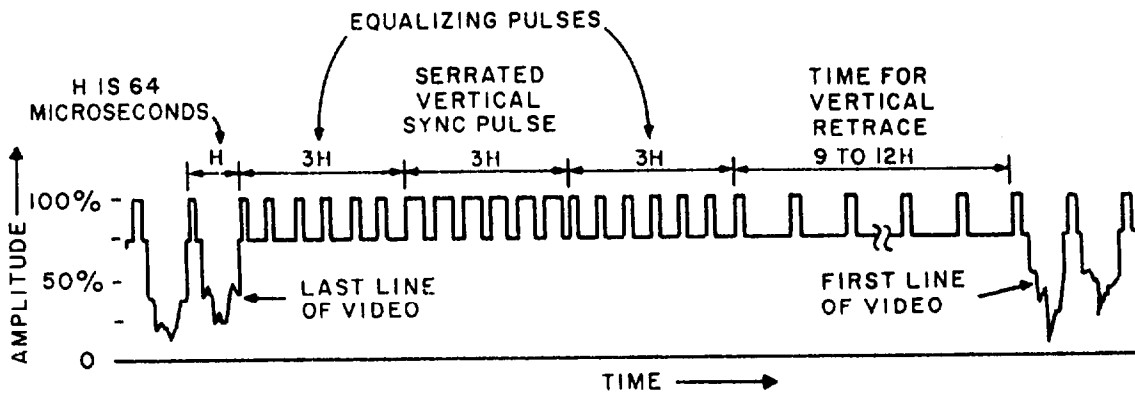


Figure 5-25.-Vertical synchronizing and equalizing pulses.

location, sufficient blanking signal is added to the video signal to provide an adequately long and steep transition at both vertical and horizontal frequencies to provide lock-in.

Some monitors may have problems synchronizing with this information. Electrical noise is a possible condition when the camera and monitor are separated by a great distance. The lock-in of such a signal becomes extremely difficult. Note in figure 5-26, view A, that there are no horizontal sync signals during vertical blanking time. The horizontal frequency circuit in the monitor is essentially free-running during this time. This circuit has the tendency to keep on the proper frequency, but it could get off frequency. This is not a problem during the blanking time. However, when the horizontal sync signals return, it may have trouble synchronizing to the new information.

The most undesirable characteristic of this system is insufficient resolution caused by the lack of interlace. Good interlace is not possible because an absolute frequency relationship between the horizontal and vertical frequencies is lacking. The nominal vertical frequency is usually 60 Hz. The horizontal frequency (usually established by a free-running oscillator) is nominally 15.75 kHz. There is no direct relationship between the two frequencies as required for good interlace. The advantages of this system are reduced costs and greater simplicity of circuits. However, marginal resolution capabilities, incompatibility, marginal stability, and general reduction of system performance limit its application and use.

**ODD-LINE INTERLACE, NO SPECIAL SYNC PULSES.**— The odd-line interlace system with no special sync pulses has a distinct advantage over the previous system. A definite relationship

exists between the horizontal scan frequency and the vertical field rate. This system (waveform seen in figure 5-26, view B) can effectively use the 2:1 odd-line interlace technique. Therefore, it provides a considerable improvement in the resolution capabilities of the system. In theory, the vertical resolution should be double that of the previous system. However, the improvement in resolution is somewhat less since it is difficult to obtain perfect interlace.

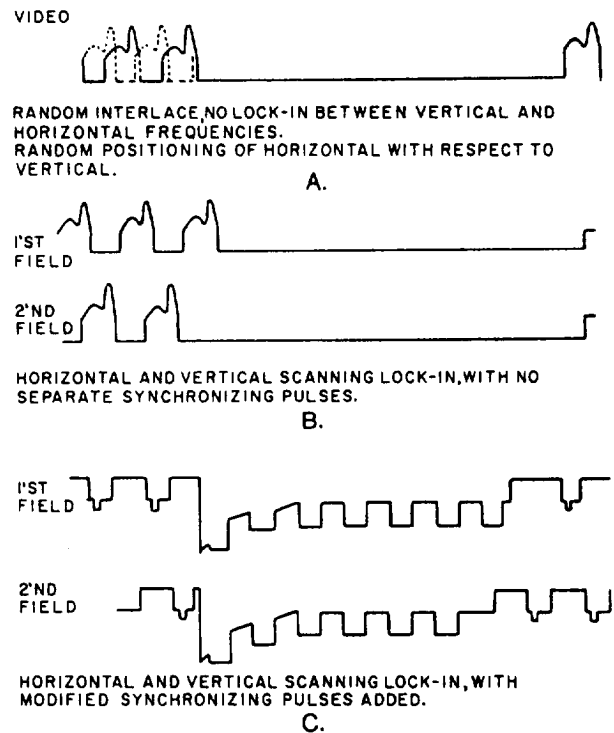


Figure 5-26.-Nonstandardized television waveforms.

Like the random interlace, this system does not provide a special synchronizing signal; therefore, it is subject to the same synchronizing limitations discussed previously. These limitations become an important problem in the more elaborate installations where a series of cameras and monitors might be separated by wide distances. For this reason, installations using these systems are usually the smaller, less complex applications, where stability and reliability may not be an important factor.

**ODD-LINE INTERLACE, MODIFIED SYNC PULSES.**— The odd-line interlace method with modified sync pulses provides further advantages over the previous two systems. However, it has a considerable number of limitations. In this system, special synchronizing pulses have been added to the video waveform (fig.5-26, view C).

Note that the synchronizing signal has been added to the tip of each horizontal blanking pulse. The sync pulses also continue through the vertical blanking interval. They provide synchronizing information for the monitor horizontal frequency-locking circuits at all times. These circuits are no longer free-running during the vertical blanking interval. Addition of these special sync pulses greatly improves the lock-in ability of the composite video signal under adverse conditions of noise and spurious signals.

**SLOW-SPEED SCAN.**— A television system that is being used frequently has a slow-speed scan technique. This technique represents a radical departure from the nominal scanning standards. It permits a scene to be picked up and transmitted successfully from one location to another, if the scene contains a limited amount of action or movement and a great deal of redundancy. It affords fair resolution and fidelity in signals transmitted over relatively economical narrow-band transmission facilities. For example, a slow-speed camera located in a bank, a message center, or a newspaper office can scan printed information and transmit it to a distant location over ordinary telephone line facilities. Some methods are able to transmit pictures having more action, such as a person talking, with reasonable clarity. Such methods, however, require a somewhat greater bandwidth.

Most slow-speed scan systems use a much slower scanning rate, with a correspondingly narrower bandwidth, than present telecasting standards. Broadcasting systems transmit a picture every 1/30 of a second, with a 4-MHz bandwidth. Slow-scan systems transmit a picture in 1/10 of a second to 2 seconds, with a video bandwidth ranging from approximately 250 kHz to as low as 500 Hz.

Most slow-speed scan systems are practical where time is available for transmission. For example, the information contained in a 5-minute commercial television program requires several hours of time to be transmitted with comparable detail by the average slow-speed scanning system. The advantages of the slow-speed system are greatly simplified equipment and relatively inexpensive transmission facilities. The disadvantages are that the scene content is limited to relatively immobile objects, resolution is marginal, and the system is incompatible with standard television systems. Rather complex scan conversion equipment is required to make the two systems compatible. Except for certain special applications, slow-speed scan systems are inferior in performance and cannot be used successfully where a high degree of resolution and detail is required.

## COMPONENTS

The pickup devices and picture tube basics are discussed in the following text.

### Camera Tubes

To assure high-quality images at the picture tube, the camera must resolve the scene into as many picture elements as practical. The quality of the picture increases as the number of elements increase. The pickup tube must produce signals that accurately represent each element. The optical-electrical conversion must have a signal-to-noise ratio high enough to assure effective pickup sensitivity at the lowest light level that may be transmitted. Ideally, when there is no light present, there should be no output signal.

The type of camera tube used is determined by the intended use of the camera and the amount of available light. The amount of light required by a camera tube is rated in candelas. The minimum number of candelas required by a camera tube is a measure of the tube's sensitivity. The following types of tubes are in use today.

**IMAGE ORTHICON.**— The image orthicon (fig. 5-27) is an ultrasensitive television camera pickup tube. The tube requires only 8 to 40 candelas for light, and is used in modern conventional and CCTV systems. When this tube is used, a light image for the subject (arrow at extreme left in figure) is picked up by the camera lens and focused on the light-sensitive face of the tube. This causes electrons to be released from each of the thousands of tiny globules in proportion to the intensity of the light striking it.

These electrons are directed on parallel courses from the back of the tube face to the target, from which

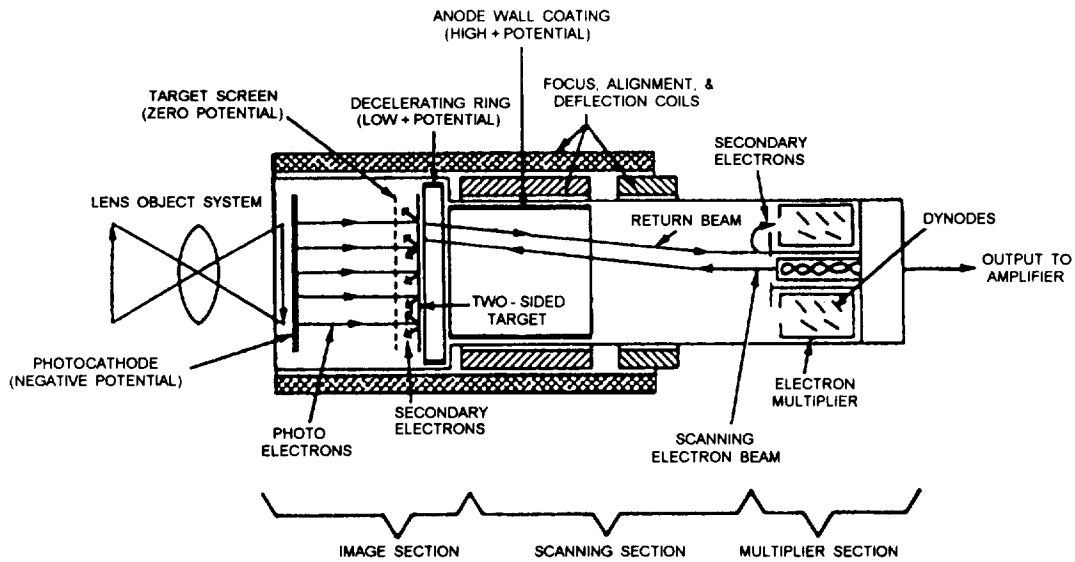


Figure 5-27. Image orthicon tube.

each striking electron liberates several more electrons, leaving a pattern of proportionate positive charges on the front of the target. When the back of the target is scanned by the beam from the electron gun in the base of the tube, enough electrons are deposited at each point to neutralize the positive charge. The rest of the beam returns to a series of electron multiplier stages or dynodes surrounding the gun.

Each dynode is a metallic disk with openings similar to a pinwheel, and operates at a positive potential of 200 to 300 volts greater than the preceding dynode. Multiplication occurs through secondary emission at each dynode. If five dynode

stages are used, each having a gain of 4, a gain of 1,000 ( $4 \times 4 \times 4 \times 4 \times 4$ ) is realized in the multiplier section. Now, consider dynodes with a gain of 5. The overall gain would be 5,000. This setup would allow the pickup tube to operate with relatively less light than the plumbicon or vidicon (to be discussed later). The electrons from the last dynode are routed through a signal-developing resistor to an extremely high B+ voltage. The output signal is then coupled to the first stage of video amplification in the camera.

**IMAGE ISOCON.**— The image isocon tube (fig. 5-28) is similar to the image orthicon in construction and operation. The main difference is

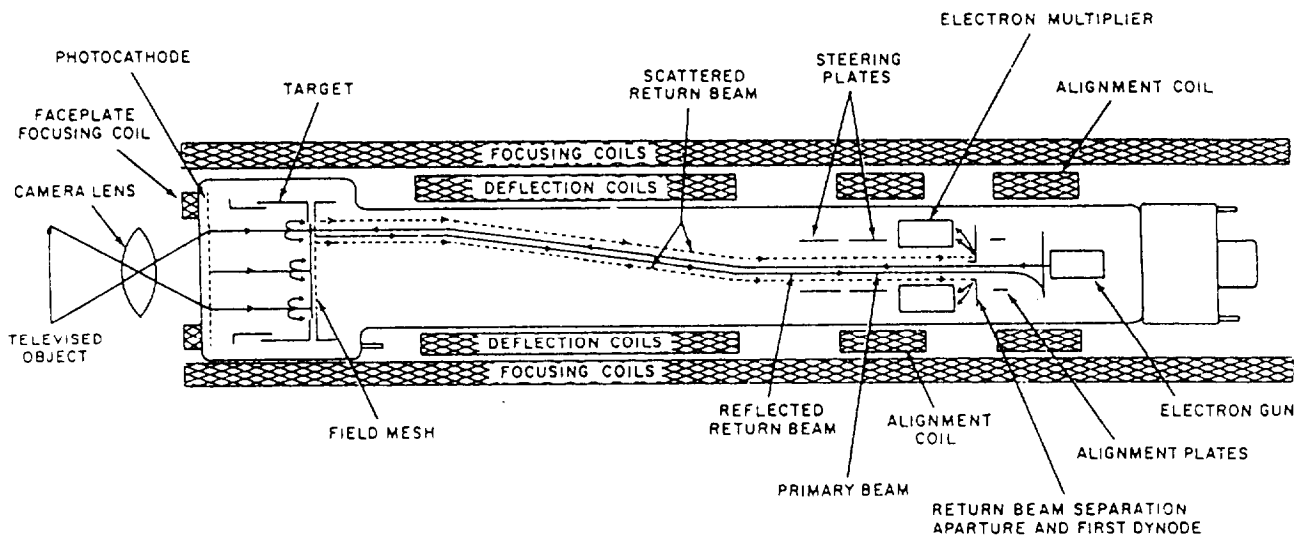


Figure 5-28. Image isocon tube.

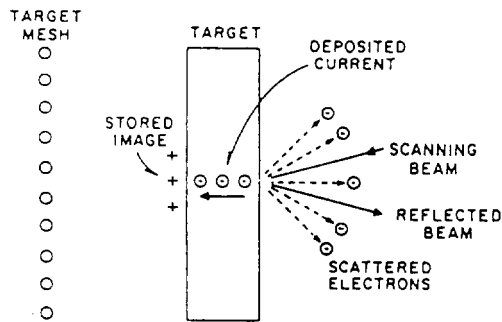


Figure 5-29. Image isocon target.

the method of extracting the video information from the returned electron beam. The image isocon uses scanning beam electrons scattered by the positive-stored charges on the target. Figure 5-29 shows this method of signal generation.

When the primary scanning electron beam hits the target, three events occur. Some of the electrons neutralize the target, some electrons reflect back to the gun, and some electrons scatter as they hit the target. Instead of using the reflected electrons, the image isocon uses the scattered electrons. These electrons, as well as the reflected electrons, return toward the electron gun. At the gun end of the tube, the reflected electrons are separated from the scattered electrons. The scattered electrons go to an electron multiplier that amplifies the signals before they are taken out of the tube.

The polarity of the signal developed by the isocon is opposite to the polarity of the signal of the orthicon. In the isocon, the maximum number of scattered electrons occurs at the highlights of the picture, while virtually no scattered electrons occur in the dark. This produces a signal that has much less noise in the lower lights. It also improves the ability of the tube to handle a very wide range of light levels without requiring additional camera adjustments.

The image isocon is useful in very low-light applications where there is a wide range of scene contrast. It is also useful where a low-noise signal is important in low-light areas.

**VIDICON.**— The vidicon camera tube (fig. 5-30) has a transparent conductive coating on the inner surface of the faceplate. This coating is known as the signal electrode. The signal electrode has a layer of photoconductive material deposited on it. When light from the scene being televised passes through the faceplate and is focused on the photoconductive layer, the resistivity of this material (which has been extremely high) is reduced in proportion to the amount of light reaching it. Because the potential gradient between adjacent elements in the photoconductive layer is much less than the potential gradient between opposite sides of the layer, electrons from the beam side of the layer leak by conduction to the other side between scans of the electron beam.

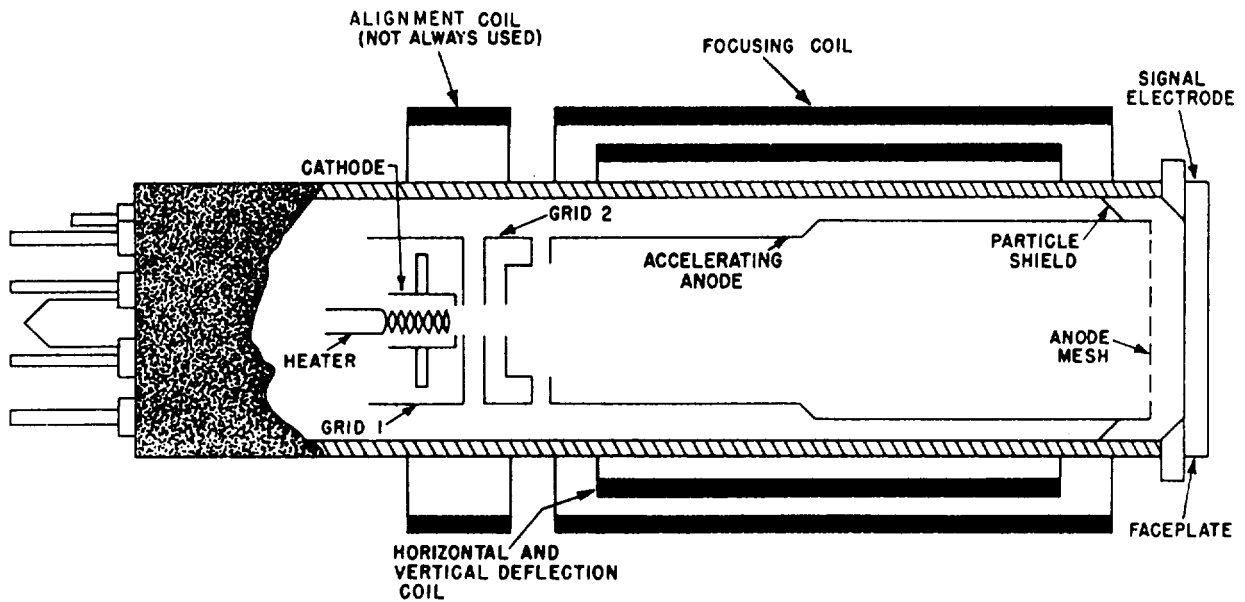


Figure 5-30. Structure of a vidicon tube.



Consequently, the potential of each element on the beam side approaches the potential of the signal electrode side. It will reach a value that varies with the amount of light falling on the element. On the next scan, the electron stream replaces a number of electrons on each element, just sufficient to return it to the potential of the cathode. Because each element is effectively a small capacitor, a capacitive current is produced in the signal electrode circuit that corresponds to the electrons deposited as the element is scanned. When these electrons flow through the load resistor in the signal electrode circuit, a voltage, which becomes the video signal, is produced.

**PLUMBICON.**— The plumbicon is similar in appearance and operation to the vidicon. It has several advantages over the vidicon. The plumbicon has a more rapid response and produces high-quality pictures at lower light levels. Because of its small size and low power consumption, the plumbicon is well suited for use in transistorized TV cameras. Its simplicity and spectral response to primary colors make it particularly useful in color cameras.

A unique feature of the plumbicon is that its color response can be varied by the manufacturer. It is, therefore, available with spectral responses for each of the primary colors. The color response of each tube is identified by the letter *R* (red), *G* (green), or *B* (blue) following the basic number. For example, a plumbicon for a green channel may be designated 55875G.

A simplified diagram of a plumbicon target is shown in figure 5-31. The faceplate (view A) has its inner surface coated with tin dioxide. This thin, transparent layer is the signal plate of the target. The tin dioxide itself is a strong N-type semiconductor. Two layers of lead oxide are deposited on the scanning side of the target. The first of these two is almost pure lead oxide. Lead oxide is an intrinsic semiconductor. The second layer of lead oxide is doped to form a P-type semiconductor. As shown in view B of figure 5-31, the three layers form a P-I-N junction.

Light from the televised scene passes through the layer of tin dioxide and is focused on the photoconductive lead oxide. Notice in view C of figure 5-31 that each picture element charge acts like a capacitor whose positive plate faces the scanning beam. The target signal plate forms the negative

plate. As the low-velocity scanning beam strikes each charged element, it releases electrons that neutralize the capacitors.

**SECONDARY ELECTRON CONDUCTION (SEC).**— This is a vidicon-like tube with a special target that uses secondary electron conduction. In this tube, light is focused on the photocathode that emits electrons into the tube. These electrons are focused to form an image of electron streams that strike the SEC target. The electrons are accelerated to approximately 10,000 electron volts by the time they strike the target. The SEC target intercepts these streams of electrons. A great number of secondary electrons from each

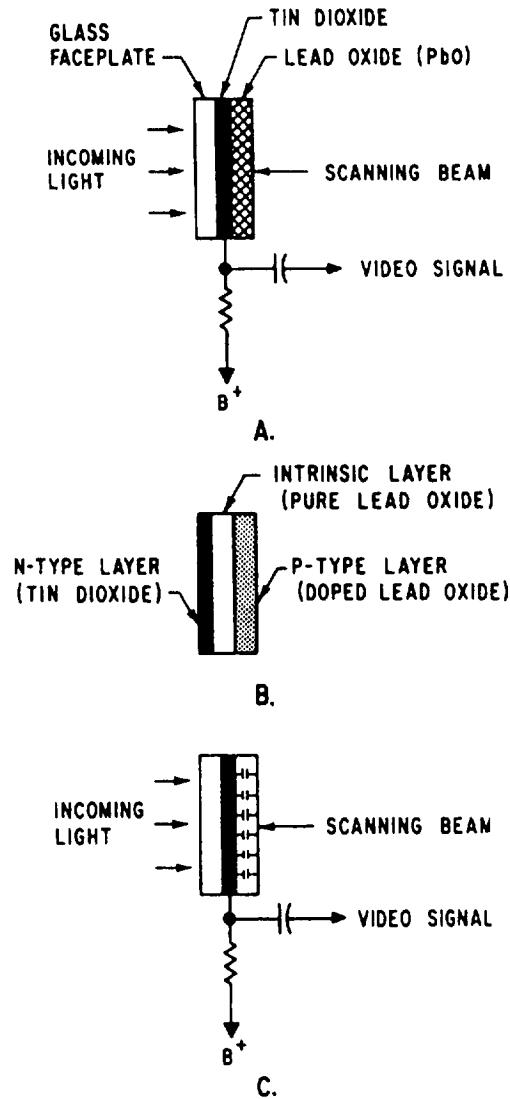


Figure 5-31.-Plumbicon target.

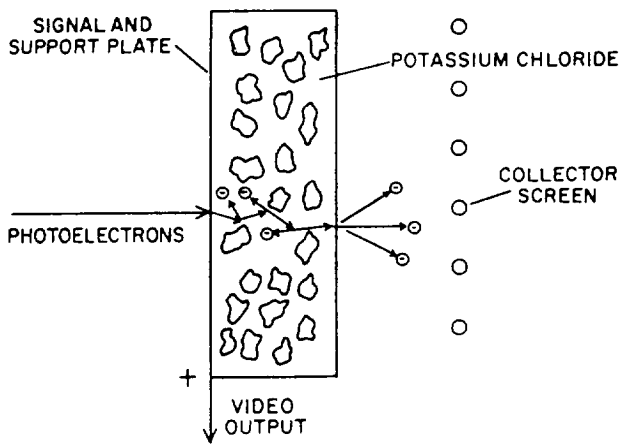


Figure 5-32.-SEC camera tube target operation.

electron striking the target are emitted and stored (fig. 5-32).

The photoelectrons possess sufficient energy to penetrate the thin, metallic signal and support plate. As they travel through the porous potassium-chloride layer, many secondary electrons are emitted as the beam strikes the interlined particles. These secondary electrons either escape to the positive collector screen or they travel through the spaces of the porous layer to the positive collector plate. This loss of electrons produces a positive charge on the scanned side of the target. Several hundred secondary electrons are emitted for each incident electron, producing a substantial gain at the target.

The video signal is developed from the target by the scanning beam discharging the positively charged areas of the target in the same manner as in a vidicon tube. This charging current, flowing out of the signal plate connection, is then amplified by an external amplifier.

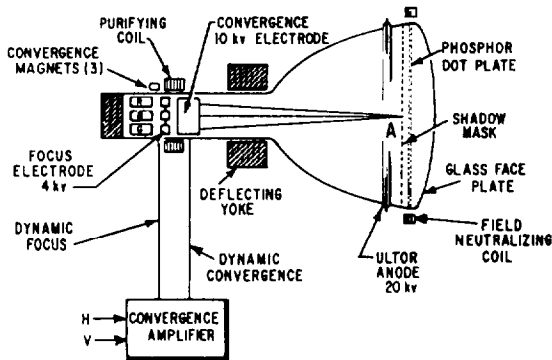


Figure 5-33.-Color picture tube.

The SEC tube has applications in extremely low-light, nighttime military TV systems where a high internal amplification and a fast speed of response to moving images are important.

### Picture Tubes

A monochrome picture tube is a specialized form of the cathode-ray tube. An electron gun in the tube directs a beam of electrons toward a fluorescent material on the screen. The screen glows when struck by the electrons. Between the gun and the screen are deflection coils that deflect the beam horizontally and vertically to form a raster. The brightness of the picture is controlled by varying the grid-bias voltage with respect to the cathode voltage. This bias can be changed by varying either the cathode voltage or the grid voltage.

Color picture tubes operate on the same basic principle as monochrome picture tubes. The difference between the two systems is the types of phosphors that coat the screen. The different types of phosphors produce colors when struck with the electron beam. Three basic or primary colors are used in combination to produce all the other desired colors. These primary colors are red, green, and blue. In a three-gun color picture tube (fig. 5-33), there is a separate gun for each of the color phosphors. The tube's screen consists of small, closely spaced phosphor dots of red, green, and blue. The dots are arranged so a red, green, and blue dot form a small triangle. The shadow mask provides a centering hole in the middle of the triangle of dots. The convergence electrode causes the three separate electron beams to meet and cross at the hole in the shadow mask.

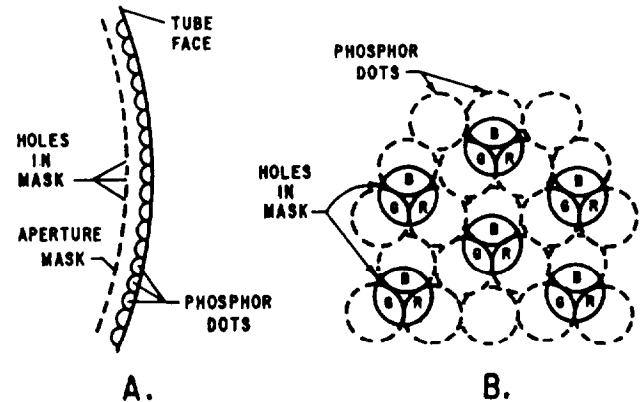


Figure 5-34.-Color picture tube. A. Side view. B. Front view.

Each electron gun is electrostatically focused by a common grid voltage. In other words, each gun has its own electrode, but all three are connected together requiring only one grid voltage. The three electron beams scan the screen and are controlled by the deflection yoke mounted externally around the neck of the tube. As the three beams scan the phosphor screen horizontally and vertically in the standard scanning pattern, the dot triads light up according to the video input signals (fig. 5-34).

The purifying coil produces a magnetic field within the tube that aligns the electron beams parallel to the neck of the tube. Rotating the purifying coil adjusts the electron beams so they strike their respective color dots without striking neighboring dots. When this adjustment is made for the red dots, the other two electron beams are aligned as well.

The high-voltage anode is a metallic ring around the tube. The field neutralizing coil aids color purity at the outer edges of the picture tube. A metal shield, called a mu-metal shield, is placed around the bell of the tube to prevent stray magnetic fields from affecting the electron beams.

## REVIEW QUESTIONS

- Q1. *Which heading indicator displays the most information?*
- Q2. *Are the three control boxes in the HSI group interchangeable between the stations?*
- Q3. *On the BDHI, what is the lubber index?*
- Q4. *What does HUD stand for?*
- Q5. *What does TDS stand for?*
- Q6. *What is a combiner, as used with the HUD system?*
- Q7. *How many different dc voltages are used in the HUD unit?*
- Q8. *In the HUD system how many basic modes of operation are there?*
- Q9. *The SENSO ARU receives inputs from what source?*
- Q10. *What is another term for a camera tube?*
- Q11. *What process is referred to as scanning?*
- Q12. *How many elements are contained in a standard television signal?*

