SERVICE MANUAL

CRT Data Displays
HD Series

Electronic
Display
Division

BALL ELECTRONIC DISPLAY DIVISION • ST. PAUL, MINNESOTA 55164

5-017-1047 A

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REV A

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SECTION 1

GENERAL INFORMATION

1.1 HD SERIES DESCRIPTION

All HD Series Monitors are solid-state, raster-scan, high-density, data terminal displays for word processing and phototypesetting. There are four different models:

a. HD-15H: 15 inch (diagonal screen size) CRT (110° deflection angle); horizontal (conventional, landscape, broadcast) format (5° tilt on CRT)
b. HD-15V: 15 inch CRT; vertical (page) format (0° or 5° tilt on CRT)
c. HD-17H: 17 inch (diagonal screen size) CRT (114° deflection angle); horizontal format (5° tilt on CRT)
d. HD-17V: 17 inch CRT; vertical format (5° tilt on CRT)

1.2 CUSTOMER INPUTS

1.2.1 VIDEO

The standard version uses TTL digital video. There are two optional versions: one uses ECL digital video and the second uses analog video.

1.2.1.1 TTL Digital Video (Standard Version)

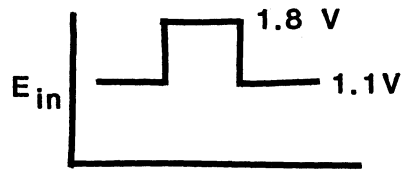
Amplitude: Industry standard TTL logic interface
Polarity: Digital 1 (positive) translates to peak white at CRT
Rise/Fall Times: 7 ns maximum
Video Blanking: See Figures 1-1, 1-2

1.2.1.2 ECL Digital Video (Optional Version)

Amplitude: Industry standard for ECL balanced line input
Polarity: Pin 5 positive with respect to pin 6 produces peak white
Rise/Fall Times: 7 ns maximum
Video Blanking: See Figures 1-1, 1-2
-5.2 Volt Supply: -5.2 volts ± 5% at 60 ma maximum

1.2.1.3 Analog Video (Optional Version)

Amplitude: 0.7 volts ± 20% p-p referenced to low level (black) of 1.1 volt ± 15% capable of driving 75 ohms



Polarity: Positive video pulse translates to peak white at CRT
Rise/Fall Times: 7 ns maximum
Video Blanking: See Figures 1-1, 1-2

1.2.2 HORIZONTAL DRIVE

Amplitude: Industry standard TTL logic interface
Frequency: 26-36 kHz
Pulse Width: 2.5-6 us
Polarity: Positive or negative (positive preferred)
Input Impedance: 1 kohm

1.2.3 VERTICAL DRIVE

Amplitude: Industry standard TTL logic interface
Frequency: 40-80 Hz
Pulse Width: 300-500 us
Polarity: Negative
Input Impedance: 1 kohm

1.2.4 POWER

100 watts nominal (Monitor is capable of using 120 vac, 220 vac or 240 vac at 50 or 60 Hz). Voltage level is determined by pre-wired optional jumper plug and by connections to the appropriate pin numbers of the input power connector.)

1.3 VIDEO AMPLIFIER CHARACTERISTICS

1.3.1 DIGITAL VIDEO AMPLIFIERS: STANDARD TTL, OPTIONAL ECL

Bandwidth: 50MHz typical
Rise/Fall Times: 7 ns typical
Output Amplitude: Peak white level adjustable to required brightness... typically, at 40 fL (P4 phosphor), output voltage = 30 volts p-p.

1.3.2 OPTIONAL LINEAR VIDEO AMPLIFIER

Bandwidth: 35 MHz typical
Rise/Fall Times: 10 ns typical
Output Amplitude: Gain is adjustable. With input noted in 1.2.1.3 and an output of 40 fL (P4 phosphor), a mid-range gain setting produces 30 volt p-p output.
Input Impedance: Selectable termination resistor. Typical value = 75 ohms.

1.4 CONTROLS

1.4.1 INTERNAL, FACTORY PRESET (SERVICE ADJUSTMENT ONLY)

Horizontal:
- Data Centering
- Oscillator (free-run frequency)
- Width
- Raster Centering

Vertical:
Data Centering
Raster Height

Focus:
Static
Dynamic

Brightness:
Brightness (internal option)
Brightness Limit

Overvoltage threshold (factory sealed)

Video:
a. TTL Digital Video (standard version)
Gain
b. ECL Digital Video (optional version)
Gain
c. Analog Video (optional version)
Contrast

Power Supply:

+70 volt coarse adjustment (factory sealed)
+70 volt fine adjustment

1.4.2 EXTERNAL

Customer supplied (optional) brightness (50 kohm potentiometer)

1.5 DISPLAY CHARACTERISTICS

1.5.1 CRT FACEPLATE DIAGONAL MEASUREMENT

15": 13.8" minimum screen
17": 16.25" minimum screen

1.5.2 CRT DEFLECTION ANGLE

For 15", 110°
For 17", 114°

1.5.3 U.L. IMPLOSION PROTECTION: T BAND

1.5.4 HIGH VOLTAGE (NOMINAL)

15" CRT: 17 kvolts
17" CRT: 18 kvolts

1.5.5 RECOMMENDED DATA DISPLAY AREA

For 15": 8¼ X 11.0"
For 17": 9½ X 12½"

1.5.6 RESOLUTION

Vertical format (page):
98 characters by 66 lines = 6468 characters

Horizontal format (conventional):
132 characters by 48 lines = 6336

Where character cell = 11 X 16 dots

1.5.7 LIGHT OUTPUT

For 15":
P4 Phosphor: 40 foot lamberts
P39 Phosphor: 15 foot lamberts

1.5.8 GEOMETRIC DISTORTION

Within ± 1% of vertical height

1.5.9 LINEARITY

Within 12 dots horizontal or vertical at 120 dots/inch reference

1.6 MONITOR TIMING

1.6.1 HORIZONTAL: See Figure 1-3

1.6.2 VERTICAL: See Figure 1-4

1.7 MECHANICAL SPECIFICATIONS

1.7.1 WEIGHT (EITHER FORMAT)

15": 27 lbs. (12.2 kg)
17": 30 lbs. (13.6 kg)

1.7.2 DIMENSIONS

1.7.2.1 HD15H (5° Tilt on CRT): See Figure 1-5

1.7.2.2 HD15V (0° Tilt on CRT): See Figure 1-6

1.7.2.3 HD15V (5° Tilt on CRT): See Figure 1-7

1.7.2.4 HD17H (5° Tilt on CRT): See Figure 1-8

1.7.2.5 HD17V (5° Tilt on CRT): See Figure 1-9

1.8 ENVIRONMENTAL SPECIFICATIONS

	OPERATING	NON-OPERATING
Ambient Temperature	10 to 40°C	-40 to 65°C
Humidity (non-condensing)	5 to 90%	5 to 90%
Altitude (maximum)	10,000 ft.	40,000 ft.

1.9 WARNINGS

1.9.1 HIGH VOLTAGE

High voltage may be present on CRT anode even when Monitor is not operating. (Never assume that bleeder resistor has discharged high voltage.) Flyback transformer (T2) generates high voltages during Monitor operation. Any conductive material placed close to transformer can cause an arc to jump the gap between case and conductive material. This occurs when the air gap ionizes and becomes a conductive path.

1.9.2 CRT

Handle CRT with care. Since CRT contains high vacuum, breakage may cause injury from flying glass. Do not hold CRT by neck since pressure on neck may cause CRT breakage. Discharge CRT high voltage before servicing Monitor. Following procedure is recommended:

Equipment Required:

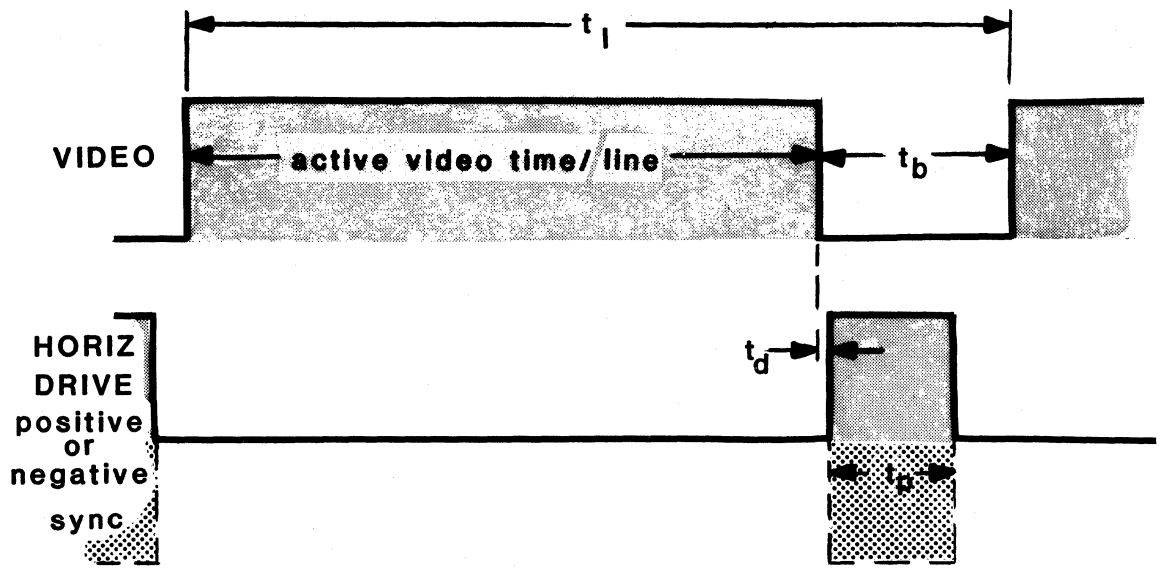
1 - Clip lead with alligator clips, both ends.
1 - Flat-blade screwdriver with long thin shaft and insulated handle. Insure handle is clean and free from foreign material.

a. Completely disconnect Monitor.
b. Attach one end of clip lead to aquadag spring.
c. Attach other end of clip lead to center portion of screwdriver shaft.
d. Grasp screwdriver handle well away from screwdriver shaft. Use one hand only. Throughout discharge procedure do not touch any thing with free hand.
e. Slip screwdriver blade between anode cap and CRT. Anode cap may tend to stick making it necessary to gently pry up edge of cap.
f. Carefully push screwdriver blade to center of anode cap and touch blade to metal anode. If CRT has not been discharged by bleeder resistor, a noticeable spark will generally result.
g. Screwdriver-anode contact must be maintained for a minimum of five (5) seconds.
h. Anode cap may be safely removed at this point.

1.9.3 X-RADIATION

Replacing T2 and/or L1 with components of different design or manufacture may result in x-radiation in excess of minimum safety levels.

Supplying Monitor with excessive voltage may also increase x-radiation beyond minimum safety levels if built-in overvoltage protection circuit is inoperative or misadjusted.



t_l = time between lines = $\frac{1}{\text{horizontal line rate}}$

$$\frac{1}{36\ \text{kHz}} \leq t_l \leq \frac{1}{26\ \text{kHz}}$$

t_d = sync delay : $-1\ \text{us} \leq t_d \leq 3\ \text{us}$

t_p = sync pulse width : $2.5\text{us} \leq t_p \leq 6\text{us}$

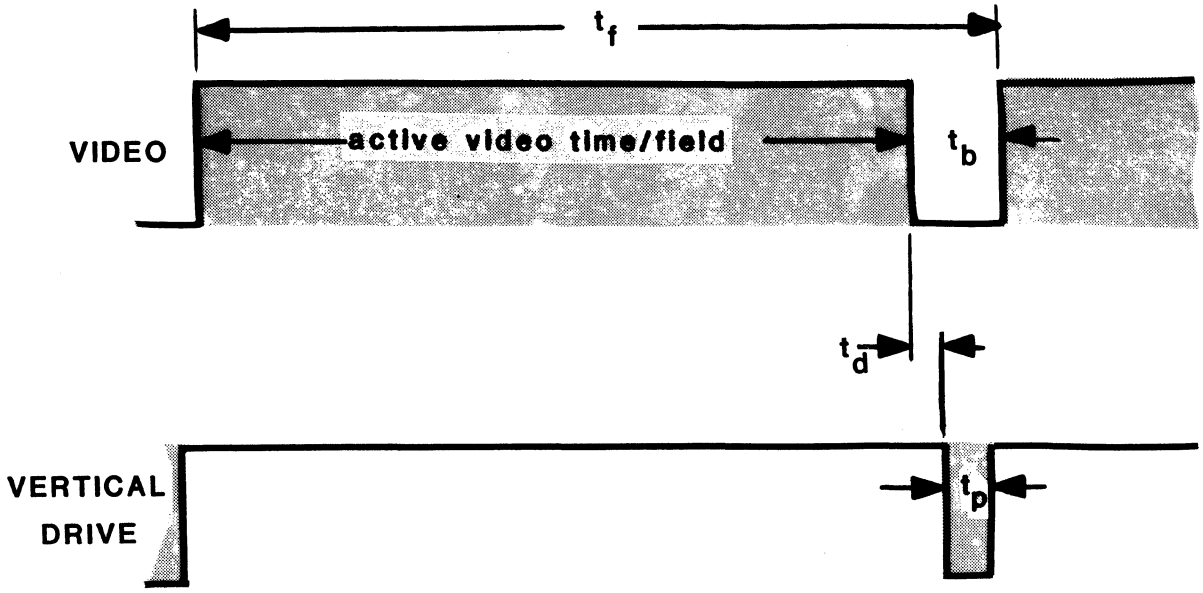
t_b = line blanking time : 7.0 us min., 10 us max.

Note: To minimize crosstalk between Horizontal Drive and active video, pulse width should occur during blanking time, i.e.

$$t_d \geq 0 \quad \text{and} \quad t_d + t_p \leq t_b$$

HORIZONTAL/VIDEO TIMING

FIGURE 1-1



t_f = time between fields: $\frac{1}{80\ Hz} \leq t_f \leq \frac{1}{40\ Hz}$

t_p = sync pulse width : 300 us $\leq t_p \leq$ 1350 us

t_b = field blanking time : 500 us min., 1350 us max.

t_d = sync delay...selected for best video centering within raster, per:

$$t_d = \frac{t_b - 500\ us}{2}$$

Examples: for t_b = 1350 us

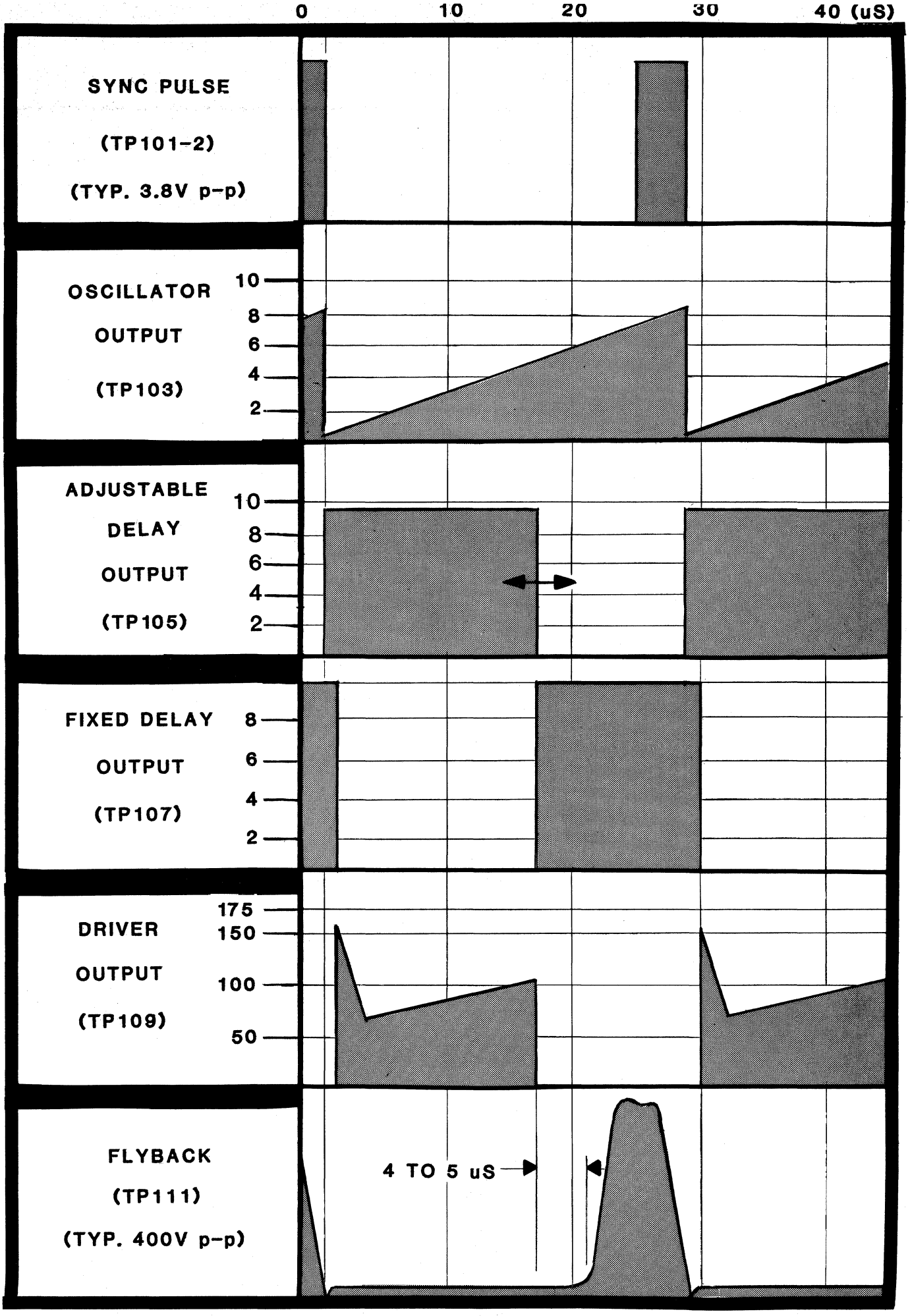
t_d = 425 us

for t_b = 500 us

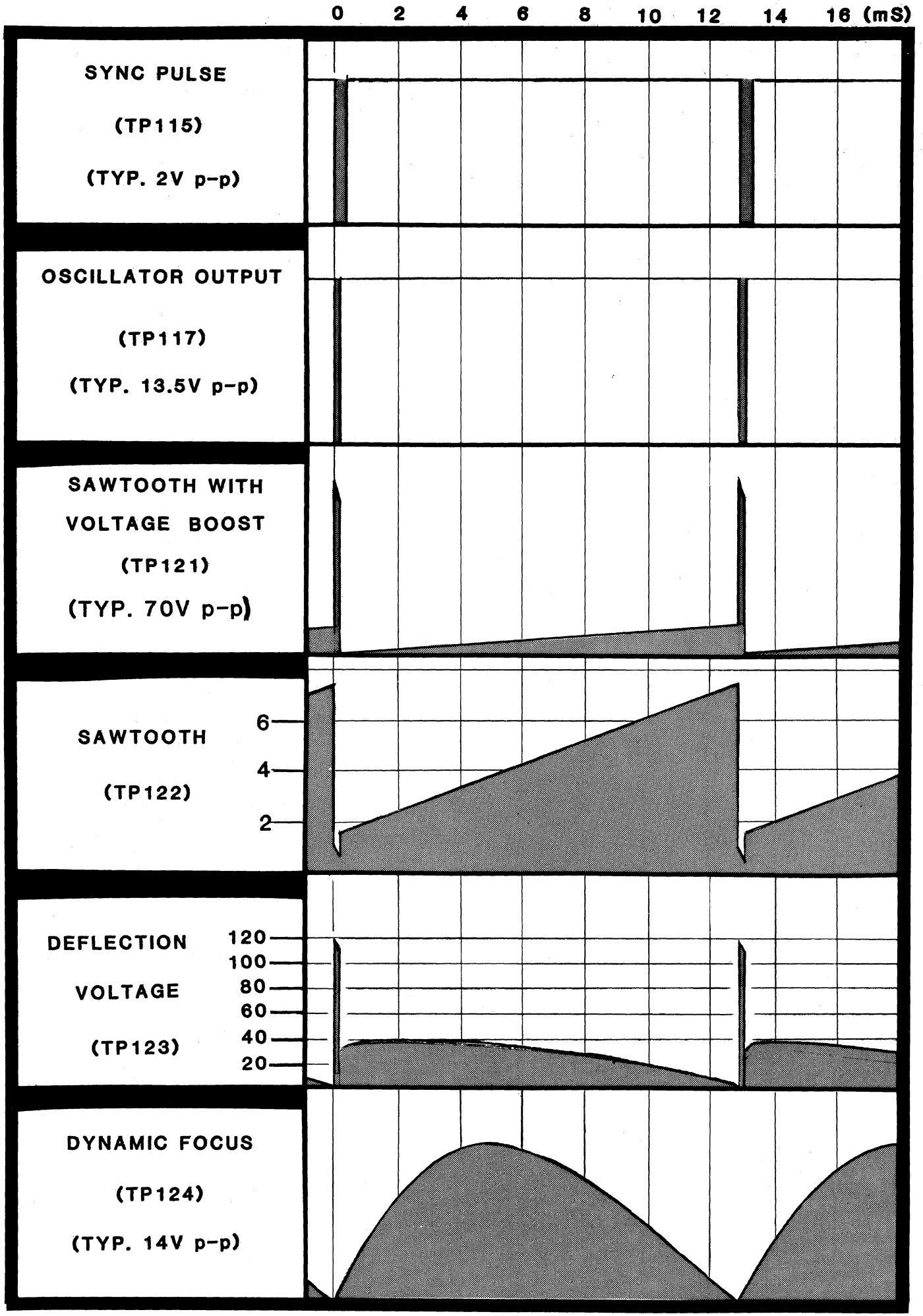
t_d = 0

VERTICAL/VIDEO TIMING

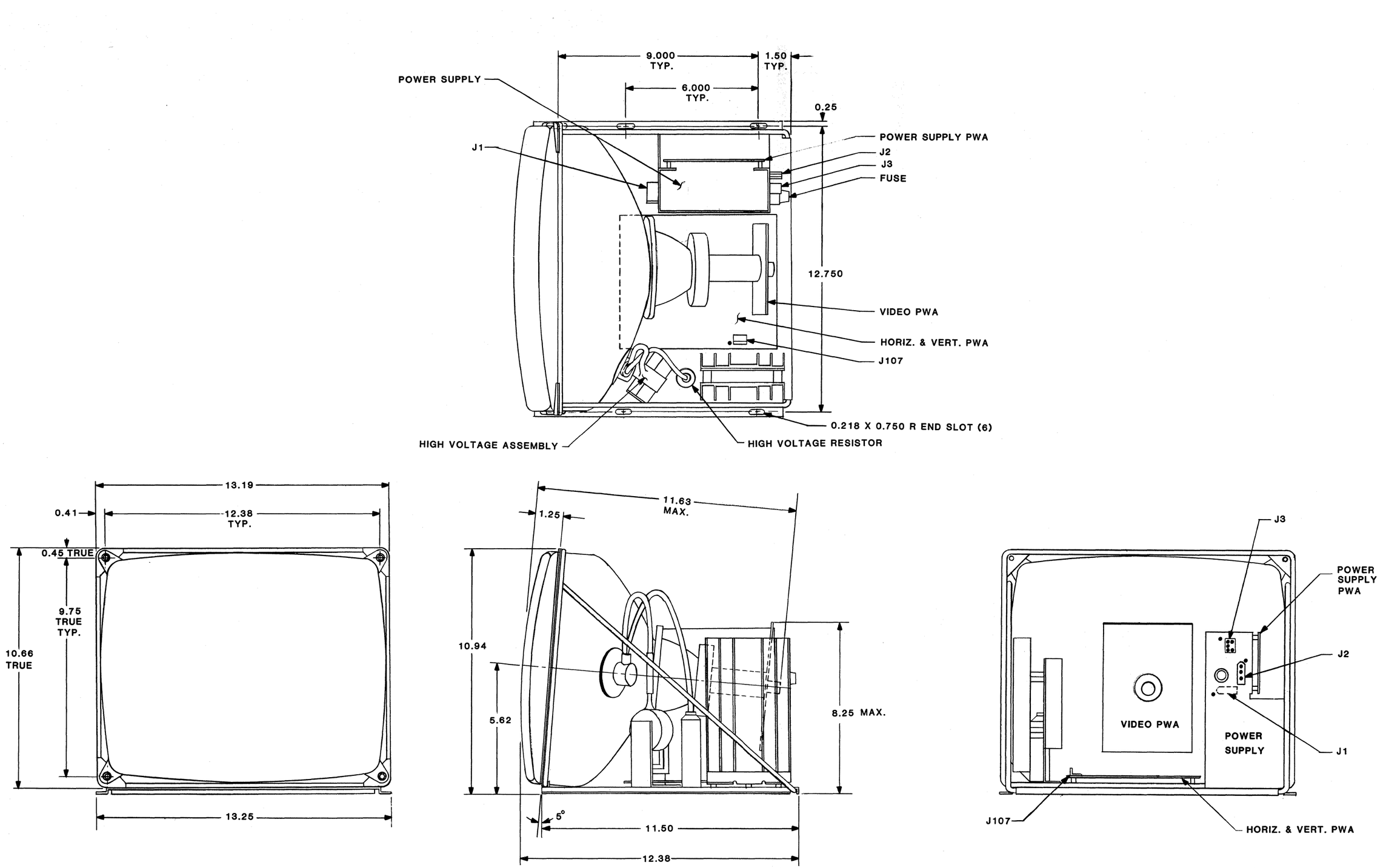
FIGURE 1-2



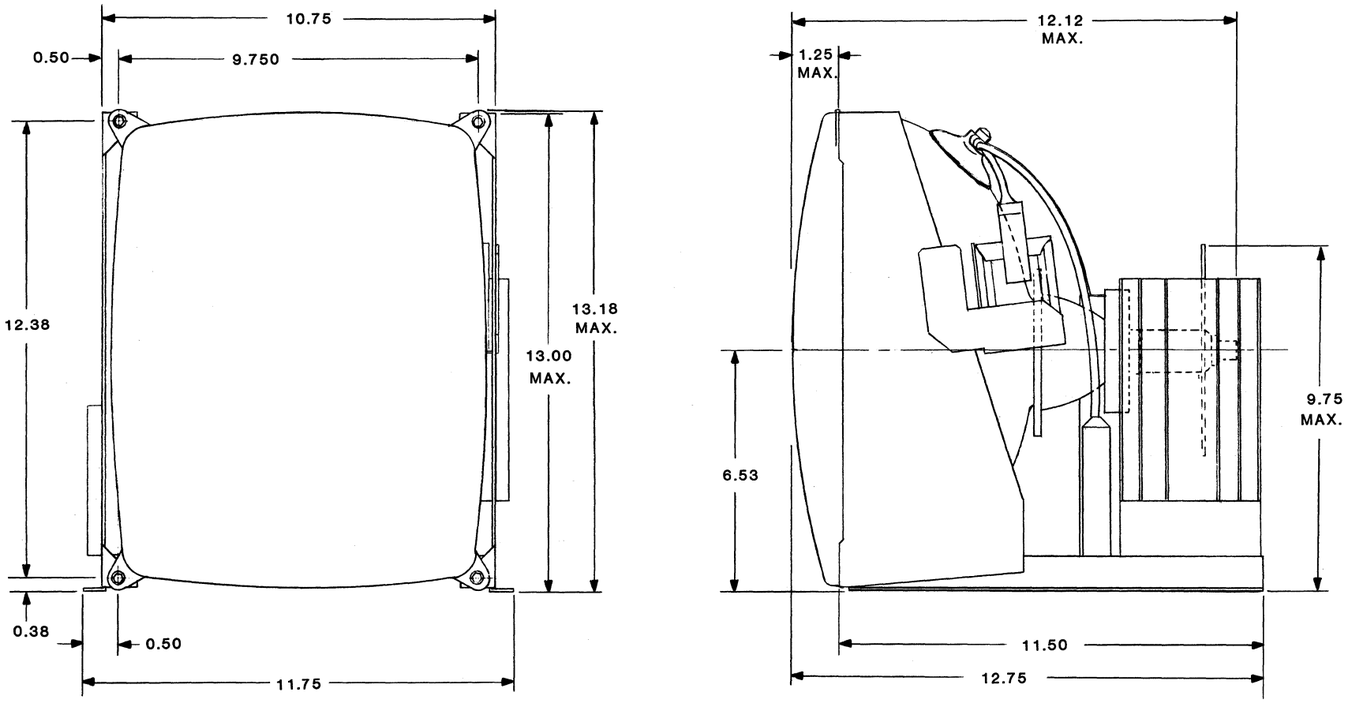
HORIZONTAL TIMING FIGURE 1-3

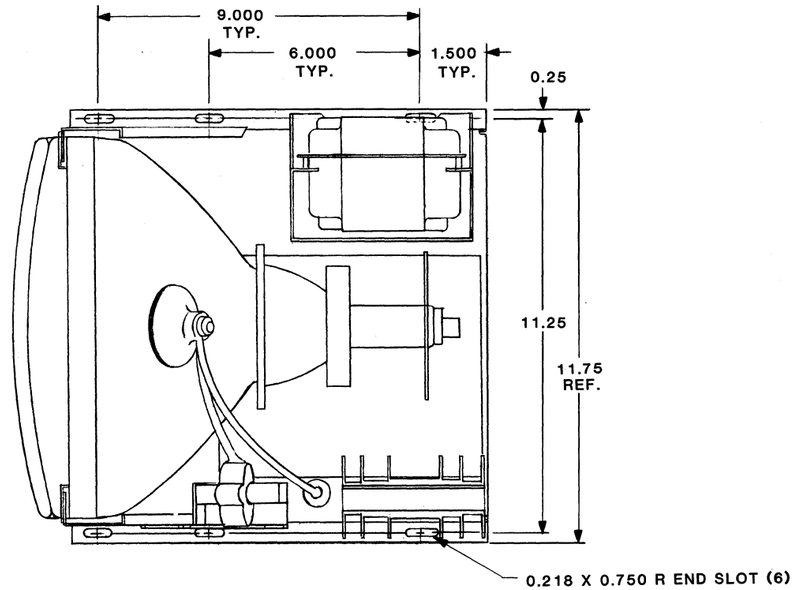


VERTICAL TIMING FIGURE 1-4



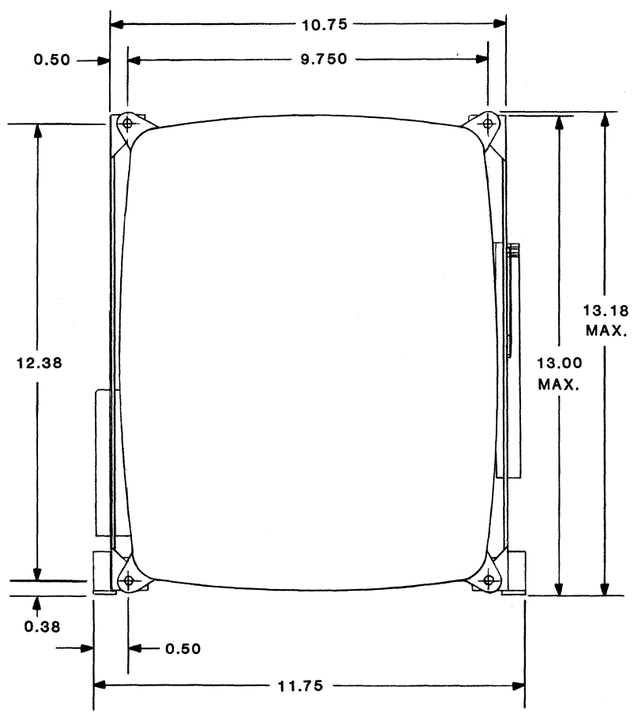
DIMENSIONS, HD15H (5° CRT TILT), FIGURE 1-5

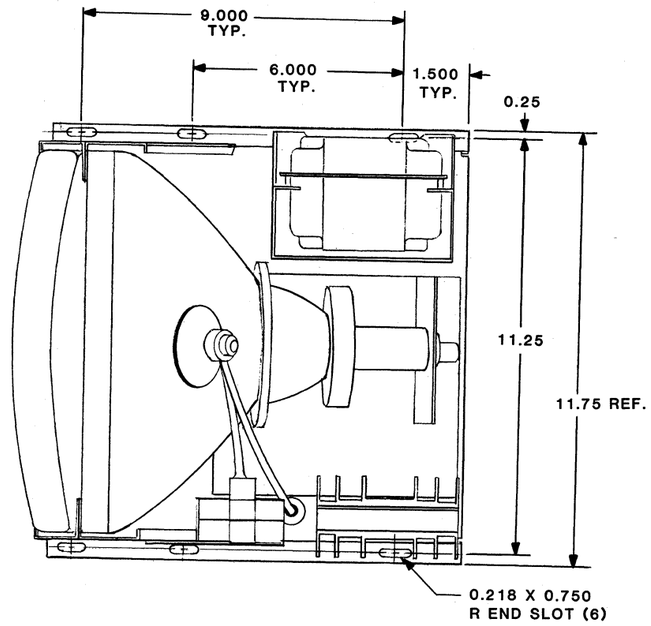


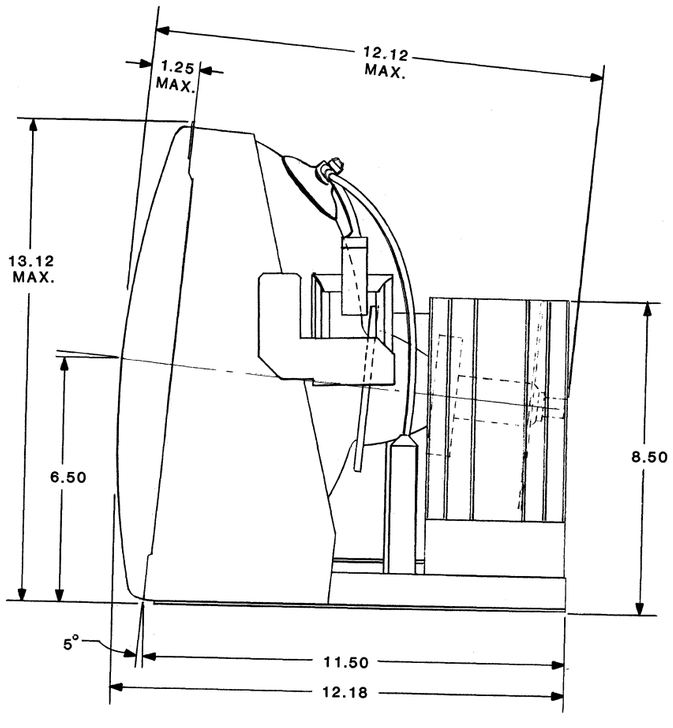


NOTE: TYPICAL LOCATION OF PWA'S & INPUT JACKS ARE SHOWN IN FIG. 1-5

DIMENSIONS, HD15V (0° CRT TILT), FIGURE 1-6

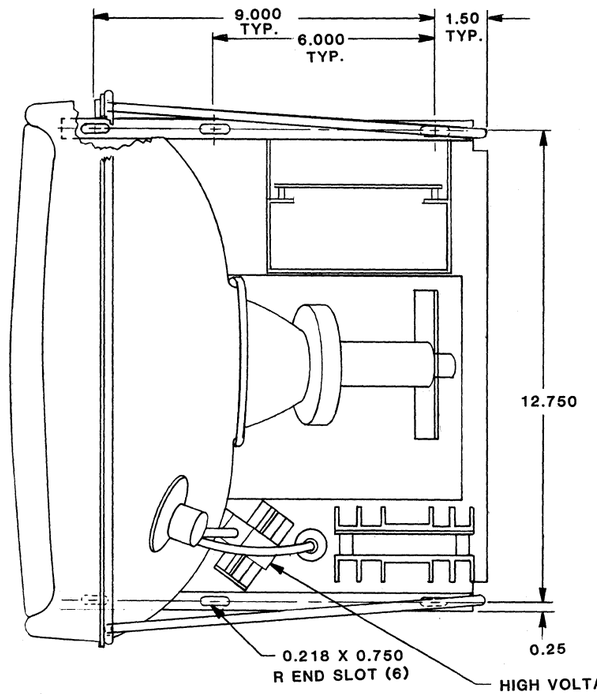


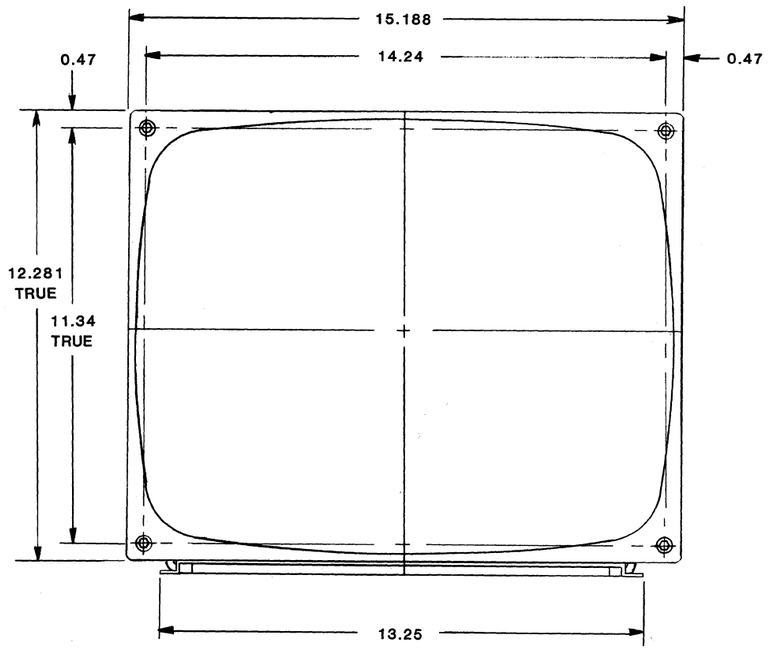


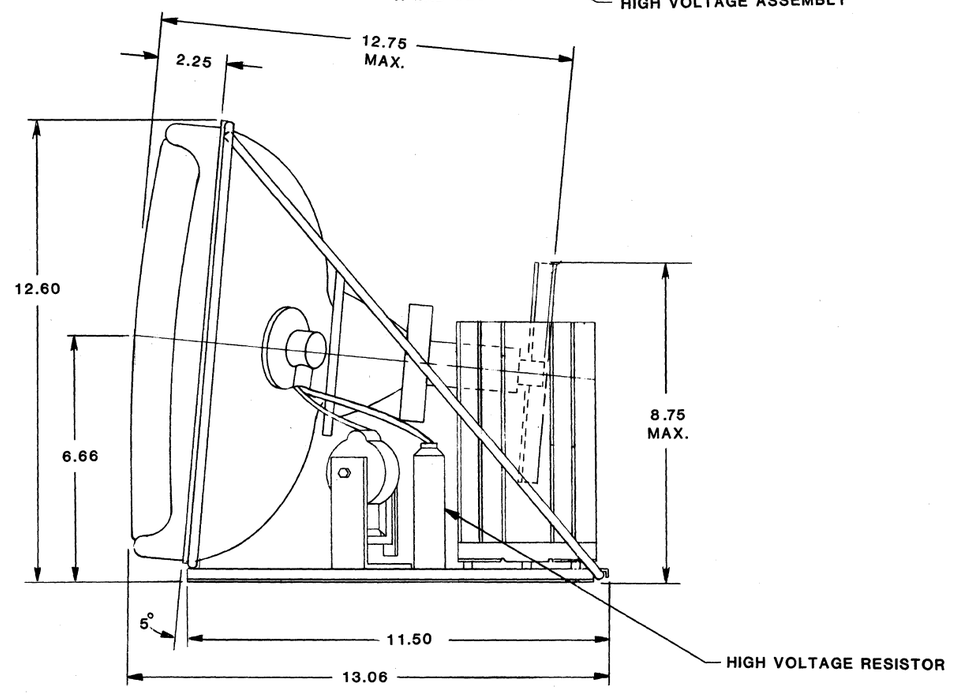


NOTE: TYPICAL LOCATION OF PWA'S & INPUT JACKS ARE SHOWN IN FIG. 1-5

DIMENSIONS, HD15V (5° CRT TILT), FIGURE 1-7

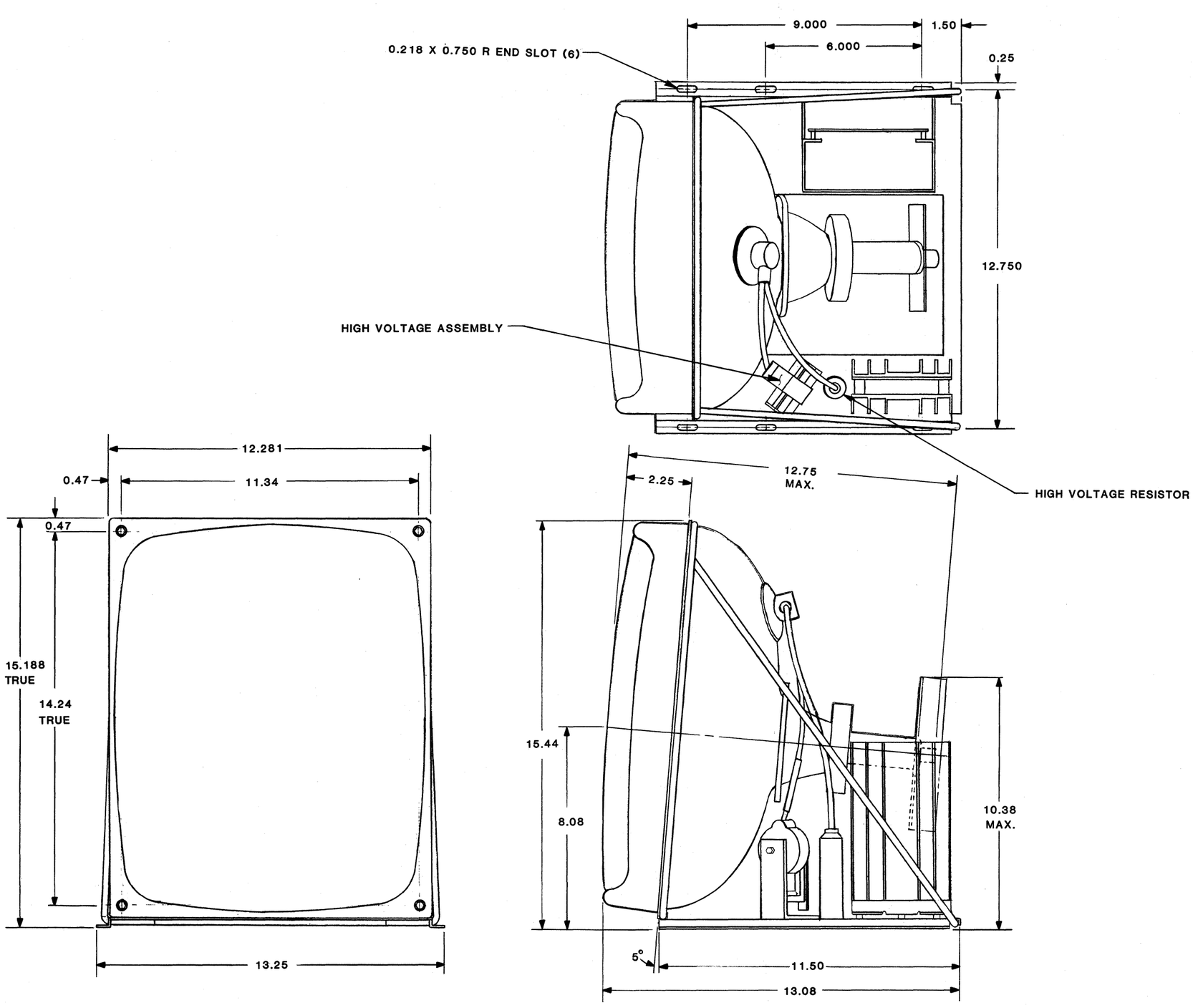






NOTE: TYPICAL LOCATION OF PWA'S & INPUT JACKS ARE SHOWN IN FIG. 1-5

DIMENSIONS, HD17H (5° CRT TILT), FIGURE 1-8



NOTE: TYPICAL LOCATION OF PWA'S & INPUT JACKS ARE SHOWN IN FIG. 1-5

DIMENSIONS, HD17V (5° CRT TILT), FIGURE 1-9

SECTION 2

INSTALLATION

2.1 MECHANICAL

Monitors are provided with four mounting holes on the bottom of the chassis. See Figures 1-5 through 1-9 for hole spacing data and dimensions.

2.2 ELECTRICAL

2.2.1 INPUTS

Monitors are supplied with two factory wired plugs (P1). The one chosen, when mated with J1, determines the required supply voltage and connections to J2. P1 plugs are stamped to indicate operating voltage required. Insure that J2 inputs match the supply voltage stamped on the P1 plug being used.

J2 Contact Identification:

PIN	FOR 120 VAC P1	FOR 220 VAC P1	FOR 240 VAC P1
1	Voltage Pin	Not Used	Voltage Pin
2	Ground	Ground	Ground
3	Not Used	Voltage Pin	Not Used
4	Voltage Pin	Voltage Pin	Voltage Pin

J3 Contact Identification:

TTL Digital or TTL Analog Video:

PIN	
1	Horizontal Sync
2	Vertical Sync
3	Sync Ground
4	Video
5	Not Used
6	Video Ground

ECL Digital Video:

PIN	
1	Horizontal Sync
2	Vertical Sync
3	Sync Ground
4	Balanced Video Input Pin
5	-5.2 volts
6	Balanced Video Input Pin

J107 (For Optional External Brightness):

PIN	
1	High side of 50 K Potentiometer
2	Not Used
3	Wiper of 50 K Potentiometer
4	Low Side of 50 K Potentiometer

Suggested Mating Connectors:

P1: Factory Supplied, Pre-wired

P2: Molex #03-06-1042, Model 1625-4 or equivalent

P3: Molex #03-06-1062, Model 1625-6 or equivalent

P4: Molex #09-50-3041, Model 2478 or equivalent

2.2.2 VIDEO

Video input lines should be twisted pair, short as possible, and separated from all other wiring.

2.2.3 GROUNDING

It is recommended that Monitor frame be tied to system ground.

NOTE: Insure Monitor frame is in solid electrical contact with terminal or console frame.

SECTION 3

ALINEMENT

Monitor is factory alined and should not require any further alinement. Following information is furnished for future reference.

Equipment Required:

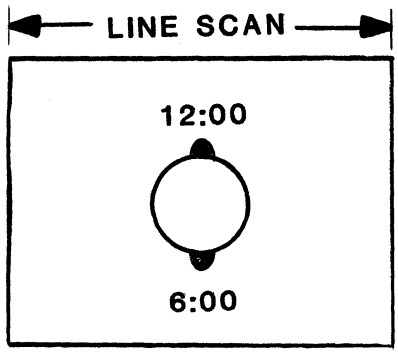
1 - Screwdriver suitable for potentiometer adjustment.
1 - Allen Wrench suitable for coil slug adjustment.
1 - Oscilloscope with 10:1 probe.
1 - Video Generator with appropriate line rate, field rate and video format.
1 - Digital dc voltmeter
1 - Light meter calibrated in foot lamberts.
Adhesive suitable for securing focus magnets.

3.1 PRELIMINARY

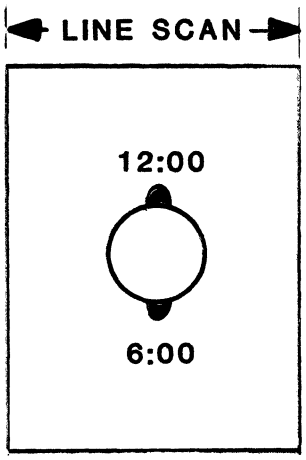
Notes:

1. Line scan must be horizontal for this procedure.
2. Throughout this procedure: ADJUST means a preliminary adjustment. SET means a final adjustment.

a. Adjust centering ring tabs to six and twelve o'clock positions as shown:



HORIZONTAL FORMAT



VERTICAL FORMAT

b. Set linearity sleeve so its dotted calibration mark and the rear of the plastic yoke collar are alined. (Foil on inside sleeve surface.)
c. Rotate yoke slightly in either direction.

3. 2 OVERVOLTAGE THRESHOLD

a. Adjust OVER V ADJ (R126 of the Vertical and Horizontal PWA) to 1/3 clockwise position. (As viewed from the side of R126 nearer the edge of the board.)

b. Set [B + ADJ] (R314 on the Power Supply) to mid-range.
c. Connect dc digital voltmeter between TP301 (+70 V on the Power Supply) and the ground lug of Power Supply capacitor C1.
d. Connect video generator (set for crosshatch test or similar linearity pattern) to Monitor.
e. Turn Monitor and video generator on.
f. Adjust [B+ LIMIT ADJ] (R316 on Power Supply), if necessary, to obtain voltmeter reading of +70 volts.
g. Place 10:1 oscilloscope probe about 2" from T2 (on chassis) and insure horizontal deflection stage is operative.
h. Using [B+ LIMIT ADJ] increase voltage to +73.5 volts.
i. Set [OVER V ADJ] by adjusting slowly clockwise until horizontal deflection stops. (Observe with 10:1 probe 2" from T2.)
j. Using [B+ LIMIT ADJ] slowly lower voltage to +70 volts and slowly raise voltage to +73.5 volts to insure deflection starts above +70 volts and stops at approximately +73.5 volts. Change [OVER V ADJ], if necessary, to meet these conditions.

3.3 POWER SUPPLY

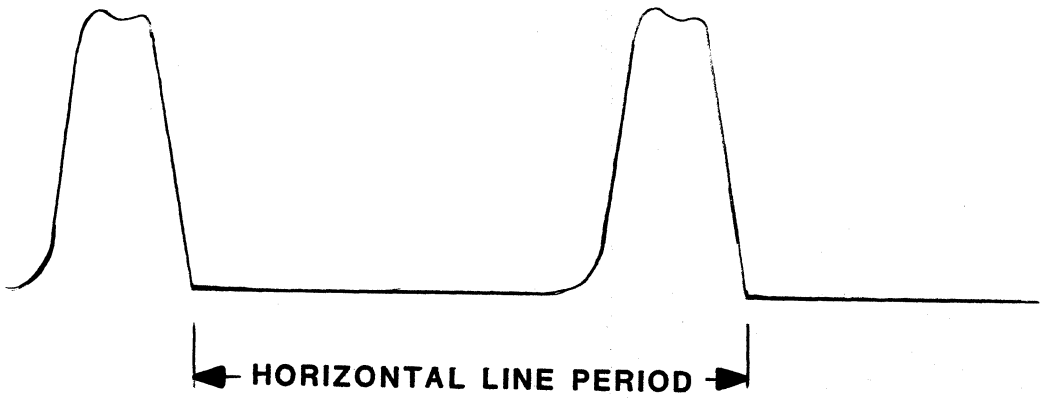
a. Set [B+ LIM ADJ] to provide +70 volts.
b. Check TP302 for +35 volts nominal.

3.4 HORIZONTAL AND VERTICAL

a-1. For Monitor with TTL Video Amplifier: Adjust [GAIN] (R202) to mid-range.
a-2. For Monitor with ECL Video Amplifier: Adjust [GAIN ADJUST] (R211) to mid-range.
a-3. For Monitor with Linear Video Amplifier: Adjust [CONTRAST] (R203) to mid-range.

NOTE: The following steps require Monitor warm-up of at least 5 minutes.

b. Set [H DATA CTRG] (R111) so video data is centered in the raster. If necessary adjust [HORIZ OSC] (R108) to lock picture horizontally.
c. Set oscilloscope to internal trigger and time base to 10 usec/div.
d. Observe horizontal flyback pulse at TP111.
e. Note the time for the horizontal line period.



f. Disable Horizontal Sync input to Monitor.
g. Set [HORIZ OSC] so horizontal line period is 2 usec longer than the time noted in step e.
h. Supply Horizontal Sync input to Monitor.
i. Check centering of video data in raster and repeat step b if necessary.
j. Adjust [H WIDTH] (L101) so raster width is approximately correct.
k. Adjust [VERT CTRG] (R159) so first data line is near top of faceplate.

NOTE: [VERT CTRG] and [HGT] (in step l) work together for orienting raster in direction of field scan.

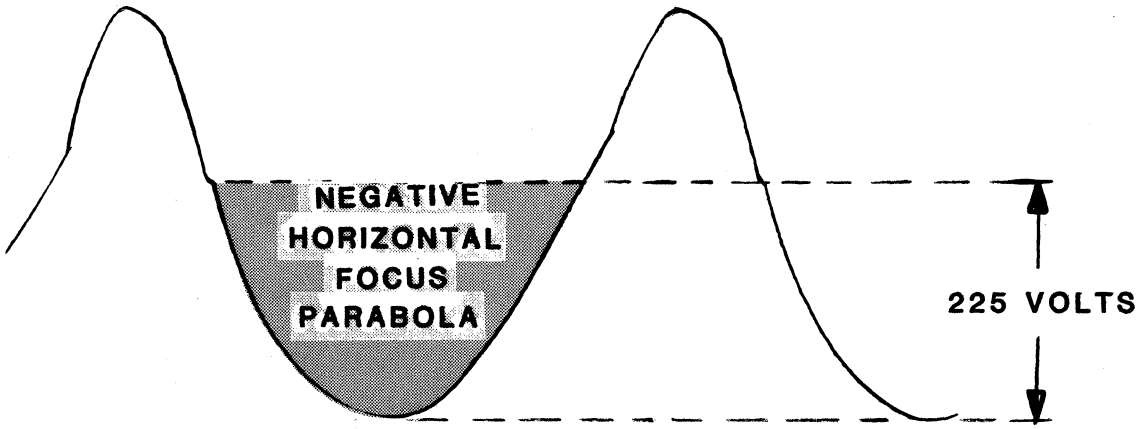
l. Adjust [HGT] (R151) so last data line is near bottom of faceplate.
m. Horizontally center the raster by adjusting the centering ring tabs.

NOTE: Tabs are used to horizontally center the raster. They must be adjusted in such a way as to introduce a magnetic vector which shifts raster only in the line scan direction. They are not to be used for field scan orientation. To prevent vertical raster displacement always maintain tab symmetry about the horizontal center. Example: Preliminary tab settings were six and twelve o'clock. Moving tabs to one and five o'clock will shift raster horizontally in one direction. Moving tabs to two and four o'clock will shift raster further in same direction. Moving tabs to seven and eleven o'clock will shift raster in opposite direction. Tab movement to eight and ten o'clock will shift raster further in opposite direction.

3.5 FOCUS

a. Adjust [H FOCUS] (L102) to mid-range.
b. Observing TP127, set [H FOCUS] to obtain waveform shown.

NOTE: Waveform should be obtained with [H FOCUS] slug partially extending from lower end of winding.



c. Turn Monitor power off.
d. Turn Monitor power on.
e. Check waveform at TP127 to insure it has not flipped over. If it has, repeat steps a through e.
f. Set video generator for alphanumeric test pattern.
g. Observe corner dots on CRT while adjusting [DC FOCUS] (R140) throughout its entire range. Note that the dots are elliptical and their long axes rotate in response to [DC FOCUS] adjustment.

h. Set [DC FOCUS] so long axes of corner dots are vertical.
i. Attach and secure magnets for best geometry and focus. Geometry outline should be rectangular with tolerance of ± 0.1". Switch between crosshatch and alphanumeric patterns as required.
j. Remove video input.
k-1. For Monitor with TTL Video Amplifier: Adjust [GAIN] for minimum brightness.
k-2. For Monitor with ECL Video Amplifier: Adjust [GAIN ADJUST] (R211) for minimum brightness.
k-3. For Monitor with Linear Video Amplifier: Adjust [CONTRAST] (R203) for minimum brightness.
l. Adjust external brightness control (customer supplied) or internal [BRT] (R175) for maximum brightness.
m. Set [BRT LIM] (R179) for raster brightness of 5 foot lamberts.
n. Set external brightness control or internal [BRT] at threshold of CRT light extinction.
o. Set video generator for white field without characters and connect to Monitor.
p-1. For Monitor with TTL Video Amplifier: Set [GAIN] for rated light output.
p-2. For Monitor with ECL Video Amplifier: Set [GAIN ADJUST] for rated light output.
p-3. For Monitor with Linear Video Amplifier: Set [CONTRAST] for rated light output.
q. Set [VERT CTRG] and [HGT] to desired height.
r. Set [H WIDTH] to desired width.
s. Using guidelines noted in 3.1.4, step m, horizontally center the white field.

NOTE: If slightly more width is desired, withdraw linearity sleeve 0.1".

SECTION 4

THEORY OF OPERATION

This section, in addition to presenting theory of operation, has been printed to facilitate use in troubleshooting. Each schematic is faced by its corresponding Test Points Location figure.

4.1 INTERCONNECTION DIAGRAM, FIGURE 4-1

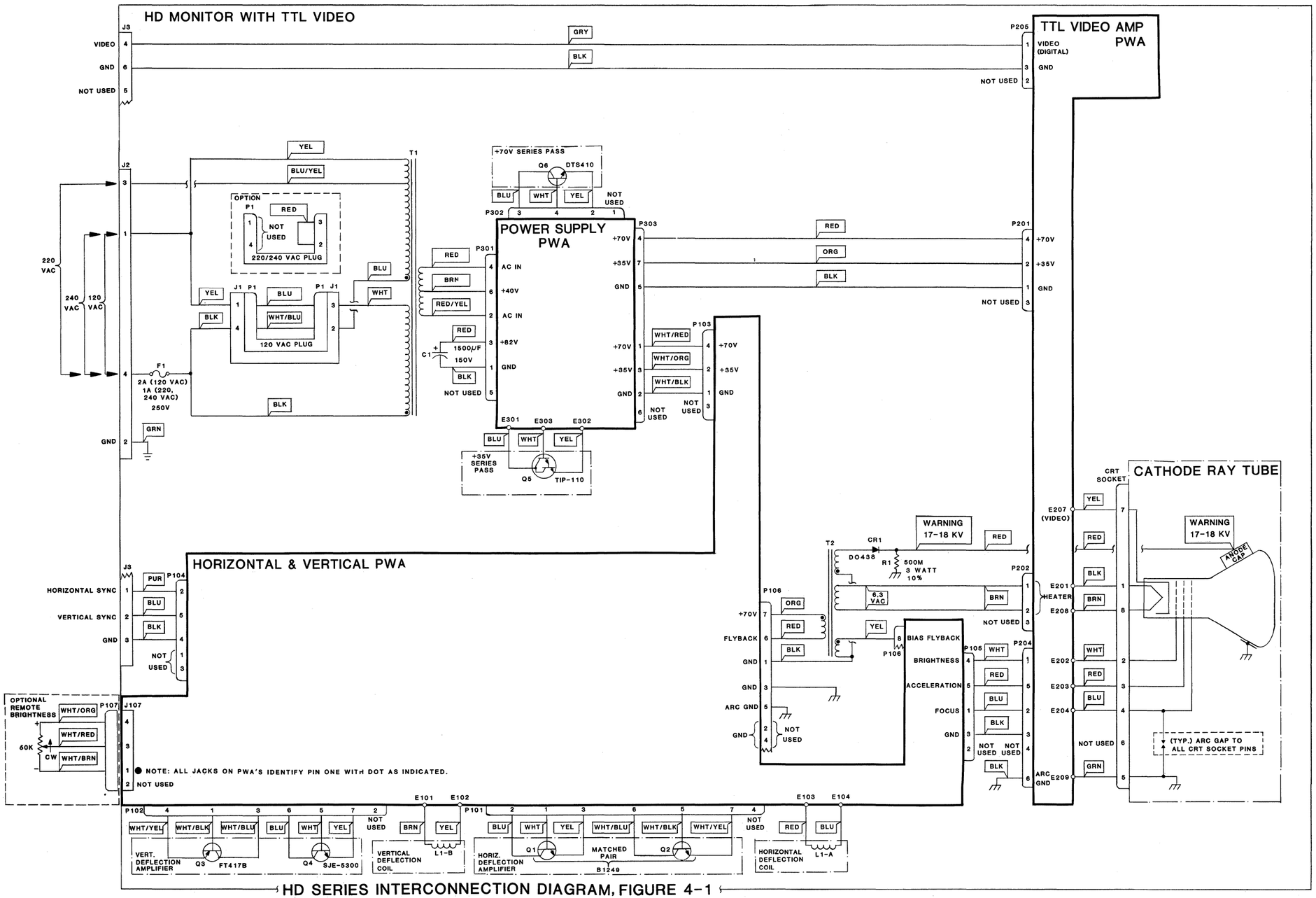
All HD Series Monitors use the same:

a. Horizontal and Vertical PWA
b. Low Voltage Power Supply PWA
c. Chassis mounted components (Except deflection yoke and horizontal flyback transformer.)

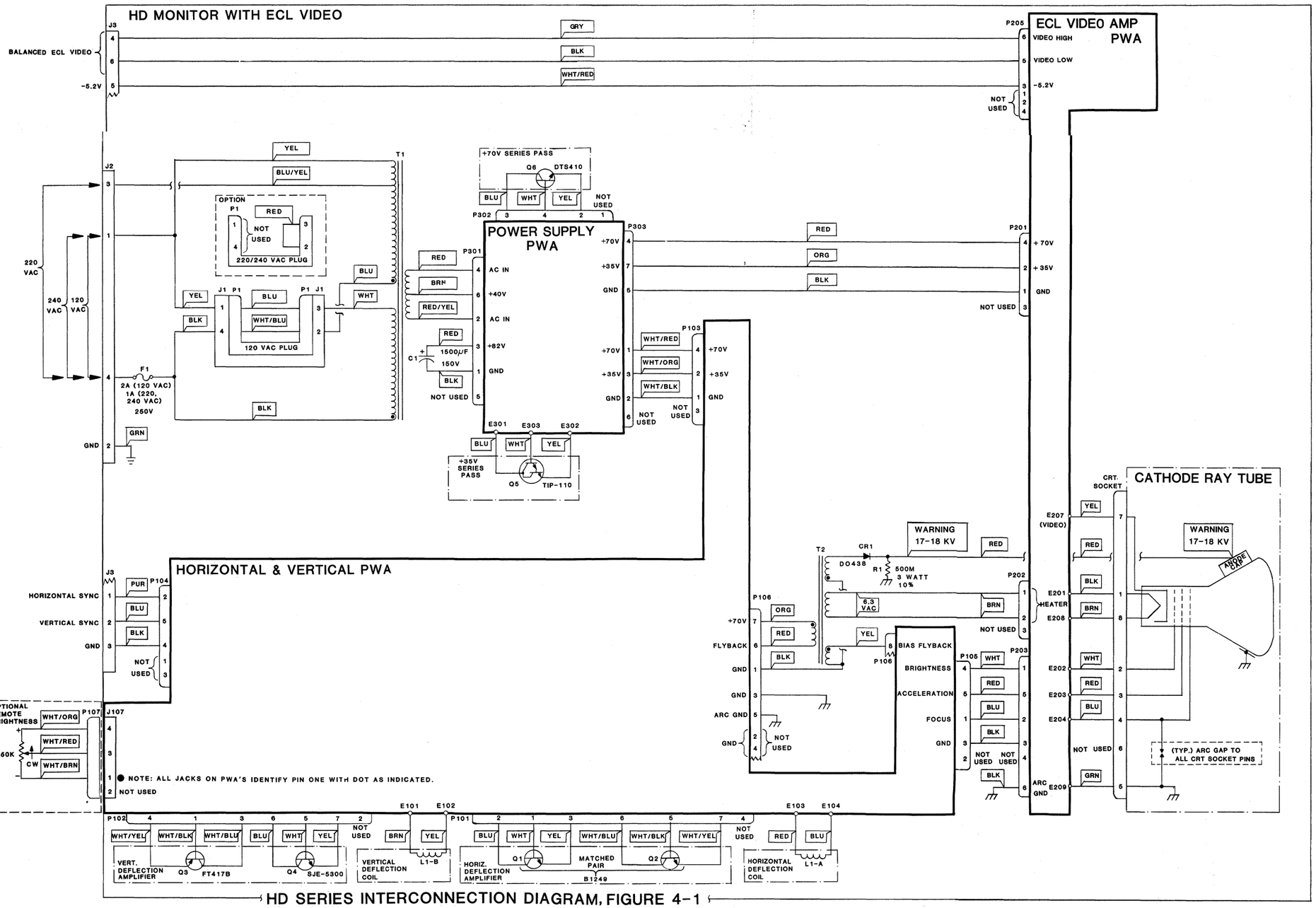
However, some component values used for the Horizontal and Vertical PWA are not standard. They are determined by the Monitor's specific use, choice of options, format, etc. Theory of operation is not affected by these variables, although they are documented on the schematics. The standard version Monitor uses TTL digital video. Interconnection Diagram, Figure 4-1, presents this standard version. There are two optional video input versions:

a. TTL Analog Video (Using a Linear Video Amplifier)
b. ECL Digital Video

The Interconnection Diagram has been printed so it can be folded to show either optional version. For the ECL Digital Video Interconnect, fold the top portion forward (and over) along the horizontal dotted line. For the TTL Analog Video Interconnect, fold the right side forward (and over) along the vertical dotted line. The Interconnection Diagram has been drawn so that inputs enter at left and outputs leave at right.



HD SERIES INTERCONNECTION DIAGRAM, FIGURE 4-1



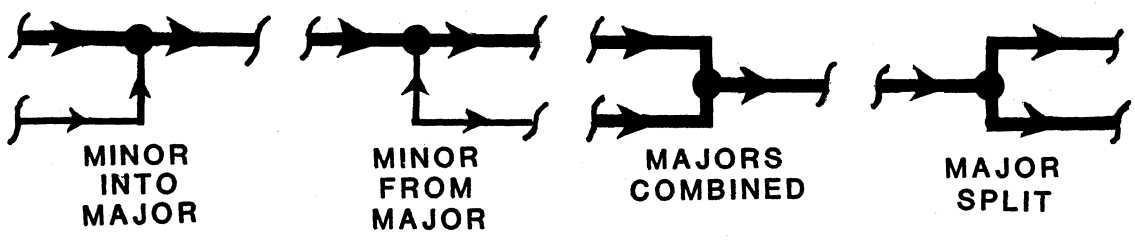
HD SERIES INTERCONNECTION DIAGRAM, FIGURE 4-1

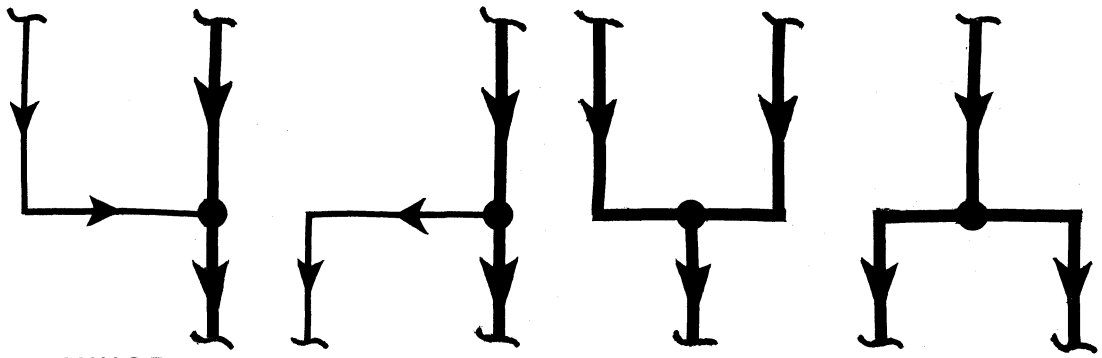
4.2 FUNCTIONAL BLOCKED SCHEMATIC STANDARDS

Schematics have been blocked into functional circuits. Block outlines are indicated by thin dash-dot-dash lines. Each block is number coded and identified in the upper, left-hand corner. The number code (circled) is the key to locating theory for that block, since each PWA theory section is consecutively numbered to this code. The identification (usually three letters with a dash number) is spelled out in the theory section. For example, AMP stands for amplifier, OSC for oscillator. The dash numbers are assigned consecutively in a schematic to identify different amplifiers, oscillators, etc.

Where practical, other standards used in schematic presentation are:

a. Major signal (data) flow is from left to right and is indicated by heavy lines and single arrowheads (—►).
b. Minor signal flow (also from left to right) is indicated by standard lines and single arrowheads (—►).
c. Feedback signal flow is from right to left and is indicated by double arrowheads (◄◄—).
d. Voltage reference signals are indicated by bullet-shaped arrowheads (—●►).
e. Hollow arrowheads (—▷) indicate fault signals. For example, an overvoltage protection circuit would have a hollow arrowhead signal. The actual signal would not be present unless an overvoltage condition (fault) occurred.
f. Input voltages are at top and grounds are at bottom of the blocks.
g. Inputs go in at left and outputs leave at right of blocks.
h. Test points are located throughout schematics and are indicated by hollow triangles containing TP and identifying numbers. Below each schematic are test point location guides. These are grouped by function and located so schematic triangles and location guide triangles point at each other as though connected by a straight vertical line.
i. Some components (such as resistors and capacitors) which change value depending on Monitor application (such as changing from horizontal to vertical format) have their reference designations (R146, C133, etc.) enclosed in bullet-shaped box (◄R146). Tabulated value changes are located at the left edge of the schematic. Each bullet-shaped box points along an imaginary straight horizontal line to its own respective values in the table. Other components which also change value from one application to another are not easily fitted into tabular form. These components are noted with an asterisk. Values noted for these components are typical values for a vertical format Monitor with horizontal frequency of 31.5 kHz.
j. Information such as voltage levels and warnings are enclosed in flag-shaped boxes which point to item concerned [+ 350V].
k. Signal flow direction has been given priority over hardware outlines ; therefore, hardware is shaped to accommodate requirement that signal flow be shown left to right.
l. Lines do not cross unless connected. Those which would ordinarily cross without connection are interrupted by broken line symbols (—∫∫—).
m. Power and signal flow lines are connected to show the order of importance as shown:





n. Options are enclosed in dashed boxes and the contents are shown in dashed form. Options are determined by Monitor application.
o. Adjustments are indicated by shadowed boxes (▭) and the notation inside appears the same as shown on the printed circuit board.

4.3 HORIZONTAL AND VERTICAL PWA THEORY

Refer to Horizontal and Vertical Functional Blocked Schematic, Figure 4-3.

HORIZONTAL DRIVE: Functional blocks (1) through (27) provide horizontal drive for the CRT. They will accept either a positive or negative sync pulse and produce correctly timed and properly shaped current ramp and flyback voltage for use by horizontal coil. One cycle involves:

NOTES:
1. Electron beam movement directions are for viewer observing face of the CRT. (Conventional scan direction.)
2. Coil current polarity assumes conventional current flow (+ to -).
3. Beam movement is smooth and continuous throughout cycle.
4. All numerical values are approximate.

A. DEFLECTION FROM CENTER SCREEN TO EXTREME RIGHT: Prior to receipt of sync pulse: AMP-3 is off. C125 in FIL-3 has been charged to +70 volts. Charge path has been (refer to FIL-2) from +70 volts through R130, through primary of TFR-2, through horizontal coil and FIL-3 to C125. There is no coil current and no beam movement. When the sync pulse is received it is coupled through CPL-1, AMP-1, CPL-2 to OSC-1 where it ends the sawtooth output of OSC-1. The negative-going trailing edge of the sawtooth is coupled through CPL-3 and ICB-1, triggering IC-1. Output pin 3 goes high, (which affects nothing) and discharge pin 7 ungrounds C105-C106 in RCD-1. When the adjustable RC time constant of RCD-1 allows pin 6 of IC-1 to reach the reference voltage level of VR-2, IC-1 switches state so that pin 7 grounds C105 -C106 and pin 3 goes low. The negative-going pin 3 output is coupled through LR-1, CPL-4, ICB-2 and triggers IC-2. Notice that IC-2, RCD-2 and VR-3 are identical to IC-1, RCD-1 and VR-2 except for the values of the RC time constants and the fact that RCD-2 has a fixed delay. When IC-2 is triggered, the output (pin 3) goes high. After RCD-2 times out, the output

goes low. The resultant square-wave output is coupled through LR-2 and CPL-5. It switches AMP-2 on and off at a 50% duty-cycle rate. AMP-2 output feeds into TFR-1 which provides 10:1 current gain in the secondary. Notice that TFR-1 is phased so that AMP-2 and AMP-3 are 180^{o} out of phase. When AMP-2 is switched off, AMP-3 is switched on. C125 in FIL-3 now begins to discharge through the parallel FIL-3/horizontal coil combination, through AMP-3 to ground. (Note, however, that C125 is large enough in capacitance so it is never fully discharged during Monitor operation.) As the coil current increases, the electron beam is moved from center to the right. When coil current = 4 amps, the beam is at extreme right of CRT. The velocity of the beam movement is determined by two things: Speed, which is proportional to the magnitude of voltage across the coil; direction (to left or right of center), which is determined by which way coil current flows.

B. FLYBACK FROM EXTREME RIGHT TO CENTER SCREEN: Flyback is intiated when AMP-3 is shut off. The magnetic fields around L101 and L1-A induce a +400 volt, 6 µs pulse @ TP111 when AMP-3 shuts off. This flyback pulse charges C118 in DT-1. (It is also used by TFR-2 primary.) Because the voltage is so much larger, beam movement is very rapid. Coil current, while flowing in the same direction, decreases rapidly from 4 to zero amps. Beam is now back to center of CRT.

C. FLYBACK FROM CENTER SCREEN TO EXTREME LEFT: The +400 volt charge on C118 now pushes coil current in the opposite direction. Current flow path is from C118 through FIL-3/coil into C125. Because of the high voltage, (and resultant high current) beam movement is very rapid. Since coil current is reversed, beam moves from center to extreme left of CRT at which point coil current = 4 amps.

D. DEFLECTION FROM EXTREME LEFT TO CENTER SCREEN: After C118 has discharged, the magnetic fields start to collapse and induce a negative voltage at TP111. Since the damper diodes CR104, CR105 in DT-1 will now be forward biased, TP111 will be clamped to one diode voltage below ground. Coil voltage magnitude is proportional to the voltage across C125. Because this voltage has not appreciably changed, the speed of the beam movement is the same as under Step A. Coil current decays from 4 toward zero amps and the beam moves toward center of CRT. Just prior to beam actually reaching center, AMP-3 is switched on and cycle A, B, C, D repeats.

(1) TR-1: (TERMINATION RESISTOR) For Horizontal Sync.
OPTION 1: Provides choice for input sync signal grounding.
(2) CPL-1: (COUPLER) Couples + or - sync pulse to AMP-1.
(3) AMP-1: (AMPLIFIER) With OPTION 2, gives capability of providing negative output pulse with either + or - input pulses.
OPTION 2: Using W112 provides negative output from positive input pulse. Using W111 provides negative output from negative input pulse.
(4) CPL-2: (COUPLER) Differentiates sync pulse (with R107, R187, R106 in OSC-1).
(5) OSC-1: (OSCILLATOR) Purpose of OSC-1 is to provide raster in absence of sync pulse. Negative sync pulse spike turns Q110 on. Q110 turns Q111 on. C102 is discharged rapidly through Q110-Q111; both turn off at end of spike. HORIZ OSC adjustment determines charge time of C102 (through R109-R108.) Charge time determines OSC-1 free-run frequency, which is set to be slightly slower than sync pulse frequency. This way, sync pulse always controls Q110-Q111 turn on. Output wave shape is sawtooth.

(6) CPL-3: (COUPLER) With R110, R113 in ICB-1, differentiates OSC-1 output, passing the negative-going, trailing edge of the sawtooth from OSC-1.
(7) ICB-1: (INTEGRATED CIRCUIT BIAS) Dc bias for IC-1, Pin 2.
(8) IC-1: (INTEGRATED CIRCUIT) Connected as monostable multivibrator. Purpose of IC-1 (together with RCD-1) is to provide an adjustable time delay. Quiescent state causes C105-C106 in RCD-1 to be shorted and IC-1 output (pin 3) to be low. Negative input pulse sets IC-1 so short is removed and output is high. Reset occurs when RCD-1 voltage equals VR-2 reference voltage (approximately 7.3 volts.)
(9) VR-1: (VOLTAGE REFERENCE) Provides +3.5 volts to pin 4 of IC-1. In effect, disables pin 4 as an input to IC-1.
(10) RCD-1: (RC DELAY) [H DATA CTRG] adjustment varies R111-R112, C105-C106 time constant. Longer RC time shifts raster data to left. Shorter time shifts data to right.
(11) VR-2: (VOLTAGE REFERENCE) Bypass capacitor stores reference voltage of about 2/3 IC-1 supply voltage.
(12) LR-1: (LOAD RESISTOR) For IC-1, Pin 3.
(13) CPL-4: (COUPLER) Ac coupling capacitor.
(14) ICB-2: (INTEGRATED CIRCUIT BIAS) Dc bias for IC-2, pin 2.
(15) IC-2: (INTEGRATED CIRCUIT) Identical in function to IC-1 except associated delay from RCD-2 is fixed, not adjustable. Establishes pulse width of TFR-1 output.
(16) OVP-1: (OVERVOLTAGE PROTECTION) Schmitt trigger with Q102 normally off, Q103 normally on. Should +70 volt increase 5% or more, Q102 switches on, turning Q103 off. OVP-1 output is grounded, disabling IC-2. With no IC-2 output, horizontal deflection stops, producing no further high voltage for CRT. This prevents excessive x-radiation from abnormally high supply voltage. Normal operation resumes when supply overvoltage condition ends. [OVER V ADJ] set to turn on OVP-1 at +73.5 volts.
(17) RCD-2: (RC DELAY) Identical in function to RCD-1 except there is no adjustment.
(18) VR-3: (VOLTAGE REFERENCE) Identical in function to VR-2.
(19) LR-2: (LOAD RESISTOR) For IC-2, pin 3.
(20) CPL-5: (COUPLER) R121 couples IC-2 output to AMP-2. CR103 provides faster AMP-2 switching by conducting when Q104 is turned off.
(21) AMP-2: (AMPLIFIER) Drives TFR-1 primary. Inductive voltage kick of primary causes overshoot which helps produce 100 volt, 50% duty-cycle square wave output at TP109. C113 helps filter inductive voltage kick.
(22) TFR-1: (TRANSFORMER) Provides 10:1 voltage step down phased so AMP-3 is off when AMP-2 is on. Voltage reduction yields a proportional current gain to provide base drive for AMP-3.
(23) FIL-1: (FILTER) Helps shape current ramp output of AMP-3.
(24) AMP-3: (AMPLIFIER) Supplies up to about 4 amps sawtooth deflection coil current. T102 provides negative feedback between emitters to equalize switching times and insure Q1 and Q2 equally share the deflection coil current.
(25) DT-1: (DAMPER & TUNING) CR104-CR105 are damper diodes which prevent flyback pulse oscillation by providing a path for deflection coil current to continue circulation. C118 aids deflection coil current ramp shaping. NOTE: E105 and E106 provide capability of paralleling C118 with optional component.
(26) FIL-3: (FILTER) [H WIDTH] adjusts raster width. L101-B controls coil current magnitude. L101-A maintains constant load for AMP-3. C125 provides S-shaping and blocks dc current.

(27) HORIZONTAL COIL: Provides electron beam deflection for line scan and flyback.

VERTICAL DRIVE: Functional blocks (28) through (51) provide vertical drive for the CRT. They will accept a negative sync pulse and produce correctly timed and properly shaped current ramp and flyback voltage for use by vertical coil. One cycle involves:

A. FLYBACK TO TOP OF SCREEN: Negative sync pulse causes IC-3 to change state so that:
   1. Pin 3 goes low: causes +130 volt output from VB-1.
   2. Pin 7 is grounded:
      a. C130 in STG-1 starts discharging.
      b. C129 in VR-4 starts discharging.
      c. Turns on: EF-1, AMP-4, Q3 in AMP-5.
      d. Turns off: Q4 in AMP-5.

   Under this set of conditons, +130 volt causes rapid deflection coil current buildup for flyback. (Beam moves to top.)

B. DEFLECTION FROM TOP TO BOTTOM OF SCREEN: When C129 in VR-4 discharges to +5 volts, IC-3 changes state so that:
   1. Pin 3 goes high:
      a. VB-1 output ends.
      b. VR-6 provides reference for pedestal step voltage at initial start of sawtooth.
   2. Pin 7 is no longer grounded:
      a. C130 in STG-1 starts charging, producing a sawtooth waveform.
      b. C129 in VR-4 starts charging.

   NOTE: Should C129 be allowed to charge to +10 volts, it would cause IC-3 to change state. However, in normal operation, another sync pulse would occur prior to this happening.

   Under this set of conditions, the sawtooth is coupled through EF-1, CPL-8, AMP-4 to AMP-5. This produces deflection coil current making beam deflect. (Beam moves from top to bottom of CRT.) Cycle repeats when next sync pulse occurs.

(28) TR-2: (TERMINATION) For Vertical Sync input.
(29) ISO-1: (ISOLATION) Provides Vertical Sync pulse isolation.
(30) CPL-6: (COUPLER) With R143, R144 in ICB-3, differentiates sync pulse.
(31) ICB-3: (INTEGRATED CIRCUIT BIAS) Dc bias for IC-3, pin 4.
(32) IC-3: (INTEGRATED CIRCUIT) Connected as an astable multivibrator whose free-run frequency is slower than sync pulse frequency. Purpose of IC-3 (along with VR-4, VR-5) is (during scan) to allow C130 in STG-1 to provide a sawtooth and (during flyback) to discharge C130 and turn VB-1 on. Initially, in the set condition (waiting for sync pulse), C129 (VR-4) is charging; IC-3, pin 3 is high; IC-3, pin 7 is not shorted to ground. Sync pulse resets IC-3 so pin 7 is shorted to ground, pin 3 is low. When C129 discharges (through R146 to pin 7) to +5 volts IC-3 sets to initial state.

(33) VR-4: (VOLTAGE REFERENCE) Monitors STG-1 feedback. Should output @ TP118 reach +10 volts (free-run state) IC-3 reset would cause pin 7 to be shorted to ground and IC-3 output (pin 3) to go low. In normal operation, sync pulse causes IC-3 to reset prior to +10 volts @ TP118. IC-3 set (where pin 7 is not shorted and pin 3 is high) occurs when voltage @ TP118 drops to +5 volts as determined by RC time constant R146-C129.

(34) VR-5: (VOLTAGE REFERENCE) Identical in function to VR-2.

(35) STG-1: (SAWTOOTH GENERATOR) [HGT] provides adjustment of sawtooth slope determined by RC time constant (combination of R193, R148, R192 when used, R149, R151 and C130.) R149 provides temperature compensation for sawtooth height.

(36) VR-6: (VOLTAGE REFERENCE) Provides small pedestal voltage step to initial part of RC curve in STG-1. Pedestal insures rapid initial response of AMP-5.

(37) DIS-1: (DISCHARGE) When the top of C130 is shorted to ground by IC-3, pin 7, the bottom of C130 goes negative. DIS-1 parallels R147 in VR-6 and provides additional discharge path for C130, limiting current carried by output stage of IC-3 (pin 3) to safe level.

(38) EF-1: (EMITTER FOLLOWER) Provides current gain for driving AMP-5.

(39) OVP-2: (OVERVOLTAGE PROTECTION) Protects EF-1 from high voltage transients.

(40) VR-7: (VOLTAGE REFERENCE) For AMP-4. [VERT CTRG] sets base bias for AMP-4. Since AMP-4 controls deflection coil current carried by AMP-5 and the amount of current determines raster position, then this adjustment controls raster position. R163 temperature compensates emitter-base junction of Q107 in AMP-4.

(41) CPL-8: (COUPLER) Couples sawtooth to AMP-4 and Q4 of AMP-5. L103 adds delay to compensate for extra stage (AMP-4) between R167 and Q3 of AMP-5.

(42) AMP-4: (AMPLIFIER) Provides drive signal for Q3 of AMP-5. Output level determines raster position.

(43) AMP-5: (AMPLIFIER) Complementary-symmetry amplifier supplies deflection coil current. CR110-CR112 provide temperature compensation for Q3-Q4. CR119 protects Q3 during flyback. During sawtooth: Q3 initally conducts fully and the amount of current conducted decreases to a minimum at the end of the sawtooth. Q4 conducts in the opposite manner; minimum at start, maximum at end. Full Q3 conduction makes the electron beam move to the top of the CRT face. Current flow is from +70 volts through CR110, R169, Q3, CR119, through the vertical coil and into C137. As the sawtooth voltage increases and Q3 conducts less, the beam is lowered.
During this portion Q4 is starting to conduct and larger amounts of current are diverted from the coil by going through Q4, CR112 and R164 to ground. Half way through the sawtooth, Q3 and Q4 are conducting equally. The entire current flows through Q3-Q4. Voltage at TP123 is half the supply voltage of +70 volts, or +35 volts. Since both sides of the coil are connected to +35 volts at this time (right side held to +35 volts through R172 in INT-1) no more current is supplied to the coil and the beam is at center. As the sawtooth voltage increases beyond the half way point the voltage across C137 (stored during first half of sawtooth) starts coil current in the opposite direction. Current path is from C137 through the deflection coil, Q4, CR112 and R164 to ground. Beam goes below CRT center and reaches bottom when sawtooth voltage is maximum. During flyback Q3 is fully on and Q4 is off. Supply voltage to Q3 is boosted by VB-1 to +130 volts providing maximum deflection coil current which moves beam rapidly to top of CRT face.

(44) CPL-7: (COUPLER) Ac coupling circuit for VB-1.

(45) VB-1: (VOLTAGE BOOST) Supplies voltage boost during flyback to provide faster retrace. Boosts +70 volts to +130 volts.
(46) CPL-9: (COUPLER) Ac feedback coupling circuit.
(47) VERTICAL COIL: Provides electron beam deflection to create raster and flyback.
(48) FIL-4: (FILTER) Provides coil damping during vertical flyback.
(49) OVP-3: (OVERVOLTAGE PROTECTION) Filters spike from coil induced voltage. Protects Q4 in AMP-5.
(50) CPL-10:(COUPLER) Ac feedback coupling circuit. Provides vertical parabola feedback for current ramp shaping.
(51) INT-1: (INTEGRATOR) Integrates deflection coil current sawtooth to create parabolic waveform. C137 stores energy during first half of sawtooth and supplies energy during last half at vertical rate. (Used for deflection coil current.)

CRT BIAS CIRCUITS: Functional Blocks (52) through (63) provide grid bias for brightness, acceleration and focus (both static and dynamic.)

(52) CPL-11:(COUPLER) Ac coupling circuit.
(53) AMP-6: (AMPLIFIER) Provides voltage amplification and phase inversion of the parabolic waveform.
(54) FIL-6: (FILTER) High frequency filter.
(55) CPL-13:(COUPLER) Ac coupling circuit.
(56) FUS-1: (FUSE) Normally very dim. Excessive current causes bright glow and eventual burn-out. Protects AMP-3.
(57) REC-1: (RECTIFIER) Uses flyback voltage to provide +400 volt output. CR116 half-wave rectifies. C122-C123 filter and store.
(58) CPL-12:(COUPLER) C121 couples flyback voltage. CR117 couples REC-1 output.
(59) VDR-1: (VOLTAGE DOUBLER) Uses flyback voltage and VDR-1 voltage to provide +800 volt output.
(60) FIL-5: (FILTER) H FOCUS adjusts p-p amplitude for the ac component of horizontal focus. Provides dynamic focus control.
(61) VR-8: (VOLTAGE REFERENCE) DC FOCUS provides adjustment for dc level used in focusing. Gives static focus control.
(62) CPL-14:(COUPLER) C124 filters and R141 isolates VR-8 output.
(63) VR-9: (VOLTAGE REFERENCE) Voltage divider supplies reference voltage for grid acceleration.
(64) FIL-2: (FILTER) Filters coil/TFR-2 voltage spikes to protect other circuits using +70 volts.
(65) GND-1: (GROUND) OPTION 3 Provides choice of floating or common grounds. Provides filtering between grounds when PWA uses floating ground.
(66) TFR-2: (TRANSFORMER) Transforms flyback voltage spikes in primary to provide secondaries supplying CRT anode, heater and grid functions.
(67) REC-1: (RECTIFIER) Half-wave rectifies one TFR-2 output. Provides 17-18 kvolts anode voltage.
(68) BR-1: (BLEEDER RESISTOR) For CRT anode. Provides high voltage discharge when Monitor is off.
(69) VR-10: (VOLTAGE REFERENCE) Voltage divider supplies reference voltage for grid brightness. External adjustment provided by customer. OPTION 4 provides choice for internal brightness adjustment.
(70) REC-2: (RECTIFIER) Half-wave rectifies one TFR-2 output. Provides approximately -105 volt pulse to charge C154 in VR-10.
(71) ISO-2: (ISOLATION) Isolates REC-2/VR-10 to prevent excessive REC-2 current.
(72) PS-1: (POWER SUPPLY) Provides filtering and/or zener regulation for five dc levels of output voltage.

VERTICAL DRIVE WAVEFORMS ARE WITH HORIZONTAL OUTPUT TRANSISTORS Q1, Q2 DISABLED BY DISCONNECTING J101.

TP115 — VERT: 1V/DIV, HORIZ: 2mS/DIV, VDC: 3.7

TP116 — VERT: 2V/DIV, HORIZ: 2mS/DIV, VDC: 2.3

TP118 — VERT: 2V/DIV, HORIZ: 2mS/DIV, VDC: 4.2

TP117 — VERT: 5V/DIV, HORIZ: 2mS/DIV, VDC: 13.5

TP119 — VERT: 5V/DIV, HORIZ: 2mS/DIV, VDC: 70.3

TP120 — VERT: 10V/DIV, HORIZ: 2mS/DIV, VDC: 9.3

TP122 — VERT: 2V/DIV, HORIZ: 2mS/DIV, VDC: 4.7

TP121 — VERT: 20V/DIV, HORIZ: 2 mS/DIV, VDC: 65.8

TP124 — VERT: 5V/DIV, HORIZ: 2mS/DIV, VDC: 34.9

TP123 — VERT: 20V/DIV, HORIZ: 2mS/DIV, VDC: 34.1

VERTICAL DRIVE TEST POINTS

LAST FOUR DIGITS OF PWA NO. — XXXX-XX

REVISION LEVEL IDENTIFIER

TP125 — VERT: 2V/DIV, HORIZ: 2mS/DIV, VDC: 4.2

TP126 — VERT: 50V/DIV, HORIZ: 2mS/DIV, VDC: 110

TP114 — +716 VDC

TP113 — +359 VDC

CRT BIAS CIRCUITS TEST POINTS

TP127 — VERT: 100V/DIV, HORIZ: 5μS/DIV, VDC: 0

TP112 — VERT: 50V/DIV, HORIZ: 5μS/DIV, VDC: 424

TP107 — VERT: 2V/DIV, HORIZ: 10μS/DIV, VDC: 4.9

TP101-1 — VERT: 2V/DIV, HORIZ: 10μS/DIV, VDC: 2.6

HORIZONTAL DRIVE TEST POINTS

TP110 — VERT: 5V/DIV, HORIZ: 10μS/DIV, VDC: −0.8

TP109 — VERT: 50V/DIV, HORIZ: 10μS/DIV, VDC: 63.7

TP102 — VERT: 2V/DIV, HORIZ: 10μS/DIV, VDC: 8.8

TP101-2 — VERT: 2V/DIV, HORIZ: 10μS/DIV, VDC: 2.0

TP103 — VERT: 2V/DIV, HORIZ: 10μS/DIV, VDC: 4.0

TP104 — VERT: 2V/DIV, HORIZ: 10μS/DIV, VDC:5.2

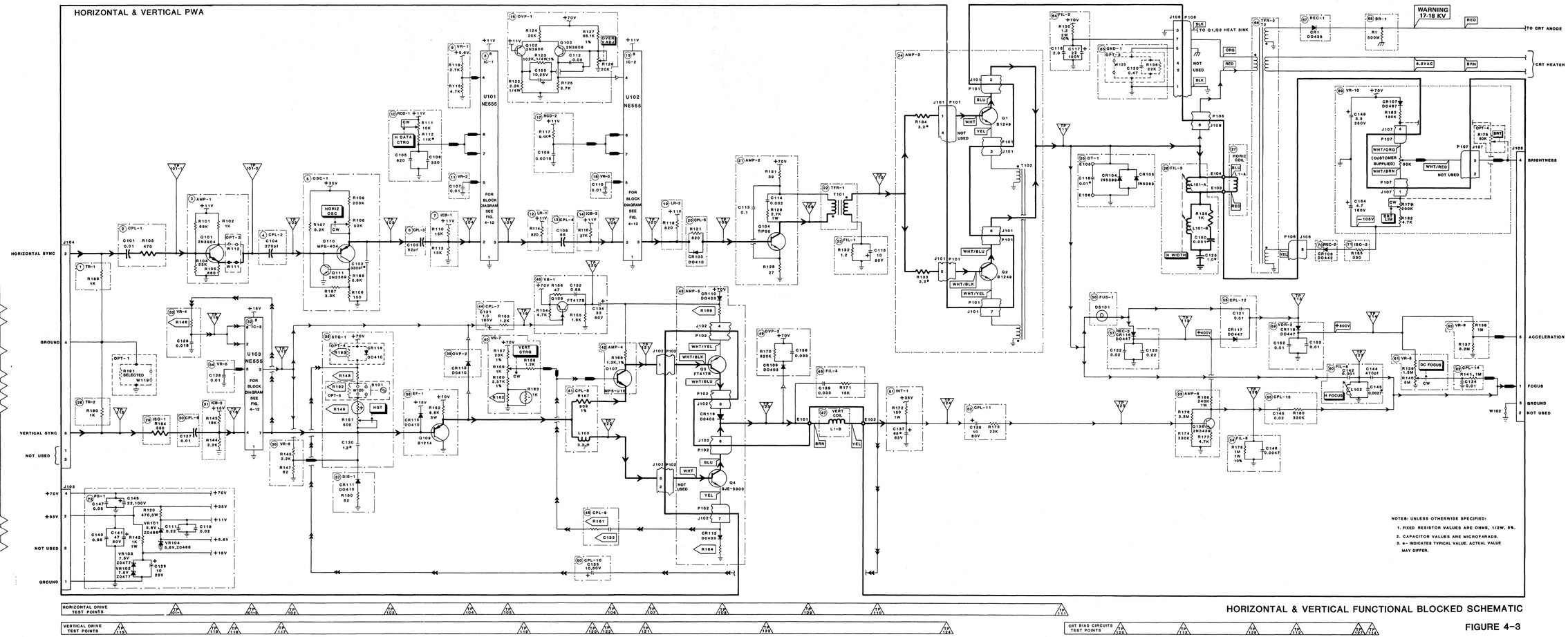
TP108 — VERT: 2V/DIV, HORIZ: 10μS/DIV, VDC: 2.2

TP111 — VERT: 50V/DIV, HORIZ: 5μS/DIV, VDC: 68.8

TP106 — VERT: 2V/DIV, HORIZ: 10μS/DIV, VDC: 10.9

TP105 — VERT: 2V/DIV, HORIZ: 10μS/DIV, VDC: 6.3

HORIZONTAL & VERTICAL TEST POINTS LOCATION, FIGURE 4-2



VALUES FOR 50-60 Hz		
HORIZONTAL FORMAT		VERTICAL FORMAT
39.3W	R160	22.3W
39K	R146	33K
20K 1%	R193	47.5K 1%
110K 1%	R148	82.5K 1%
36.7K 1%	R192	22K
390	R162	680
2.2K +Tc	R149	4.7K +Tc
22K	R161	12K
0.1	C133	0.33
35.3W	R164	22.3W

NOTES: UNLESS OTHERWISE SPECIFIED:

1. FIXED RESISTOR VALUES ARE OHMS, 1/2W, 5%.
2. CAPACITOR VALUES ARE MICROFARADS.
3. # - INDICATES TYPICAL VALUE. ACTUAL VALUE MAY DIFFER.

HORIZONTAL & VERTICAL FUNCTIONAL BLOCKED SCHEMATIC

FIGURE 4-3

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4.4 TTL VIDEO AMPLIFIER PWA THEORY

Refer to TTL Video Amplifier PWA Functional Blocked Schematic, Figure 4-5.

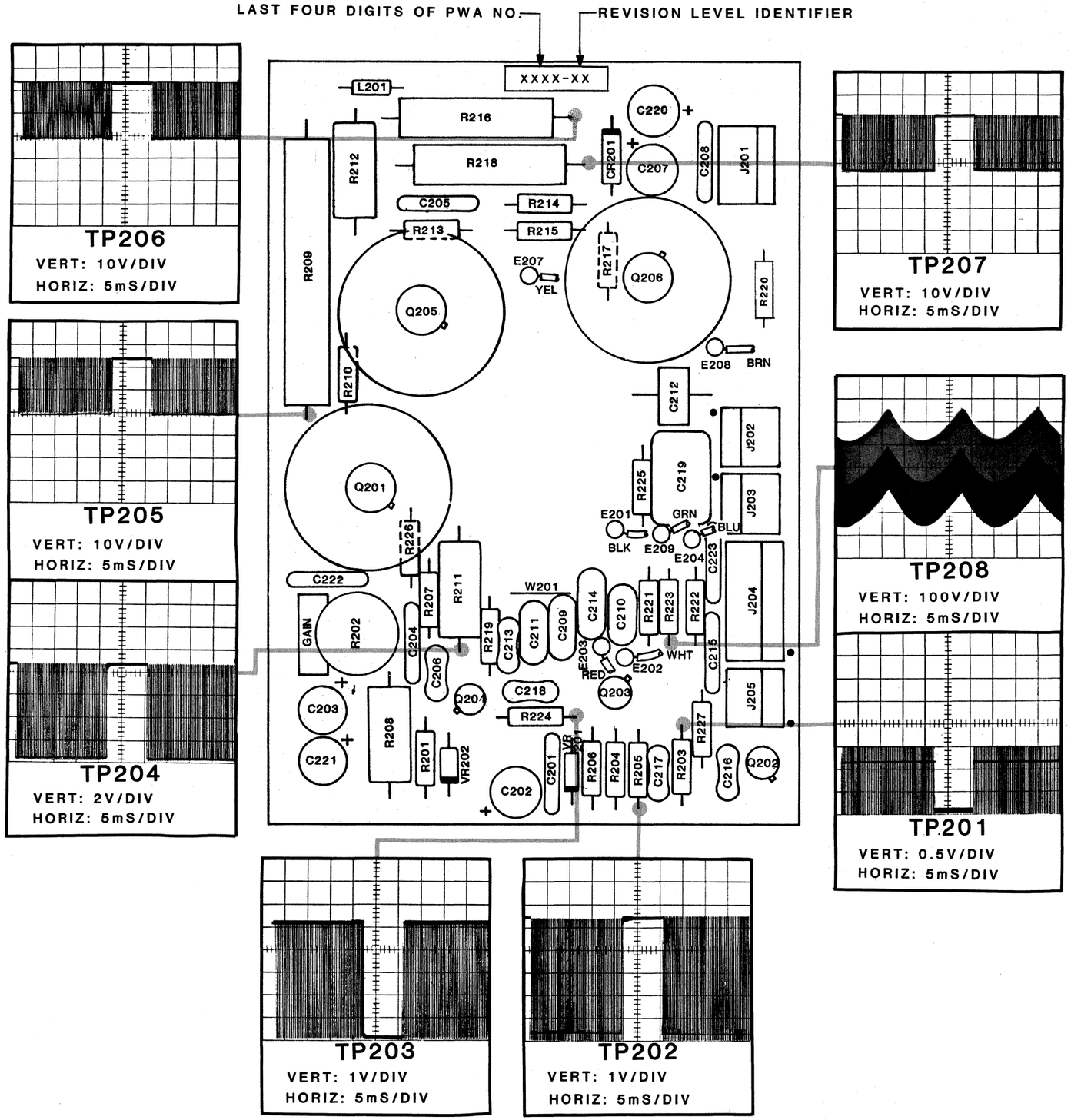
Functional blocks (1) through (15) provide 50 MHZ bandpass amplification.

OPTION 1: Provides choice of terminated or unterminated input. Resistor value optional.

(1) CPL-1: (COUPLER) Couples video signal. C216 speeds up AMP-1 turn-off by producing a negative spike from the negative-going edge of the video signal.
(2) AMP-1: (AMPLIFIER) Amplifies and inverts video signal.
(3) CPL-2: (COUPLER) Identical in function to CPL-1.
(4) AMP-2: (AMPLIFIER) Amplifies and inverts video signal.
(5) CPL-3: (COUPLER) Identical in function to CPL-1.
(6) AMP-3: (AMPLIFIER) Cascode circuit amplifies and inverts video signal. L201, R207, C206 provide high frequency peaking. R211, in conjunction with VR-1 setting, establishes low frequency gain. R209 is collector load resistor.
(7) VR-1: (VOLTAGE REFERENCE) GAIN determines video contrast by establishing output level of AMP-3.
(8) FIL-1: (FILTER) Filters VR-1 output.
(9) ISO-1: (ISOLATION) Isolation resistor. Aids in high frequency oscillation suppression.
(10) VD-1: (VOLTAGE DIVIDER) Along with L201-R209 (in AMP-3), establishes dc bias for Q201 collector (in AMP-3) and Q205 base (in EF-1.)
(11) EF-1: (EMITTER FOLLOWER) Provides isolation and current gain.
(12) ISO-2: (ISOLATION) Isolation resistor. Aids in high frequency oscillation suppression.
(13) EF-2: (EMITTER FOLLOWER) Provides isolation and current gain.
(14) OVP-1: (OVERVOLTAGE PROTECTION) Provides transient voltage protection from CRT arcing.
(15) ISO-3: (ISOLATION) Isolation resistor.
(16) CATHODE RAY TUBE: Conventional CRT. Socket has integral arc gap protection for each pin.
(17) ISO-4: (ISOLATION) Value of resistor selected to match CRT heater requirement.
(18) FIL-2: (FILTER) Filters brightness bias voltage. Provides ac ground for grid one.
(19) FIL-3: (FILTER) Filters acceleration bias voltage.
(20) ISO-5: (ISOLATION) Isolation resistor.

Functional blocks (21) through (25) provide arc suppression and filtering for CRT cathode and grids.

(21) AG-1: (ARC GAP) C212 is gas filled arc gap with associated 2pF capacitance.
(22) AG-2: (ARC GAP) Ceramic disc arc capacitor.
(23) AG-3: (ARC GAP) Ceramic disc arc capacitor.
(24) AG-4: (ARC GAP) Ceramic disc arc capacitor.
(25) AG-5: (ARC GAP) Ceramic disc arc capacitor.
(26) PS-1: (POWER SUPPLY) Filters and/or zener regulates to provide three output voltages.

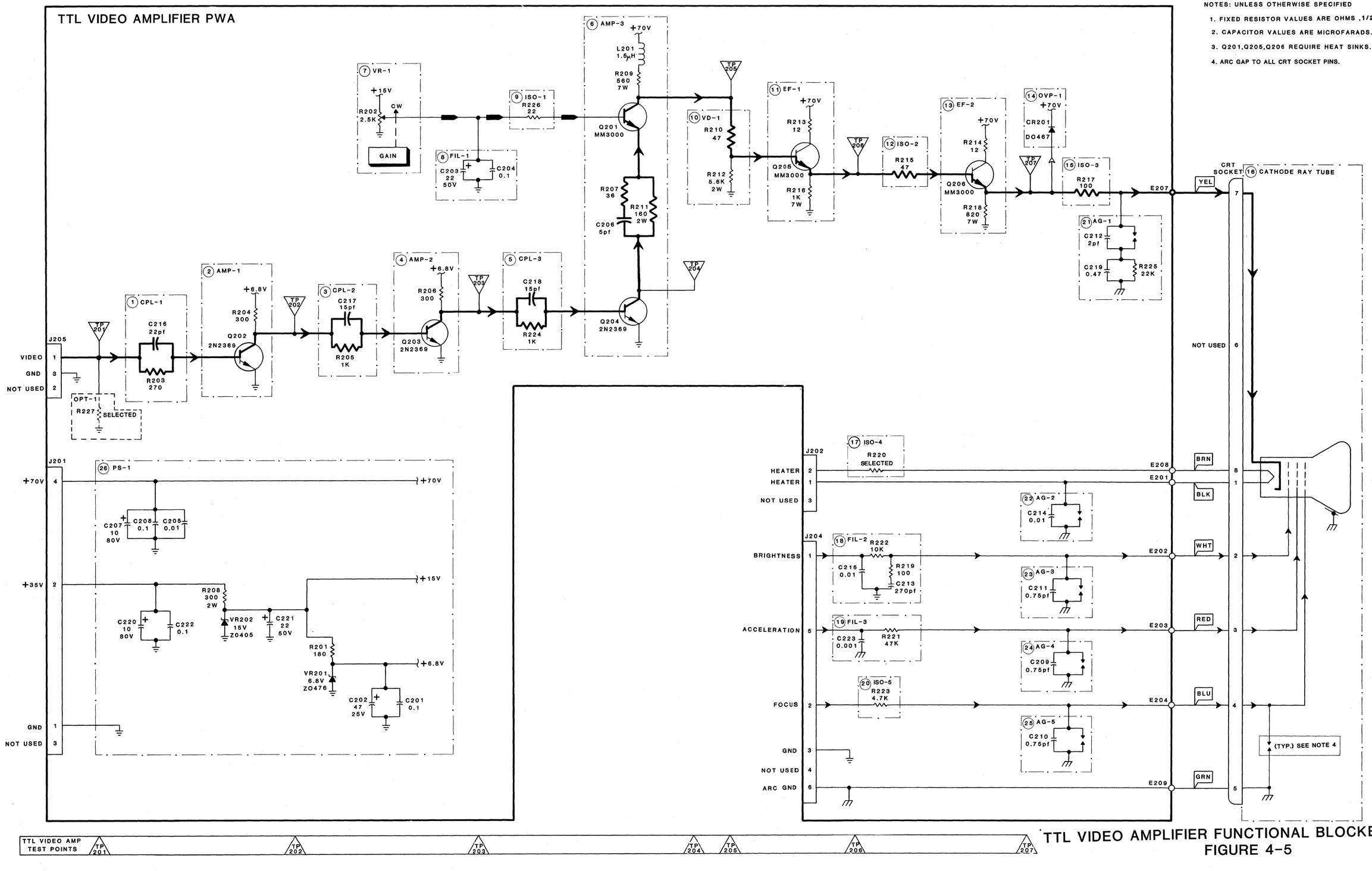


TTL VIDEO AMPLIFIER TEST POINTS LOCATION, FIGURE 4-4

TTL VIDEO AMPLIFIER PWA

NOTES: UNLESS OTHERWISE SPECIFIED

1. FIXED RESISTOR VALUES ARE OHMS ,1/2W,5%
2. CAPACITOR VALUES ARE MICROFARADS.
3. Q201,Q205,Q206 REQUIRE HEAT SINKS.
4. ARC GAP TO ALL CRT SOCKET PINS.



TTL VIDEO AMP TEST POINTS: TP 201, TP 202, TP 203, TP 204, TP 205, TP 206, TP 207

TTL VIDEO AMPLIFIER FUNCTIONAL BLOCKED SCHEMATIC
FIGURE 4-5

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4.5 POWER SUPPLY PWA THEORY

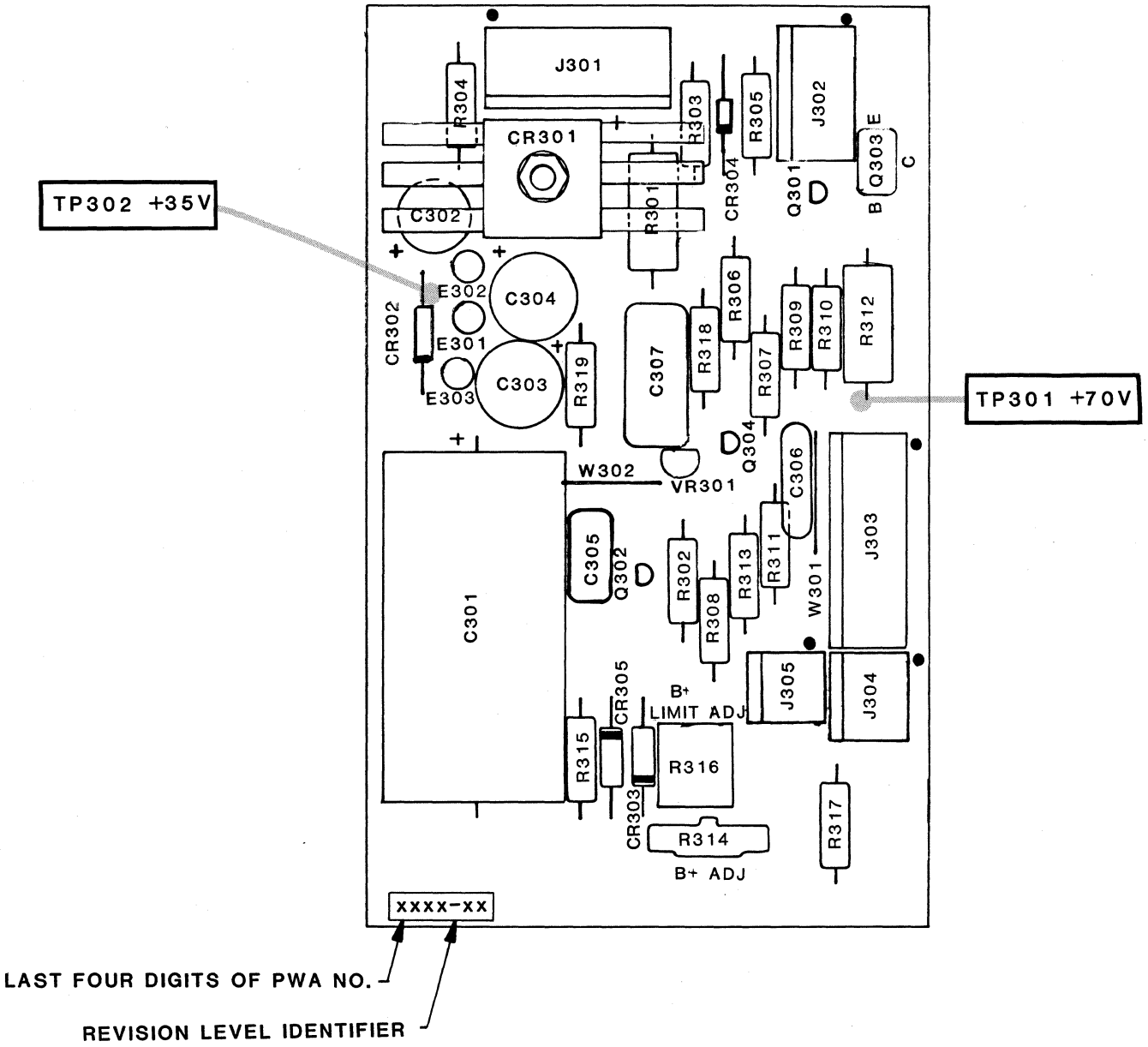
Refer to Power Supply Functional Blocked Schematic, Figure 4-7.

Functional blocks (1) through (14) provide regulated +70 volts.

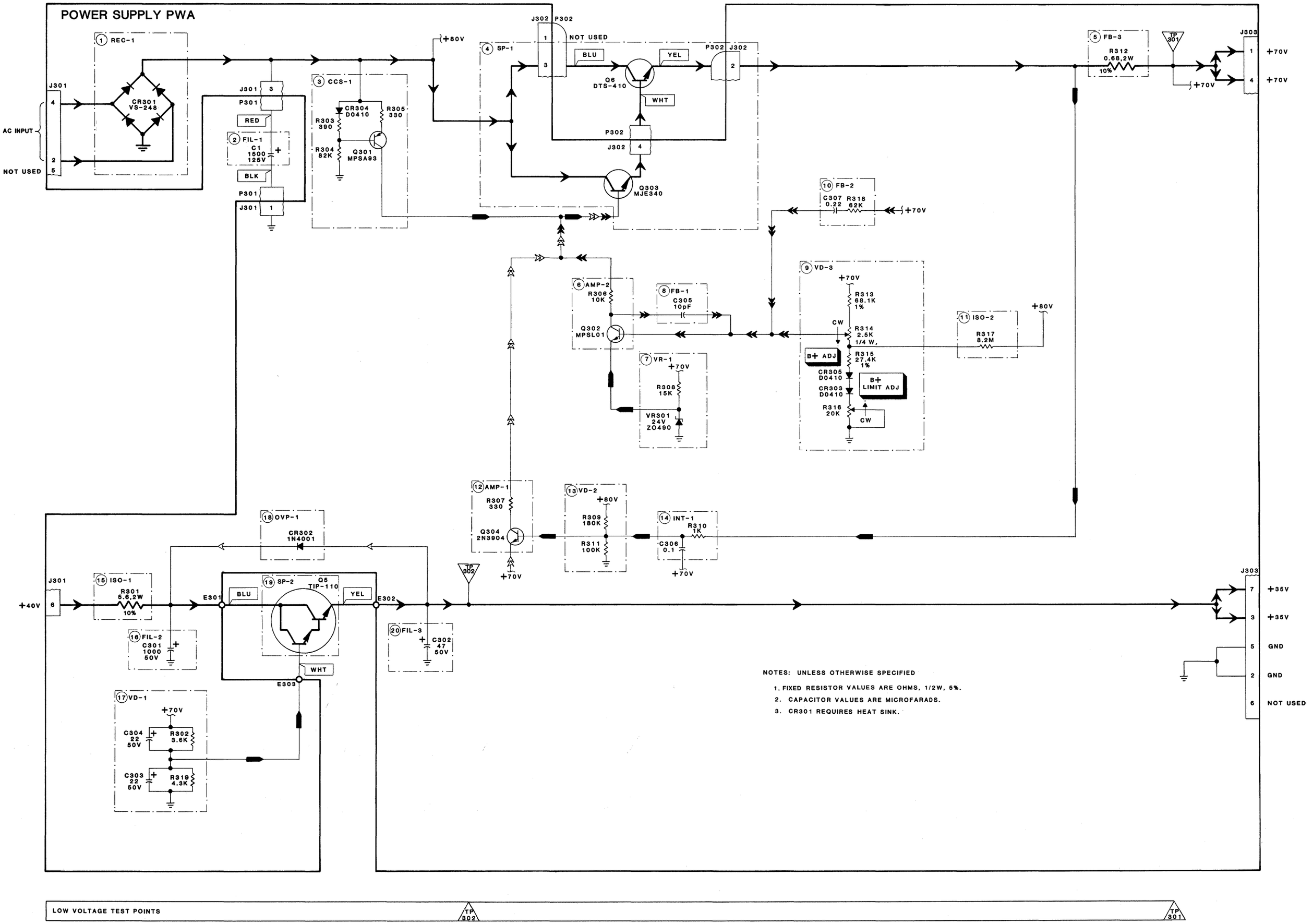
(1) REC-1: (RECTIFIER) Full-wave bridge rectifier.
(2) FIL-1: (FILTER) Filters REC-1 output.
(3) CCS-1: (CONSTANT CURRENT SOURCE) Acts as a constant current source for SP-1, AMP-1 and AMP-2.
(4) SP-1: (SERIES PASS) Conventional Darlington connected series pass.
(5) FB-3: (FEEDBACK) Provides voltage feedback determined by load current.
(6) AMP-2: (AMPLIFIER) Error Amplifier. In normal circuit operation (with AMP-1 off) Q302 determines how much current SP-1 is allowed to receive from CCS-1. This circuit, along with VD-3 and associated circuits, provide voltage regulation for +70 volt output.
(7) VR-1: (VOLTAGE REFERENCE) Provides emitter reference voltage for Q302 in AMP-2.
(8) FB-1: (FEEDBACK) Negative feedback prevents high frequency oscillation of AMP-2.
(9) VD-3: (VOLTAGE DIVIDER) Provides feedback path (to AMP-2) for +70 volt output errors. B+ LIMIT ADJ sets upper limit of control for B+ ADJ which provides final adjustment for the +70 volt output. CR305, CR303 provide temperature compensation for Q302 in AMP-2. R313, R315 are 1% tolerance for long term stability.
(10) FB-2: (FEEDBACK) High pass filter. Improves high frequency regulation for +70 volt output.
(11) ISO-2: (ISOLATION) Isolation resistor feeds forward for 120 Hz ripple rejection.
(12) AMP-1: (AMPLIFIER) During normal circuit operation Q304 is off. Excessive current through FB-3 would cause a voltage drop on the +70 volt output. This is fed back to Q304 emitter causing it to turn on. Additional CCS-1 current output would then be diverted from SP-1, resulting in current foldback on the +70 volt output.
(13) VD-2: (VOLTAGE DIVIDER) Provides "keep-alive" bias for AMP-1 when current foldback is operative.
(14) INT-1: (INTEGRATOR) Prevents AMP-1 turn-on during initial current surge at Monitor turn-on. C306 helps eliminate noise spikes.

Functional Blocks (15) through (20) provide regulated +35 volts.

(15) ISO-1: (ISOLATION) Limits current surge during initial Monitor turn-on and provides a voltage drop.
(16) FIL-2: (FILTER) Provides +40 volt filtering.
(17) VD-1: (VOLTAGE DIVIDER) Establishes reference voltage for +35 volt output. Capacitors provide lower impedance reference than resistors alone.
(18) OVP-1: (OVERVOLTAGE PROTECTION) Provides CRT arcing protection for SP-2.
(19) SP-2: (SERIES PASS) Conventional Darlington series pass.
(20) FIL-3: (FILTER) Provides +35 volt filtering.



POWER SUPPLY TEST POINTS LOCATION, FIGURE 4-6



POWER SUPPLY FUNCTIONAL BLOCKED SCHEMATIC, FIGURE 4-7

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4.6 LINEAR VIDEO AMPLIFIER PWA THEORY

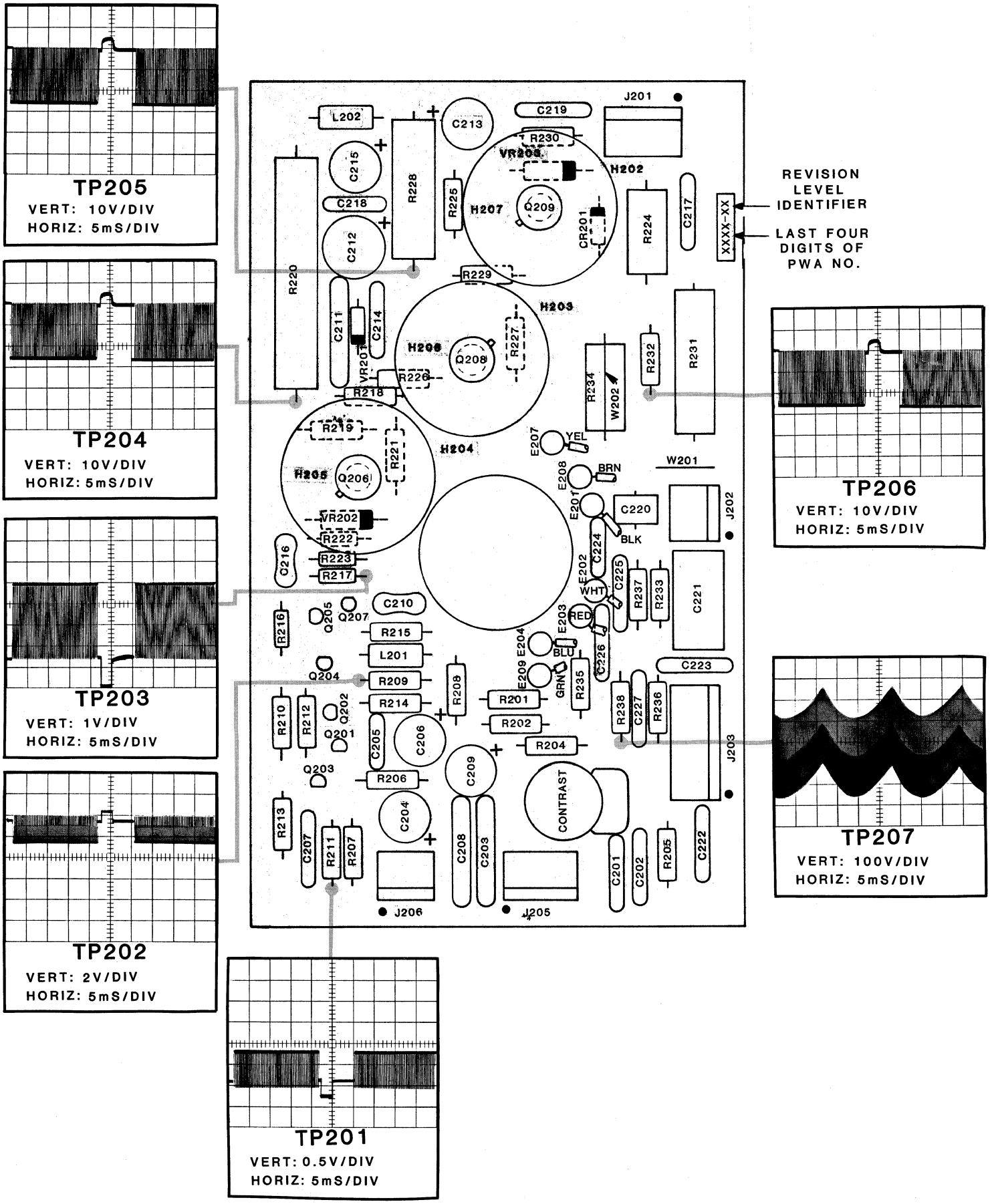
Refer to Linear Video Amplifier Functional Blocked Schematic, Figure 4-9.

Functional blocks (1) through (20) provide linear 50 MHz bandpass amplification.

(1) TR-1: (TERMINATION RESISTOR) Video termination resistor.
(2) ISO-2: (ISOLATION) Limits base drive to AMP-2.
(3) AMP-2: (AMPLIFIER) Amplifies and inverts video signal. Collector load for Q203 is AMP-1.
(4) AMP-1: (AMPLIFIER) Similar to a differential amplifier. The difference between base drives determines transistor conduction when AMP-2 turns on. When one transistor conducts more, the other will conduct less. C205 provides negative feedback to prevent high frequency oscillation. L201 is peaking inductor.
(5) VD-1: (VOLTAGE DIVIDER) Provides base drive voltage references for both sides of AMP-1. CONTRAST setting determines p-p amplitude of video signal output at TP202. C201 and C202 provide filtering.
(6) FIL-1: (FILTER) Filters voltage reference for Q201 in AMP-1.
(7) ISO-1: (ISOLATION) Provides high frequency oscillation suppression.
(8) DEC-1: (DECOUPLER) Decouples +12 volt input to Q201 of AMP-1.
(9) FIL-2: (FILTER) Identical in function to FIL-1.
(10) ISO-3: (ISOLATION) Identical in function to ISO-1.
(11) AMP-3: (AMPLIFIER) Lowers the dc video level from a +12 volt high at TP202 to a zero volt low at TP203. Q204 provides voltage gain while Q205 provides current gain. C210-R215 improves high frequency response.
(12) AMP-4: (AMPLIFIER) Standard cascode amplifier configuration providing high input impedance and high gain. L202 is high frequency peaking coil.
(13) DEC-3: (DECOUPLER) Decouples +70 volt input to AMP-4.
(14) ISO-4: (ISOLATION) Provides high frequency oscillation suppression.
(15) ISO-5: (ISOLATION) Provides high frequency oscillation suppression.
(16) EF-1: (EMITTER FOLLOWER) Provides isolation and current gain.
(17) ISO-6: (ISOLATION) Identical in function to ISO-5.
(18) EF-2: (EMITTER FOLLOWER) Provides isolation and current gain.
(19) OVP-1: (OVERVOLTAGE PROTECTION) Provides transient voltage protection from CRT arcing.
(20) ISO-7: (ISOLATION) Identical in function to ISO-5.
(21) CATHODE RAY TUBE: Conventional CRT. Socket has integral arc gap protection for each pin.
(22) ISO-8: (ISOLATION) Value of resistor selected to match CRT heater requirement.
(23) FIL-3: (FILTER) Filters brightness bias voltage. Provides ac ground for grid one.
(24) FIL-4: (FILTER) Filters acceleration bias voltage.
(25) ISO-9: (ISOLATION) Isolation resistor.
(26) ISO-10:(ISOLATION) Isolation resistor.

Functional blocks (27) through (30) provide arc protection and filtering for CRT cathode and grids.

(27) AG-1: (ARC GAP) C220 is gas-filled arc gap with associated 2pF capacitance.
(28) AG-2: (ARC GAP) Ceramic disc arc gap capacitor.
(29) AG-3: (ARC GAP) Ceramic disc arc gap capacitor.
(30) AG-4: (ARC GAP) Ceramic disc arc gap capacitor.
(31) PS-1: (POWER SUPPLY) Provides filtering and/or zener regulation to provide three dc output voltages.

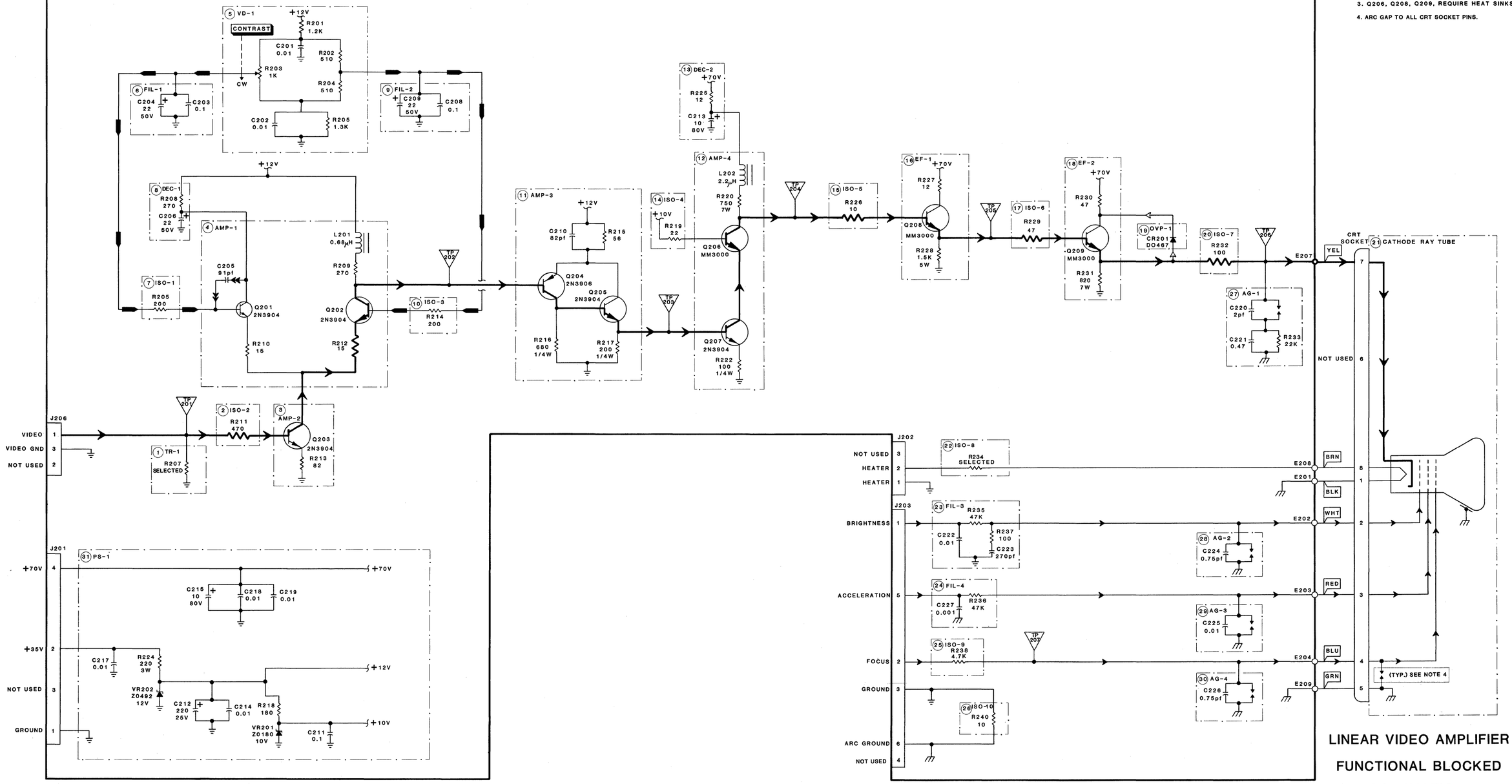


LINEAR VIDEO AMPLIFIER TEST POINTS LOCATION, FIGURE 4-8

LINEAR VIDEO AMPLIFIER PWA

NOTES: UNLESS OTHERWISE SPECIFIED

1. FIXED RESISTOR VALUES ARE OHMS, 1/2W, 5%.
2. CAPACITOR VALUES ARE MICROFARADS.
3. Q206, Q208, Q209, REQUIRE HEAT SINKS.
4. ARC GAP TO ALL CRT SOCKET PINS.



LINEAR VIDEO AMPLIFIER FUNCTIONAL BLOCKED SCHEMATIC

FIGURE 4-9

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4.7 ECL VIDEO AMPLIFIER PWA THEORY

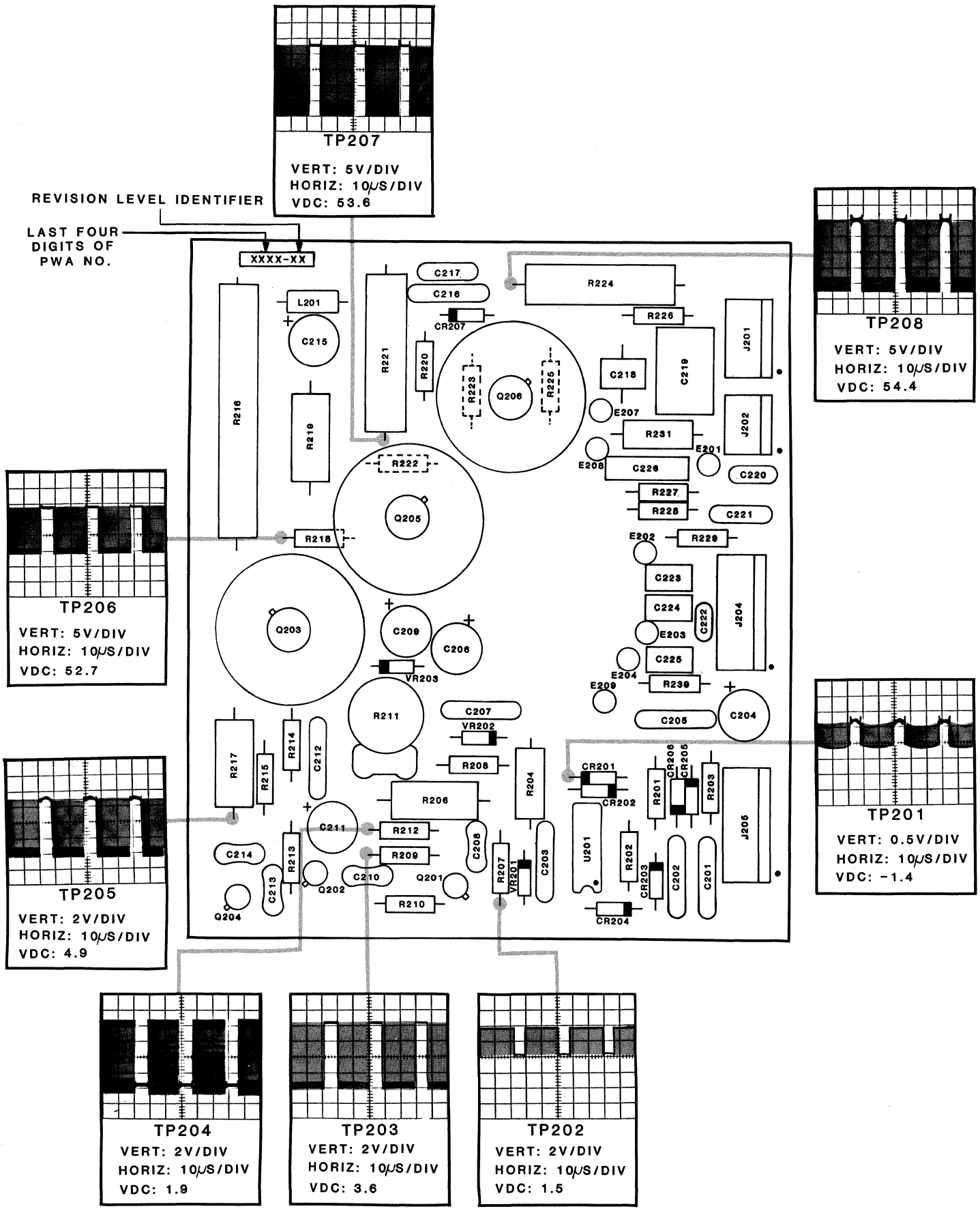
Refer to ECL Video Amplifier Functional Blocked Schematic, Figure 4-11.

Functional blocks (1) through (20) provide 50 MHz bandpass amplification.

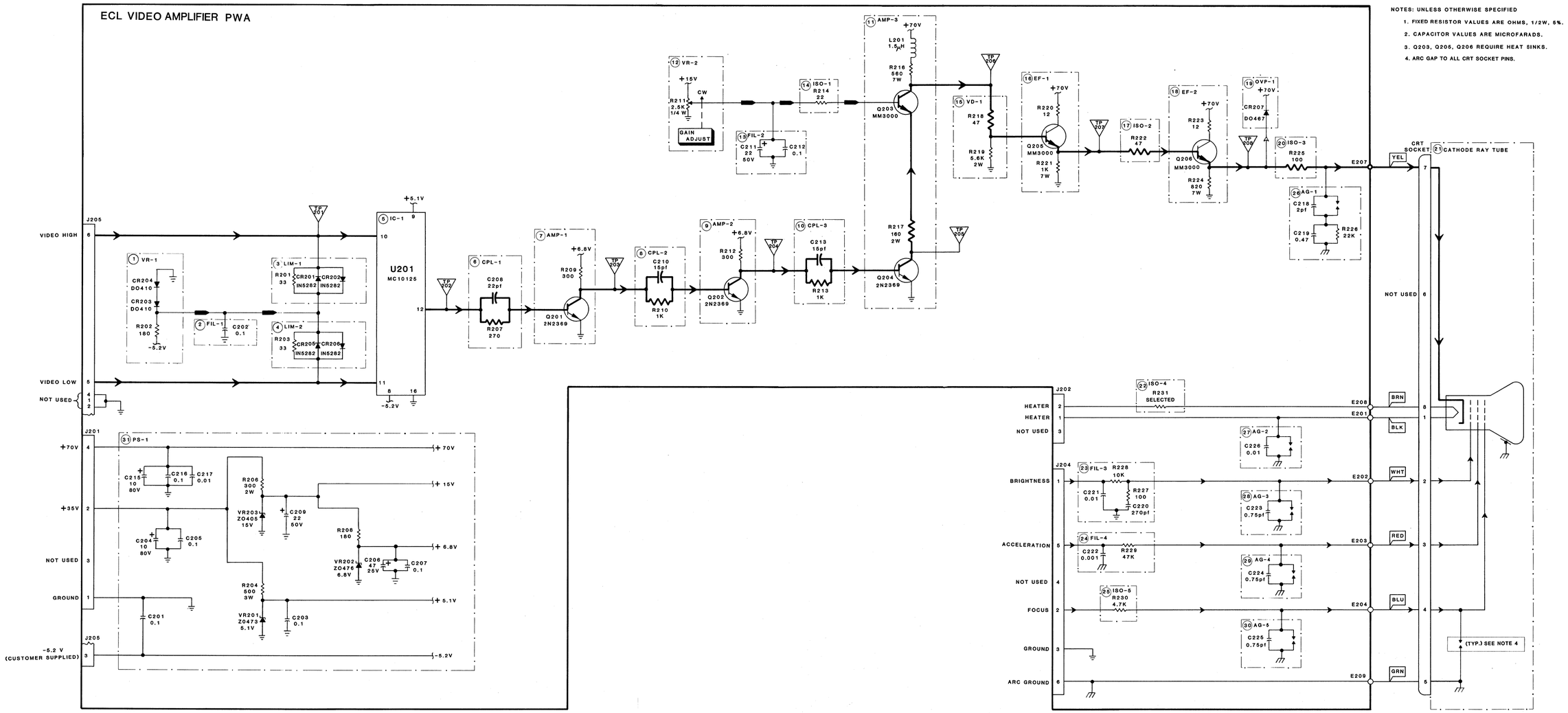
(1) VR-1: (VOLTAGE REFERENCE) Provides -1.4 volt nominal reference for U201.
(2) FIL-1: (FILTER) Filters VR-1 voltage reference.
(3) LIM-1: (LIMITER) Provides arc protection for U201.
(4) LIM-2: (LIMITER) Identical to LIM-1.
(5) IC-1: (INTEGRATED CIRCUIT) Translates ECL video signals to TTL video levels.
(6) CPL-1: (COUPLER) Couples video signal. C208 speeds up AMP-1 turn-off by producing a negative spike from the negative going edge of the video signal.
(7) AMP-1: (AMPLIFIER) Amplifies and inverts video signal.
(8) CPL-2: (COUPLER) Identical in function to CPL-1.
(9) AMP-2: (AMPLIFIER) Amplifies and inverts video signal.
(10) CPL-3: (COUPLER) Identical in function to CPL-1.
(11) AMP-3: (AMPLIFIER) Cascode circuit amplifies and inverts video signal. L201 provides high frequency peaking. R217, in conjunction with VR-2 setting, establishes low frequency gain. R216 is collector load resistor.
(12) VR-2: (VOLTAGE REFERENCE) GAIN ADJUST determines video contrast by establishing output level of AMP-3.
(13) FIL-2: (FILTER) Filters VR-2 output.
(14) ISO-1: (ISOLATION) Isolation resistor. Aids in high-frequency oscillation suppression.
(15) VD-1: (VOLTAGE DIVIDER) Along with L201-R216 (in AMP-3), establishes dc bias for Q203 collector (in AMP-3) and Q205 base (in EF-1).
(16) EF-1: (EMITTER FOLLOWER) Provides isolation and current gain.
(17) ISO-2: (ISOLATION) Isolation resistor. Aids in high frequency oscillation suppression.
(18) EF-2: (EMITTER FOLLOWER) Provides isolation and current gain.
(19) OVP-1: (OVERVOLTAGE PROTECTION) Provides transient voltage protection from CRT arcing.
(20) ISO-3: (ISOLATION) Isolation resistor.
(21) CATHODE RAY TUBE: Conventional CRT. Socket has integral arc gap protection for each pin.
(22) ISO-4: (ISOLATION) Value of resistor selected to match CRT heater requirement.
(23) FIL-3: (FILTER) Filters brightness bias voltage. Provides ac ground for grid one.
(24) FIL-4: (FILTER) Filters acceleration bias voltage.
(25) ISO-5: (ISOLATION) Isolation resistor.

Functional blocks (26) through (30) provide arc suppression and filtering for CRT cathode and grids.

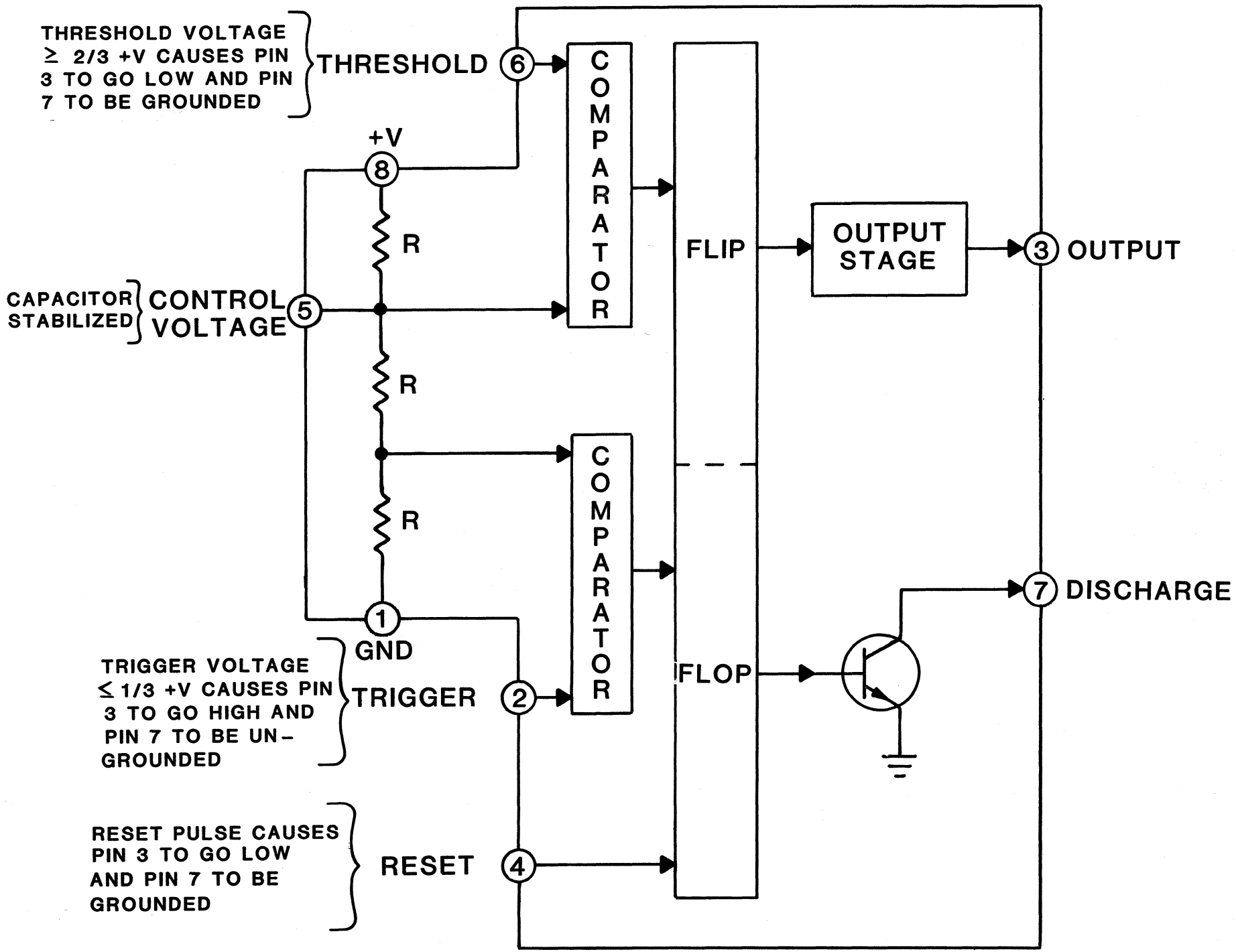
(26) AG-1: (ARC GAP) C218 is gas filled arc gap with associated 2pF capacitance.
(27) AG-2: (ARC GAP) Ceramic disc arc capacitor.
(28) AG-3: (ARC GAP) Ceramic disc arc capacitor.
(29) AG-4: (ARC GAP) Ceramic disc arc capacitor.
(30) AG-5: (ARC CAP) Ceramic disc arc capacitor.
(31) PS-1: (POWER SUPPLY) Filters and/or zener regulates to provide five dc output voltages.



ECL VIDEO AMPLIFIER TEST POINTS LOCATION, FIGURE 4-10



ECL VIDEO AMPLIFIER FUNCTIONAL BLOCKED SCHEMATIC, FIGURE 4-11



NE555 BLOCK DIAGRAM, FIGURE 4-12

SECTION 5

TROUBLESHOOTING

NOTE: Test Point Locations (Figures 4-2, 4-4, 4-6, 4-8 and 4-10) are located in Section 4 so they could be opposite their respective schematics.

5.1 TROUBLESHOOTING CHART, FIGURE 5-1

NOTE: If horizontal or vertical deflection problems are present, disconnect P202 from the video amplifier. This protects CRT from spot burn by removing heater voltage. Follow troubleshooting chart to isolate fault to a particular PWA.

5.2 ADDITIONAL TESTS

5.2.1 HORIZONTAL AND VERTICAL PWA

5.2.1.1 Horizontal Section

a. Check flyback pulse at TP111.
b. Check T2 radiated pulse by holding a 10:1 oscilloscope probe about 2" from T2.
c. Check for parabolic voltage across S-shaping capacitor C125 in FIL-3.
d. Check dc current to output stages by measuring voltage drop across R130 in FIL-2. A typical voltage drop of 0.6 V indicates a normal current of about 0.5 amperes. Current at a high brightness level should be somewhat higher, however.
e. Check TP109. Signal loss may indicate:
   1. OVP-1 has activated due to excessive supply voltage.
   2. OVP-1 has malfunctioned.
   3. Malfunction in low level or driver circuits.
f. In following the TROUBLESHOOTING CHART, if DS101 was checked and found to be bad the chart indicated trouble source from circuit elements. Another possible trouble source is an internal CRT short. Isolate the problem area by disconnecting CRT socket and replacing DS101. If DS101 opens, the CRT is eliminated as a trouble source. If it does not open, but does after the CRT socket is connected, the circuitry is eliminated as a trouble source.
g. Other Voltage Checks:
   CRT, GRID 1 (J105, Pin 4): Variable with brightness control from -100 to +5 volts.
   CRT, GRID 2 (J105, Pin 5): about +715 volts.
   CRT, GRID 4 (J105, Pin 1): Variable with focus parabola from 0 to +700 volts.

5.2.1.2 Vertical Section

If waveforms at TP121 and TP122 are not normal, Q3 and Q4 are suspect. The CRT is a good indicator of output stage current. For example, if Q3 is open, the raster will be pulled down and compressed at bottom. An open Q4 will cause the same effect at the top of the CRT. To permit accurate measurements of low amplitude waveforms for Q107 and Q3 disable the voltage boost pulse by shorting R154 with a jumper. Waveforms should be typical except flyback time will be longer and linearity at the top will be affected.

5.2.2 TTL, LINEAR AND ECL VIDEO AMPLIFIERS

Trouble in the video amplifier, regardless of which one is used, is best isolated by comparing observed waveforms with those shown on the Test Point Location drawing for the PWA in question. Once trouble is isolated to a particular stage, voltage measurement should pinpoint the faulty component.

5.3 CRT REPLACEMENT

An intense blue haze (glow) or blue jitter near the electron gun are indications of a faulty CRT. A slight bluish haze in the neck of the CRT makes the tube suspect but not necessarily faulty.

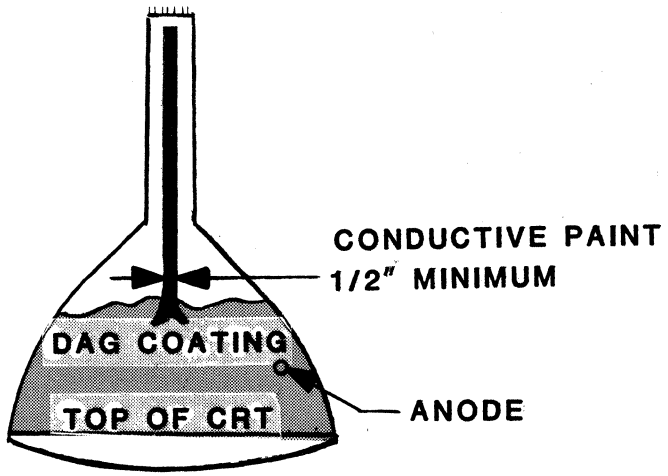
5.3.1 CRT REMOVAL

When it has been determined that CRT replacement is necessary, use the following procedure:

a. Completely disconnect Monitor.
b. Follow CRT discharge procedure in Section 1.8.2.
c. Disconnect high voltage anode.
d. Carefully remove CRT socket.

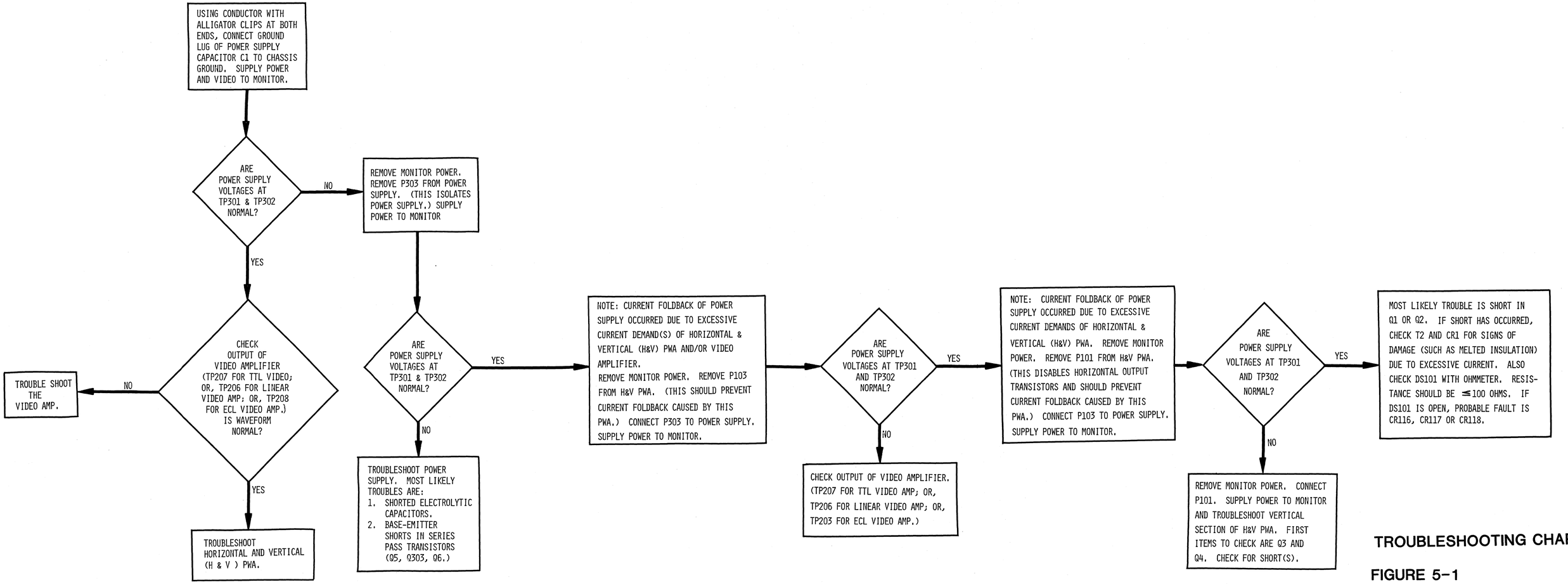
5.3.2 PREPARING NEW CRT FOR INSTALLATION

Apply conductive paint as shown. This is necessary to provide a ground for the linearity sleeve. Grounding the sleeve in this manner will prevent any charge build-up which could cause CRT arcing. Use televison Tube Koat, catalog #49-2 from GC Electronics, or equivalent.



5.3.3 INSTALLING NEW CRT

Reverse the removal procedure of Section 5.3.1.



TROUBLESHOOTING CHART

FIGURE 5-1

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SECTION 6

PARTS REPLACEMENT

6.1 ORDERING PARTS

Order spare and replacement parts from nearest area sales office:

CALIFORNIA:	Campbell	(408) 374 4120
	Upland	(714) 985-7110
ILLINOIS:	Downers Grove	(312) 960-4434
MAINE:	Burlington	(617) 273-0608
NEW JERSEY:	Ocean	(201) 922-2800
TEXAS:	Dallas	(214) 522-3060
UNITED KINGDOM:	Newbury, Berkshire	(44) 635-30770
WEST GERMANY:	Offenbach	(49) 0611 817041

The following parts information will be needed:

a. Model: Example... HD17V
b. Part Number: Example... 1-015-1249 (check footnotes for parts with asterisks).
c. Description: Example... Transistors, Matched Pair
d. Reference Symbol: Example... Q1, Q2
e. Where Located: Example... Chassis mounted.
   For parts located on a PWA, supply the PWA number and revision level identifier. This number will take the form of: 6-002-XXXX-XX. The 6-002 part of the number is standard for all PWA's for the HD Series Monitor. This part (6-002), along with the next four numbers (represented by the first four X's) make up the complete PWA number. The last two X's represent the revision level identifier. The correct numbers to replace these six X's are stamped on the COMPONENT side of the printed wiring board used to make the PWA. (Note: numbers on the CONDUCTOR side of the printed wiring board have no significance for parts replacement). Each TEST POINTS LOCATION figure shows the location of these numbers.

6.2 PARTS LISTS

6.2.1 CHASSIS MOUNTED PARTS

REF SYM	DESCRIPTION	PART NUMBER
	CAPACITOR	
C1	1500μF-125V	1-012-2313

6.2.1 CHASSIS MOUNTED PARTS (Cont.)

REF SYM	DESCRIPTION	PART NUMBER
	TRANSISTORS	
Q1, Q2	MATCHED PAIR, B1249	1-015-1249
Q3	FTB 417B	1-015-1220
Q4	SJE-5300	1-015-1216
Q5	TIP-110	1-015-1237
Q6	DTS410	1-015-0410

The remainder of the chassis mounted components are identified by part number with stamped tags.

6.2.2 ECL VIDEO AMPLIFIER PWA

REF SYM	DESCRIPTION	PART NUMBER
	CAPACITOR	
C201	.1μF-100-20	1-012-2370
C202	.1μF-100-20	1-012-2370
C203	.1μF-100-20	1-012-2370
C204	10μF-80	1-012-2260
C205	.1μF-100-20	1-012-2370
C206	47μF-25	1-012-2165
C207	.1μF-100-20	1-012-2370
C208	22pF-500-5	1-012-2418
C209	22μF-50	1-012-2193
C210	15pF-500-5	1-012-2412
C211	22μF-50	1-012-2193
C212	.1μF-100-20	1-012-2370
C213	15pF-500-5	1-012-2412
C214	NOT USED	
C215	10μF-80	1-012-2260
C216	.1μF-100-20	1-012-2370
C217	.01μF-500-20	1-012-0740
C218	2pF-230V ARC GAP	1-012-0111
C219	.47μF-100-10	1-012-1007
C220	270pF-1000-10	1-012-0395
C221	.01μF-500-20	1-012-0740
C222	.001μF-1000-20	1-012-0540
C223	.75pF-1000 ARC GAP	1-012-0110
C224	.75pF-1000 ARC GAP	1-012-0110
C225	.75pF-1000 ARC GAP	1-012-0110
C226	.01μF-1000 ARC GAP	1-012-0112
	DIODE	
CR201	IN5282	1-021-0497
CR202	IN5282	1-021-0497
CR203	D0410	1-021-0410
CR204	D0410	1-021-0410

6.2.2 ECL VIDEO AMPLIFIER PWA (Cont.)

REF SYM	DESCRIPTION	PART NUMBER
CR205	IN5282	1-021-0497
CR206	IN5282	1-021-0497
CR207	D0467	1-021-0467
	TERMINATION POINT	
E201	CRT SOCKET, BLK LD	
E202	CRT SOCKET, WHT LD	
E203	CRT SOCKET, RED LD	
E204	CRT SOCKET, BLU LD	
E205	NOT USED	
E206	NOT USED	
E207	CRT SOCKET, YEL LD	
E208	CRT SOCKET, BRN LD	
E209	CRT SOCKET, GRN LD	
	COIL	
L201	1.5µH	1-016-0393
	TRANSISTORS	
Q201	2N2369	1-015-1212
Q202	2N2369	1-015-1212
Q203	MM3000	1-015-1211
Q204	2N2369	1-012-1212
Q205	MM3000	1-015-1211
Q206	MM3000	1-015-1211
	RESISTOR	
R201	33-1/2-5	1-011-2234
R202	180-1/2-5	1-011-2252
R203	33-1/2-5	1-011-2234
R204	500-3-5	1-011-2706
R205	NOT USED	
R206	300-2-5	1-011-2467
R207	270-1/2-5	1-011-2256
R208	180-1/2-5	1-011-2252
R209	300-1/2-5	1-011-2257
R210	1K-1/2-5	1-011-2270
R211	VAR 2.5K-1/4-20	1-011-5741
R212	300-1/2-5	1-011-2257
R213	1K-1/2-5	1-011-2270
R214	22-1/2-5	1-011-2230
R215	NOT USED	
R216	560-7-5	1-011-2675
R217	160-2-5	1-011-2733
R218	47-1/2-5	1-011-2238
R219	5.6K-2-5	1-011-2654
R220	12-1/2-5	1-011-2224
R221	1K-7-5	1-011-2660
R222	47-1/2-5	1-011-2238
R223	12-1/2-5	1-011-2224

6.2.2 ECL VIDEO AMPLIFIER PWA (Cont.)

REF SYM	DESCRIPTION	PART NUMBER
R224	820-7-5	1-011-2541
R225	100-1/2-5	1-011-2246
R226	22K-1/2-5	1-011-2302
R227	100-1/2-5	1-011-2246
R228	10K-1/2-5	1-011-2294
R229	47K-1/2-5	1-011-2310
R230	4.7K-1/2-5	1-011-2286
R231***	SELECTED	
	CONNECTOR	
J201	4 CONT, 124A	1-039-0168
J202	3 CONT, 12A	1-039-0164
J203	NOT USED	
J204	6 CONT, 12356A	1-039-0193
J205	6 CONT, 23456A	1-039-0192
	ZENER	
VR201	Z0473, 5.1V	1-021-0473
VR202	Z0476, 6.8V	1-021-0476
VR203	Z0405, 15V	1-021-0405
	INT CKT	
U201	MC10125	1-025-0124
	MISCELLANEOUS	
	CRT SOCKET	6-004-0898
	PWB	1-029-0489
	HEATSINK (3)	1-015-5072
	TRANSIPAD (3)	3-019-0134
	SOCKET, IC	1-022-0450

6.2.3 HORIZONTAL AND VERTICAL PWA

REF SYM	DESCRIPTION	PART NUMBER
	CAPACITOR	
C101	0.01μF-500-20	1-012-0740
C102*	330pF-500-5	1-012-2422
C103	82pF-500-5	1-012-2435
C104	270pF-500-5	1-012-0396
C105	620pF-300-5	1-012-2430
C106	330pF-500-5	1-012-2350
C107	0.01μF-500-20	1-012-0740

*Typical Component: Actual component may differ. Check actual component before ordering.

***Optional Component: May or may not be used, depending on HD model.

6.2.3 HORIZONTAL AND VERTICAL PWA (Cont.)

REF SYM	DESCRIPTION	PART NUMBER
C108	68pF-500-5	1-012-2431
C109	0.0015μF-1000-5	1-012-2314
C110	0.01μF-500-20	1-012-0740
C111	0.22μF-100-5	1-012-2337
C112	0.05μF-100-20	1-012-2374
C113	0.1μF-100-20	1-012-2370
C114	0.002μF-1000-20	1-012-2219
C115	10μF-80	1-012-2260
C116	?μF-200-5	1-012-2221
C117	22μF-100	1-012-2311
C118*	0.01μF-1600-10	1-012-2225
C119	0.02μF-100-20	1-012-2372
C120***	0.47μF-50-10	1-012-2353
C121	0.01μF-1000-20	1-012-2214
C122	0.02μF-1000-20	1-012-2217
C123	0.02μF-1000-20	1-012-2217
C124	0.01μF-3000-20	1-012-2379
C125*	1μF-200-5	1-012-2327
C126	10μF-25	1-012-2211
C127	0.01μF-500-20	1-012-0740
C128	0.01μF-500-20	1-012-0740
C129	0.018μF-400-5	1-012-2333
C130*	1.2μF-100-5	1-012-2447
C131	1μF-160	1-012-2251
C132	0.68μF-100-5	1-012-2339
C133*	0.33-100-10 (VERTICAL FORMAT)	1-012-2296
	0.1-100-5 (HORIZONTAL FORMAT)	1-012-2336
C134	33μF-80	1-012-2259
C135	10μF-80	1-012-2260
C136	0.033μF-630-5	1-012-2340
C137*	68μF-50	1-012-2486
C138	10μF-80	1-012-2260
C139	0.033μF-400-10	1-012-2288
C140	0.05μF-100-20	1-012-2374
C141	47μF-50	1-012-2157
C142	0.001μF-1000-20	1-012-0540
C143*	.0027-1000-5	1-012-2316
C144	470pF-1000-5	1-012-2282
C145	0.02μF-1000-20	1-012-2217
C146	0.0047μF-1000-20	1-012-2317
C147	0.05μF-100-20	1-012-2374

*Typical Component: Actual component may differ. Check actual component before ordering.

***Optional Component: May or may not be used, depending on HD model.

6.2.3 HORIZONTAL AND VERTICAL PWA (Cont.)

REF SYM	DESCRIPTION	PART NUMBER
C148	22μF-100	1-012-2311
C149	3.3μF-250	1-012-2228
C150	0.001μF-1000-20	1-012-0540
C151	NOT USED	
C152	0.01μF-3000-20	1-012-2379
C153	0.01μF-3000-20	1-012-2379
C154	4.7μF-160	1-012-2195
C155	10μF-25	1-012-2211
	DIODE	
CR101	NOT USED	
CR102	NOT USED	
CR103	D0410	1-021-0410
CR104	IN5399	1-021-0448
CR105	IN5399	1-021-0448
CR106	D0442	1-021-0442
CR107	D0467	1-021-0467
CR108	NOT USED	
CR109	D0403	1-021-0403
CR110	D0403	1-021-0403
CR111	D0410	1-021-0410
CR112	D0403	1-021-0403
CR113	D0410	1-021-0410
CR114***	D0410	1-021-0410
CR115	D0410	1-021-0410
CR116	D0447	1-021-0447
CR117	D0447	1-021-0447
CR118	D0447	1-021-0447
CR119	D0403	1-021-0403
DS101	LAMP, GLOW	1-026-0308
	TERMINATION POINT	
E101*	WIRE/CONT, BRN	1-043-1215
E102*	WIRE/CONT, YEL	1-043-4214
E103*	WIRE/CONT, RED	1-043-2332
E104*	WIRE/CONT, BLU	1-043-6334
	CONNECTOR, RECPT	
J101	7 CONT, 123567A	1-039-0182
J102	7 CONT, 134567A	1-039-0183

*Typical Component: Actual component may differ. Check actual component before ordering.

***Optional Component: May or may not be used, depending on HD model.

6.2.3 HORIZONTAL AND VERTICAL PWA (Cont.)

REF SYM	DESCRIPTION	PART NUMBER
J103	4 CONT, 124A	1-039-0168
J104	5 CONT, 245A	1-039-0174
J105	5 CONT, 1345A	1-039-0189
J106	8 CONT, 135678A	1-039-0149
J107	4 CONT, 134A	1-039-0169
	COIL	
L101*	WIDTH	1-016-0375
L102	FOCUS	1-016-0355
L103	3.3μH	1-016-0253
	TRANSISTOR	
Q101	2N3904	1-015-1144
Q102	2N3906	1-015-1145
Q103	2N3906	1-015-1145
Q104	TIP50	1-015-1238
Q105	NOT USED	
Q106	2N3439	1-015-1221
Q107	MPSU10	1-015-1184
Q108	FT417B	1-015-1220
Q109	B1214	1-015-1214
Q110	MPS404	1 015-1224
Q111	2N2369	1-015-1212
	RESISTOR	
R101	68K-1/2-5	1-011-2314
R102	1K-1/2-5	1-011-2270
R103	470-1/2-5	1-011-2262
R104	33K-1/2-5	1-011-2306
R105	680-1/2-5	1-011-2266
R106	150-1/2-5	1-011-2250
R107	8.2K-1/2-5	1-011-2292
R108**	VAR, 50K-1/2-20	1-011-5716
R109	200K-1/2-5	1-011-2677
R110	15K-1/2-5	1-011-2298
R111**	VAR, 10K-1/2-20	1-011-5714
R112*	11K-1/2-5	1-011-2295
R113	13K-1/2-5	1-011-2297
R114*	820-1/2-5	1-011-2268
R115	4.7K-1/2-5	1-011-2286
R116	27K-1/2-5	1-011-2304
R117*	9.1K-1/2-5	1-011-2642
R118*	820-1/2-5	1-011-2268

*Typical Component: Actual component may differ. Check actual component before ordering.

**Typical Potentiometer: Actual potentiometer may differ. Check part number on actual potentiometer before ordering.

6.2.3 HORIZONTAL AND VERTICAL PWA (Cont.)

REF SYM	DESCRIPTION	PART NUMBER
R119	2.7K-1/2-5	1-011-2280
R120	470-3-5	1-011-2673
R121	820-1/2-5	1-011-2268
R122	2.2K-1/4-5	1-011-2580
R123	102K-1/4-1	1-011-2727
R124	20K-1/2-5	1-011-2301
R125	2.7K-1/2-5	1-011-2280
R126	VAR, 20K-1-20	1-011-5753
R127	68.1K-1/2-1	1-011-2546
R128	27-1/2-5	1-011-2232
R129	2.7K-1-5	1-011-2682
R130	1.2-2-10	1-011-1395
R131	39-1/2-5	1-011-2236
R132	1.2-2-10	1-011-1395
R133*	3.3-2-10	1-011-1571
R134*	3.3-2-10	1-011-1571
R135	1K-1/2-5	1-011-2270
R136***	22K-1/2-5	1-011-2302
R137	8.2M-1/2-5	1-011-2364
R138	1M 1/2-5	1-011-2342
R139	1.5M-1/2-5	1-011-2346
R140	VAR, 5M-1/4-20	1-011-5742
R141	1M-1/2-5	1-011-2342
R142	1K-1-5	1-011-2697
R143	18K-1/2-5	1-011-2300
R144	2.2K-1/2-5	1-011-2278
R145	2.2K-1/2-5	1-011-2278
R146*	33K-1/2-5 (VERTICAL FORMAT)	1-011-2306
	39K-1/2-5 (HORIZONTAL FORMAT)	1-011-2308
R147	62-1/2-5	1-011-2645
R148*	82.5K-1/2-5 (VERTICAL FORMAT)	1-011-2714
	110K-1/2-5 (HORIZONTAL FORMAT)	1-011-2742
R149*	4.7K @ 25°C (VERTICAL FORMAT)	1-011-7010
	2.2K @ 25°C (HORIZONTAL FORMAT)	1-011-7009
R150	82-1/2-5	1-011-2244
R151	VAR, 50K-1/2-20	1-011-5716
R152	6.8K-3-5	1-011-2674
R153	1.2K-1/2-5	1-011-2272
R154	4.7K-1/2-5	1-011-2286
R155	1.8K-1/2-5	1 011-2276
R156	47-1/2-5	1-011-2238
R157	20K-1/2-1	1-011-2539
R158	1.2K-1/2-5	1-011-2272

*Typical Component: Actual component may differ. Check actual component before ordering.

***Optional Component: May or may not be used, depending on HD model.

6.2.3 HORIZONTAL AND VERTICAL PWA (Cont.)

REF SYM	DESCRIPTION	PART NUMBER
R159	VAR, 1K-1/2-20	1-011-5713
R160	2.37K-1/2-1	1-011-2670
R161*	12K-1/2-5 (VERTICAL FORMAT)	1-011-2296
	22K-1/2-5 (HORIZONTAL FORMAT)	1-011-2302
R162*	680-1/2-5 (VERTICAL FORMAT)	1-011-2266
	390-1/2-5 (HORIZONTAL FORMAT)	1-011-2260
R163	1K @ 25°C	1-011-7001
R164*	22-3-5 (VERTICAL FORMAT)	1-011-2531
	35-3-5 (HORIZONTAL FORMAT)	1-011-2667
R165	NOT USED	
R166	NOT USED	
R167	909-1/2-1	1-011-2542
R168	1.3K-1/2-1	1-011-2543
R169*	22-3-5 (VERTICAL FORMAT)	1-011-2531
	39-3-5 (HORIZONTAL FORMAT)	1-011-2664
R170	820K-1/2-5	1-011-2340
R171	15K-1/2-5	1-011-2298
R172	150-1-5	1-011-2678
R173	22K-1/2-5	1-011-2302
R174	330K-1/2-5	1-011-2330
R175***	VAR, 50K-1/2W-20	1-011-5716
R176	3.3M-1/2-5	1-011-2354
R177	4.7K-1/2-5	1-011-2286
R178	1M-1-10	1-011-2391
R179**	VAR, 200K-1/3-30	1-011-5747
R180	330K-1/2-5	1-011-2330
R181	NOT USED	
R182	4.7K-1/2-5	1-011-2286
R183	130K-1/2-5	1-011-2707
R184	330-1/2-5	1-011-2258
R185	330-1/2-5	1-011-2258
R186	240K-1-5	1-011-2662
R187	3.3K-1/2-5	1-011-2282
R188	5.6K-1/2-5	1-011-2288
R189	1K-1/2-5	1-011-2270
R190	1K-1/2-5	1-011-2270
R191***	SELECTED	
R192***	22K-1/2-5 (VERTICAL FORMAT)	1-011-2302
	35.7K-1/2-1 (HORIZONTAL FORMAT)	1-011-2744
R193***	47.5K-1/2-1 (VERTICAL FORMAT)	1-011-2741
	20K-1/2-1 (HORIZONTAL FORMAT)	1-011-2539

*Typical Component: Actual component may differ. Check actual component before ordering.

**Typical Potentiometer: Actual potentiometer may differ. Check part number on actual potentiometer before ordering.

***Optional Component: May or may not be used, depending on HD model.

6.2.3 HORIZONTAL AND VERTICAL PWA (Cont.)

REF SYM	DESCRIPTION	PART NUMBER
S101	SWITCH	1-018-0260
	TRANSFORMER	
T101	HORIZ DRIVER	1-017-5435
T102	PULSE	1-017-5434
	INT CKT	
U101	NE555	1-025-0118
U102	NE555	1-025-0118
U103	NE555	1-025-0118
	ZENER	
VR101	Z0466, 5.6V	1-021-0466
VR102	Z0477, 7.5V	1-021-0477
VR103	Z0477, 7.5V	1-021-0477
VR104	Z0466, 5.6V	1-021-0466
	JUMPER WIRE	
W101	JUMPER WIRE	1-045-0140
W102	JUMPER WIRE	1-045-0140
W103	JUMPER WIRE	1-045-0140
W104	JUMPER WIRE	1-045-0140
W105	JUMPER WIRE	1-045-0140
W106	JUMPER WIRE	1-045-0140
W107	JUMPER WIRE	1-045-0140
W108	JUMPER WIRE	1-045-0140
W109	JUMPER WIRE	1-045-0140
W110	JUMPER WIRE	1-045-0140
W111***	JUMPER WIRE	1-045-0140
W112***	JUMPER WIRE	1-045-0140
W113	JUMPER WIRE	1-045-0140
W114	JUMPER WIRE	1-045-0140
W115	JUMPER WIRE	1-045-0140
W116	JUMPER WIRE	1-045-0140
W117	JUMPER WIRE	1-045-0140
W118	NOT USED	
W119	JUMPER WIRE	1-045-0165
W120***	JUMPER WIRE	1-045-0165
W121	JUMPER WIRE	1-045-0140
W122	JUMPER WIRE	1-045-0140
W123***	JUMPER WIRE	1-045-0165
W124	JUMPER WIRE	1-045-0100
	MISCELLANEOUS	
	PWB	1-029-0528
	IC SOCKET (3)	1-022-0448

***Optional Component: May or may not be used, depending on HD model.

6.2.3 HORIZONTAL AND VERTICAL PWA (Cont.)

REF SYM	DESCRIPTION	PART NUMBER
	CLAMP LOOP	2-050-0170
	BRKT L101 SUPPORT	2-017-1252
	MCHSCR 8-32 X 1/4	3-011-0520
	LKWSHR #8 INT	3-013-0182

6.2.4 POWER SUPPLY PWA

REF SYM	DESCRIPTION	PART NUMBER
	CAPACITOR	
C301	1000µF-50	1-012-2281
C302	47µF-50	1-012-2157
C303	22µF-50	1-012-2193
C304	22µF-50	1-012-2193
C305	10pF-500-5	1-012-2407
C306	.1µF-100-20	1-012-2370
C307	.22µF-200-10	1-012-0930
	DIODE	
CR301	ASSY, RECTIFIER	6-003-0800
CR302	IN4001	1-021-0499
CR303	D0410	1-021-0410
CR304	D0410	1-021-0410
CR305	D0410	1-021-0410
H301*	SOCKET XSTR	1-041-0110
	CONNECTOR	
J301	6 CONT, 12346A	1-039-0180
J302	4 CONT, 234A	1-039-0170
J303	7 CONT, 123457A	1-039-0181
J304	NOT USED	
J305	NOT USED	
	TRANSISTORS	
Q301	MPSA93	1-015-1202
Q302	MPSL01	1-015-1170
Q303	MJE340	1-015-1244
Q304	2N3904	1-015-1144
	RESISTOR	
R301	5.6-2-10	1-011-1610
R302	3.6K-1/2-5	1-011-2283
R303	390-1/2-5	1-011-2260

*Typical Component: Actual component may differ. Check actual component before ordering.

6.2.4 POWER SUPPLY PWA (Cont.)

REF SYM	DESCRIPTION	PART NUMBER
R304	82K-1/2-5	1-011-2316
R305	330-1/2-5	1-011-2258
R306	10K-1/2-5	1-011-2294
R307	330-1/2-5	1-011-2258
R308	15K-1/2-5	1-011-2298
R309	180K-1/2-5	1-011-2324
R310	1K-1/2-5	1-011-2270
R311	100K-1/2-5	1-011-2318
R312	.68-2-10	1-011-2217
R313	68.1K-1/2-1	1-011-2546
R314	VAR, 2.5K-1/4-20	1-011-5636
R315	27.4K-1/2-1	1-011-2522
R316	VAR, 20K-1/2-20	1-011-5712
R317	8.2M-1/2-5	1-011-2364
R318	62K-1/2-5	1-011-2313
R319	4.3K-1/2-5	1-011-2285
	ZENER	
VR301	Z0490, 24V	1-021-0490
	JUMPER WIRE	
W301	.65/16.5	1-045-0165
W302*	.65/16.5	1-045-0165
	MISCELLANEOUS	
	PWB	1-029-0514

6.2.5 LINEAR VIDEO AMPLIFIER PWA

REF SYM	DESCRIPTION	PART NUMBER
	CAPACITOR	
C201	.01μF-100-20	1-012-2371
C202	.01μF-100-20	1-012-2371
C203	.1μF-100-20	1-012-2370
C204	22μF-50	1-012-2193
C205	91pF-500-5	1-012-2436
C206	22μF-50	1-012-2193
C207	NOT USED	
C208	.1μF-100-20	1-012-2370
C209	22μF-50	1-012-2193
C210	82pF-500-5	1-012-2435
C211	.1μF-100-20	1-012-2370

*Typical Component: Actual component may differ. Check actual component before ordering.

6.2.5 LINEAR VIDEO AMPLIFIER PWA (Cont.)

REF SYM	DESCRIPTION	PART NUMBER
C212	220µF-25	1-012-2159
C213	10µF-80	1-012-2260
C214	.01µF-100-20	1-012-2371
C215	10µF-80	1-012-2260
C216	NOT USED	
C217	.01µF-100-20	1-012-2371
C218	.01µF-500-20	1-012-0740
C219	.01µF-500-20	1-012-0740
C220	2pF-230	1-012-0111
C221	.47µF-100-10	1-012-1007
C222	.01µF-100-20	1-012-2371
C223	270pF-1000-10	1-012-0395
C224	.75pF-1000	1-012-0110
C225	.01µF-1000	1-012-0112
C226	.75pF-1000	1-012-0110
C227	.001µF-1000-20	1-012-0540
	DIODE	
CR201	D0467	1-021-0467
	TERMINATION POINT	
E201	CRT SOCKET, BLK LD	
E202	CRT SOCKET, WHT LD	
E203	CRT SOCKET, RED LD	
E204	CRT SOCKET, BLU LD	
E205	NOT USED	
E206	NOT USED	
E207	CRT SOCKET, YEL LD	
E208	CRT SOCKET, BRN LD	
E209	CRT SOCKET, GRN LD	
	CONNECTOR	
J201	4 CONT, 124A	1-039-0168
J202	3 CONT, 12A	1-039-0164
J203	6 CONT, 12356A	1-039-0193
J204	NOT USED	
J205	NOT USED	
J206	3 CONT, 13A	1-039-0165
	COIL	
L201	.68µH	1-016-0297
L202	2.2µH	1-016-0394
	TRANSISTOR	
Q201	2N3904	1-015-1144
Q202	2N3904	1-015-1144
Q203	2N3904	1-015-1144
Q204	2N3906	1-015-1145
Q205	2N3904	1-015-1144

6.2.5 LINEAR VIDEO AMPLIFIER PWA (Cont.)

REF SYM	DESCRIPTION	PART NUMBER
Q206	MM3000	1-015-1211
Q207	2N3904	1-015-1144
Q208	MM3000	1-015-1211
Q209	MM3000	1-015-1211
	RESISTOR	
R201	1.2K-1/2-5	1-011-2272
R202	510-1/2-5	1-011-2263
R203	VAR, 1K-1/4-20	1-011-5691
R204	510-1/2-5	1-011-2263
R205	1.3K-1/2-5	1-011-2273
R206	200-1/2-5	1-011-2253
R207***	SELECTED	
R208	270-1/2-5	1-011-2256
R209	270-1/2-5	1-011-2256
R210	15-1/2-5	1-011-2226
R211	470-1/2-5	1-011-2262
R212	15-1/2-5	1-011-2226
R213	82-1/2-5	1-011-2244
R214	200-1/2-5	1-011-2253
R215	56-1/2-5	1-011-2240
R216	680-1/4-5	1-011-2628
R217	200-1/4-5	1-011-2576
R218	180-1/2-5	1-011-2252
R219	22-1/2-5	1-011-2230
R220	750-7-5	1-011-2540
R221	NOT USED	
R222	100-1/4-5	1-011-2552
R223	NOT USED	
R224	220-3-5	1-011-2207
R225	12-1/2-5	1-011-2224
R226	10-1/2-5	1-011-2222
R227	12-1/2-5	1-011-2224
R228	1.5K-5-5	1-011-2694
R229	47-1/2-5	1-011-2238
R230	47-1/2-5	1-011-2238
R231	820-7-5	1-011-2541
R232	100-1/2-5	1-011-2246
R233	22K-1/2-5	1-011-2302
R234***	SELECTED	
R235	47K-1/2-5	1-011-2310
R236	47K-1/2-5	1-011-2310
R237	100-1/2-5	1-011-2246
R238	4.7K-1/2-5	1-011-2286
R239	NOT USED	
R240	10-1/2-5	1-011-2222

***Optional Component: May or may not be used, depending on HD model.

6.2.5 LINEAR VIDEO AMPLIFIER PWA (Cont.)

REF SYM	DESCRIPTION	PART NUMBER
	ZENER	
VR201	Z0180, 10V	1-021-0180
VR202	Z0492, 12V	1-021-0492
VR203	NOT USED	
	JUMPER WIRE	
W201	JUMPER WIRE	1-045-0140
W202	JUMPER WIRE	1-045-0255
	MISCELLANEOUS	
	PWB	1-029-0496
	HEATSINK (3)	1-015-5072
	SOCKET CRT	6-004-0898
	TRANSIPAD (3)	3-019-0134
	CLAMP, CMPNT	2-050-0202
	MCHSCR, 6-32X1	3-011-1105
	MCHSCR, 6-32X3/8 (2)	3-011-1106
	NUT, 6-32 (3)	3-012-0308
	LK WSHR, #6 INT (3)	3-013-0160

6.2.6 TTL VIDEO AMPLIFIER PWA

REF SYM	DESCRIPTION	PART NUMBER
	CAPACITOR	
C201	.1µF-100-20	1-012-2370
C202	47µF-25	1-012-2165
C203	22µF-50	1-012-2193
C204	.1µF-100-20	1-012-2370
C205	.01µF-500-20	1-012-0740
C206	5pF-500-10	1-012-2405
C207	10µF-80	1-012-2260
C208	.1µF-100-20	1-012-2370
C209	.75pF-1000	1-012-0110
C210	.75pF-1000	1-012-0110
C211	.75pF-1000	1-012-0110
C212	2pF-230	1-012-0111
C213	270pF-1000-10	1-012-0395
C214	.01µF-1000	1-012-0112
C215	.01µF-500-20	1-012-0740
C216	22pF-500-5	1-012-2418
C217	15pF-500-5	1-012-2412
C218	15pF-500-5	1-012-2412
C219	.47µF-100-10	1-012-1007
C220	10µF-80	1-012-2260
C221	22µF-50V	1-012-2193
C222	.1µF-100-20	1-012-2370
C223	.001µF-1000-20	1-012-0540

6.2.6 TTL VIDEO AMPLIFIER PWA (Cont.)

REF SYM	DESCRIPTION	PART NUMBER
	DIODE	
CR201	D0467	1-021-0467
CR202	NOT USED	
	TERMINATION POINT	
E201	CRT SOCKET, BLK LD	
E202	CRT SOCKET, WHT LD	
E203	CRT SOCKET, RED LD	
E204	CRT SOCKET, BLU LD	
E205	NOT USED	
E206	NOT USED	
E207	CRT SOCKET, YEL LD	
E208	CRT SOCKET, BRN LD	
E209	CRT SOCKET, GRN LD	
	CONNECTOR	
J201	RECPT 4 CONT, 124A	1-039-0168
J202	RECPT 3 CONT, 12A	1-039-0164
J203	NOT USED	
J204	RECPT 6 CONT, 12356A	1-039-0193
J205	RECPT 3 CONT, 13A	1-039-0165
	COIL	
L201	1.5μH	1-016-0393
	TRANSISTOR	
Q201	MM3000	1-015-1211
Q202	2N2369	1-015-1212
Q203	2N2369	1-015-1212
Q204	2N2369	1-015-1212
Q205	MM3000	1-015-1211
Q206	MM3000	1-015-1211
	RESISTOR	
R201	180-1/2-5	1-011-2252
R202	VAR, 2.5K-1/4-20	1-011-5741
R203	270-1/2-5	1-011-2256
R204	300-1/2-5	1-011-2257
R205	1K-1/2-5	1-011-2270
R206	300-1/2-5	1-011-2257
R207	36-1/2-5	1-011-2728
R208	300-2-5	1-011-2467
R209	560-7-5	1-011-2675
R210	47-1/2-5	1-011-2238
R211	160-2-5	1-011-2733
R212	5.6K-2-5	1-011-2654
R213	12-1/2-5	1-011-2224
R214	12-1/2-5	1-011-2224

6.2.6 TTL VIDEO AMPLIFIER PWA (Cont.)

REF SYM	DESCRIPTION	PART NUMBER
R215	47-1/2-5	1-011-2238
R216	1K-7-5	1-011-2660
R217	100-1/2-5	1-011-2246
R218	820-7-5	1-011-2541
R219	100-1/2-5	1-011-2246
R220***	SELECTED	
R221	47K-1/2-5	1-011-2310
R222	10K-1/2-5	1-011-2294
R223	4.7K-1/2-5	1-011-2286
R224	1K-1/2-5	1-011-2270
R225	22K-1/2-5	1-011-2302
R226	22-1/2-5	1-011-2230
R227***	SELECTED	
	ZENER	
VR201	Z0476, 6.8V	1-021-0476
VR202	Z0405, 15V	1-021-0405
	JUMPER WIRE	
W201	JUMPER WIRE	1-045-0140
	MISCELLANEOUS	
	PWB	1-029-0488
	HEATSINK (3)	1-015-5072
	SOCKET CRT	6-004-0898
	TRANSIPAD (3)	3-019-0134
	CMPNT, CLAMP	2-050-0202
	MCHSCR, 6-32X1	3-011-1105
	MCHSCR, 6-32X3/8 (2)	3-011-1106
	NUT, 6-32 (3)	3-012-0308
	LK WSHR, #6 INT (3)	3-013-0160

***Optional Component: May or may not be used, depending on HD model.

HELP US TO HELP YOU

Should you find errors, please take a moment and let us know:

A. TYPOGRAPHICAL ERRORS:

PAGE	ERROR

B. TECHNICAL ERRORS:

PAGE/FIG. NO.	ERROR (USE ADDITIONAL PAPER IF NEEDED)

C. MANUAL USED FOR: SERVICING GENERAL INFORMATION
SPARE PARTS ORDERS OTHER_____

_____

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D. DO YOU FIND THIS MANUAL MORE HELPFUL THAN A "STANDARD" MANUAL?

YES NO

E. COMMENTS: _____

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_____

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INSTALLATION AND OPERATING MANUAL

MALFUNCTION REPORT

Dear Customer:

We are trying to manufacture the most reliable product possible. You would do us a great courtesy by completing this form should you experience any failures.

1. Type Unit _____ Serial No. _____

   Module (if applicable) _____

2. Part failed (Name and Number) _____

3. Cause of failure (if readily available) _____

   _____

   _____

   _____

4. Approximate hours/days of operation to failure _____

5. Failure occurred during:

   Final Inspection Customer Installation Field Use

6. Personal Comment:

   _____

   _____

   _____

Customer _____

Address _____

Signed _____

Date _____

Ball Electronic Display Division
P.O. Box 43376
St. Paul, Minnesota 55164
Telephone 612-786-8900 TWX 910-563-3552


Ball