HEWLETT-PACKARD CO.

THEORY OF OPERATION
09826-66580 CRT ANALOG BOARD

1.0 GENERAL DESCRIPTION

This document describes the circuitry on the 09826-66580 CRT Analog board that is used in the 9836A. The ´80 board is very similar to the sweep board of the HP 262X series of terminals (02620-60002) from DTD and the display driver board from the 64100 microprocessor development station (64100-66523) from Colorado Springs. The following documents should be on hand when studying this theory of operation:

1) D-09826-66580-4 Schematic Diagram
2) C-09826-66580-6 Block Diagram
3) C-09826-66580-7 Timing Diagram

This board has four basic functions. They are:

1) To generate the current required for the vertical deflection of the electron beam.
2) To generate the current required for the horizontal deflection of the electron beam.
3) To supply the grid voltages and the accelerating potential for the electron beam.
4) To amplify the video signals to the voltage level required to drive the cathode of the tube.

Each function will be discussed in a seperate section below but a general overview is given here:

The 9836 display is a raster scanned CRT. It utilizes magnetic deflection and is refreshed at a rate of 50 or 60 Hertz (factory selectable by a jumper on the Alpha board). The Alpha board of the 9836A (09826-66576) supplies the horizontal sync (AHRTC), vertical sync (AVRTC bar), and video drive signals (FULL bar and HALF bar) to the ´80 board. The CRT displays 390 horizontal scan lines (Alpha mode can access only 375 lines) and operates at a horizontal sweep rate of 24.90 kHz. The vertical retrace time is dependent upon the refresh rate. When the refresh rate is set at 60 Hz (USA, Japan, and Canada) the vertical retrace pulse is 763 us long and the video is blanked for

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25 AHRTC pulses. When the refresh rate is 50 Hz the vertical retrace pulse is 2.29 ms long and the video is blanked for 108 AHRTC pulses. Video is displayed for 29.7 us during the horizontal trace time and blanked for 10.5 us allowing time for horizontal retrace. Graphics operates at a basic clock frequency of 17.18 MHz with 512 dots per horizontal line. Alpha operates at a basic clock frequency of 25.77 MHz with 720 dots per line. The graphics display starts 16 graphic's dots before the alpha display and extends 16 graphic's dots beyond the alpha display. And as mentioned above, the graphic's display uses 15 lines at the top of the screen that the alpha display does not.

2.0 GENERATION OF THE VERTICAL DEFLECTION CURRENT

Vertical deflection is accomplished using an active op-amp circuit. It is used because the refresh rate is slow (50 or 60 Hz) and it makes the circuit fairly straight forward. Norton op-amps are used so that only one supply is needed but because of that, the yoke must be AC coupled; therefore, there is no vertical position adjustment. The circuit has one input (AVRTC bar) which is active low and its output is the current through the vertical yoke winding. These can be seen in the timing diagram. Its basic functional areas can be seen in the block diagram. Each area will be covered in a section below.

2.1 CURRENT AMPLIFIER

The current amplifier's basic function is to increase the power of the input signal so that the vertical yoke can be driven with enough current to deflect the electron beam the correct amount. Because of the relatively large inductance of the vertical yoke winding (14.5 mH), only about 250mA peak is required. The op-amp part of the current amp serves to invert the signal (so that it has the correct polarity) and to drive the output stage. Notice that the feedback comes not directly from the output of the op-amp or the output stage, but from a 3.3 ohm current sensing resistor. This is important because the load (the vertical yoke) is reactive and desired output is current, not voltage, so the small series resistor is an easy way of sampling the current.

The output stage is a unity voltage gain push-pull emitter-follower. It is implemented using complimentary npn and pnp darlingtons. Diodes are used to bias the circuit for proper operation. The gain of the overall amplifier is about 74 uA/V.

This current amplifier exhibits some nonlinearities that must be overcome. When a straight, upward sloping ramp is the input, instead of getting a straight, downward sloping ramp out, the ramp will be somewhat concave. This is compensated by adding some concavity to the input signal. This will be covered in the section on the ramp generator.

2.2 VOLTAGE DOUBLER

During retrace it is necessary to change the current through the yoke from max negative to max positive current in a short period of time (763us for 60 Hz operation). Because of the inductance of the yoke this requires more than the 12 volts that is available from the regular supply. The voltage doubling network overcomes this problem by providing about 24 volts to the current amplifier. This is accomplished by using a transistor switch and a 22uF capacitor. During the vertical trace the transistor is off, so the negative side of the capacitor is at ground and the capacitor is charged to 12 volts through a diode. During the retrace the transistor is turned on so that the negative side of the capacitor is raised to 12 volts and since the voltage across a capacitor cannot change instantaneously, the diode shuts off and the capacitor feeds the op-amp and output stage with 24 volts.

2.3 RAMP GENERATION AND RESET

The basic ramp is generated using a standard op-amp integrator configuration. When AVRTC bar is high, no current is going into the inverting input and a positive going ramp is generated. When AVRTC bar is low, current is sourced into the inverting input and the output of the op-amp is held at near zero volts. The slope of the ramp is determined by the amount of current that is sourced into the non-inverting input. As the current gets larger the ramp gets 'steeper'.

The ramp reset network just uses AVRTC bar and injects current into the inverting input when the signal is low. The .0047 uF capacitor acts as a speed-up mechanism at the beginning of the retrace.

As mentioned above, the current amplifier has some nonlinearity that is taken care of by the ramp generator. To do this, a slight concavity is added to the ramp by using positive feedback. To take care of any variation in gain or other op-amp parameters, the amount of positive feedback is variable by using the vertical linearity adjustment pot. To get more concavity, the positive feedback resistance is made smaller.

2.4 S-SHAPING NETWORK

It was brought up in the last section that the slope of the ramp is controlled by the amount of current that is injected into the non-inverting input of the op-amp. This principle is used to give the basic ramp a slight S-shape which is needed to make up for the fact that the point of deflection of the electron beam is not at the center of curvature of the tube face. The shape of the waveform used to do this is shown in the timing diagram. Notice that at the beginning and end of the cycle the voltage at the output of the S-shaping op-amp is smaller than in the middle of the cycle. This makes the slope of the ramp greater in the middle of the trace than at either end which gives the slight S-shape.

3.0 GENERATION OF THE HORIZONTAL DEFLECTION CURRENT

Horizontal deflection is generated by a resonant circuit of the type commonly found in television receivers. This type of circuit is widely used because it is inexpensive and consumes little power. A significant part of the display quality is determined by the accuracy of the horizontal deflection waveform. This accuracy is obtained by small modifications to the basic resonant sweep circuit. These modifications are the details which make the circuit unique and ultimately determine its cost and reliability.

3.1 THE BASIC RESONANT SWEEP CIRCUIT

The fundamental componants of the resonant sweep circuit are shown in the block diagram of the '80 board. There are two resonant modes in the circuit. One is the resonance between Cs and the horizontal yoke. This resonance is active during the trace period. The other resonance is between the capacitor Cr and the horizontal yoke. This resonance is active during horizontal retrace. The retrace resonant frequency is about 100 times higher than the trace resonance.

Steady state operation of the circuit is easy to understand if one assumes ideal components with no loss. The sequence of events is as follows: Assume that positive current is flowing from ground, through the yoke and horizontal drive transistor and back to ground. Retrace is initiated by switching off the horizontal drive transistor, which causes the current flowing in the yoke to charge the retrace capacitor Cr. As Cr charges, the voltage developed slows the current flowing in the yoke until all of the energy that had been stored in the yoke is now stored in the retrace capacitor. At this point the yoke current is zero and the voltage across Cr is at a maximum. This voltage causes current to begin to flow back into the yoke from the retrace capacitor until all the energy is once again stored in the yoke. The effect of the retrace resonance is to reverse the current in the yoke, quickly, without the loss of energy.

Peak current is now flowing through the yoke and into ground. If the damper diode were not in the circuit, the yoke current would be a sine wave at the frequency of the retrace resonance. The damper diode, however, will not let a negative voltage develop across Cr. The result is that Cr is effectively shorted and the yoke current flows through the diode into the S-shaping capacitor Cs. This capacitor was unimportant during retrace because it is effectively a short at the retrace resonant frequency. Now, however, it slowly builds up a charge until the yoke current is again at zero and all of the energy of the circuit is now stored in Cs. Sometime before the yoke current goes to zero, the norizontal drive transistor is turned on. This allows the trace resonance to continue for another half cycle. During this interval, energy is transfered from Cs back into the yoke until the voltage on Cs goes to zero and the yoke current is again at a maximum, with the beam at the end of a norizontal trace. At this point the transistor is switched off and the cycle repeats.

Of course the circuit is not ideal, resistive losses disipate energy which must be resupplied to the circuit. The energy is replenished on each cycle by the action of the flyback transformer. When the horizontal drive transistor switches off, part of the energy stored in the primary inductance of the flyback transformer is transfered to the retrace capacitor (high voltage injection). This energy comes from the power supply and is built up in the flyback transformer during the second half of the trace period. In this way the flyback transformer determines the width of the display. The yoke current grows until an equilibrium is reached between the amount of energy injected and the amount of energy dissipated on each cycle.

The resulting waveforms are snown in the '80 board timing diagram. The slight S-shaping during the trace compensates for the geometric properties of the display surface. The amount of S-snaping is determined by the frequency of the trace resonance. Note the values of current and voltage involved; the maximum yoke current is about 1.8 Amps and the retrace pulse is about 275 volts.

3.2 SOME DETAILS ABOUT HORIZONTAL DEFLECTION

The width of the display is adjusted by changing the inductance in series with the yoke. This changes the resonant frequencies and allows the transfer of energy between the yoke and the capacitors to occur at different rates. Because the time per trace is fixed by the digital circuitry in the alpha board, a change in the energy transfer rate means that the maximum yoke current will change, and correspondingly, the width will change.

Good linearity is obtained by the inclusion of the linearity coil. The linearity coil is a saturate inductor which is biased with a magnet so that its inductance is a function of the current through it. For the first part of the trace when the total energy in the trace resonant circuit is at its largest, the inductance of the linearity coil is at its largest. By the end of the trace some of the energy has been lost to the resistance but the current through the the lineartity coil is in the opposite direction so its inductance is at a minimum. This change of inductance during the sweep equalizes the positive and negative excursions of the yoke current and linearizes the display. Obviously, the linearity coil must be matched to the losses in the horizontal resonant circuit.

The purpose of the base dirve circuit is to amplify the horizontal sync signal (AHRTC), and to isolate this signal from the high currents and voltages on the output side. The base drive transformer uses positive feedback to reduce the power required on the signal side. A monostable-multivibrator is used to set the duty cycle of the horizontal drive transistor. It is set so that the transistor will be off for 13.75 us each cycle. The occurance of shutting off the horizontal drive transistor can be varied with respect to the video signals by changing the period of the one-shot that serves as the horizontal delay circuit. By shortening the delay period, the retrace occurs earlier with respect to the video so that the displayed video moves closer to the end of the trace. This makes the display shift to the right as the operator sees it. The display may be shifted to the left by lengthening the delay period. But remember that the duty cycle of the horizontal drive transistor is fixed and is not affected by the horizontal position control. So the horizontal position control just affects the position of the display within the raster and does not affect the position or size of the raster itself.

PRELIMINARY

4.0 VOLTAGE GENERATION

The flyback transformer is used to generate the voltages required by the CRT and video amplifier. There are four different voltages obtained from this part. The voltages are generated during the flyback pulse; therefore, they have a low duty cycle. Because of this, good diodes must be used for rectification of these fast pulses (approx. 8us wide). Fortunately, however, the frequency is high (24.90 kHz) and the current required is relatively small so the regulation is good on all supplies. The four supplies are:

1) A positive voltage of 12 kV for electron acceleration. This is called the anode voltage.
2) A positive 800 V supply for grids G2 (intensity) and G4 (focus) in the CRT.
3) A negative 44 volt supply for G1 of the CRT.
4) A positive 40 volt supply for the video amplifier.

The 12 kV anode supply includes a bleeder resistor for safety and to help regulate the high voltage. This supply will drop down to a safe energy level in less than 10 seconds after power down.

Control of the focus and intensity is obtained by dividing the 800 volt supply down with resistive divider networks. Both of these networks have potentiometers in them so that adjustments may be made. The intensity control has two pots; one compensates for variations in CRT's and one gives the operator the ability to compensate for variations in ambient lighting conditions.

Regulation of the voltage for G1 down to -42 volts is accomplished with a Zener diode circuit. This is done to reduce the amount of variation from unit to unit. It is important to do this because the G1 voltage determines the ideal cathode current, and if the cathode current is not near that ideal amount, long term degradation of the dot size could occur.

Arc protection in the form of spark-gap capacitors is provided for each of the grids so that if the anode voltage arcs to any of the grids, the current will have a path to ground without having to travel through the rest of the circuit.

PRELIMINARY

5.0 VIDEO AMPLIFIER

The video amplifier is a simple circuit which uses active pull-up to speed up the drive. All the transistors in this circuit are used in switching mode. The output amplifier can have one of three outputs, 30 volts (beam off), 0 volts (beam full on), or 6 volts (half bright). There are two inputs to the amp, FULL bar and HALF bar. Both signals are active low and FULL bar will override HALF bar. As can be seen from the schematic, both inputs are connected to an ´LS38. An ´LS38 was chosen as a compromise between speed and low-level input current. It was important to have the low-level input current small enough to allow for the proper termination resistor of the 50 ohm coax which is used to carry the FULL bar and HALF bar signals from the ´76 board to the ´80 board. The inductor in the amplifier is used to speed the transition times of the video pulse. A drawing of a video pulse one dot wide is shown in the timing diagram. The slope of the edges can be seen to be about 1000 volts per microsecond.

The neon bulbs on the filament and cathode leads are for arc suppression and serve the same function as the spark-gap cap´s on the CRT grids.

6.0 LAYOUT

Care has been taken in the routing of traces and grounding so that large loops could be avoided. The spacing of high voltage traces is such that the board will meet IEC 380 safety specifications and trace size has been chosen to accomodate the expected currents. The connection for the CRT cathode was moved near the video amp to reduce EMI and a guard trace was put in place around the high voltage section of the circuit to give any stray currents that may develop during high humidity a path to ground before they get to the more sensitive circuitry.

DC LOADING SPECIFICATION

09826-66580
CRT ANALOG BOARD

The DC load on the system power supplies is shown in the table below.

Supply	Measured RMS	Measured Peak	
+12v	1.2	1.4	Amps
-12v	67	70	mA

The following table gives the loading for the four digital signals that enter the ´80 board. All four signals originate on the Alpha board (09826-66576).

Signal Name	Load IC´s	Eq. # LSTTL Loads
HALF	´LS38	1
FULL	´LS38	3
AVRTC	´06	8
AHRTC	´LS221	1

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