CRT Clock/TV/Scope

Assembly and User Manual

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TABLE OF CONTENTS

INTRODUCTION

The CRT Clock/TV/Scope is the result of efforts to develop a reasonably simple circuit that incorporates a few common and fun uses of an electrostatic CRT. The PCB was mainly designed to drive a 2-inch to 3-inch oscilloscope CRT, but some 5-inch CRTs will work. Short descriptions of the available features are as follows:

- The XYZ Scope mode allows direct access to the deflection amplifiers for DC-coupled XYZ inputs. Applications include stereo audio monitoring, Lissajous figures, or another external scope clock.

- The Clock mode consists of the minimal hardware version of the Dutchtronix Scope Clock (firmware V3.0); it provides all the CRT on-screen features but lacks the LED and RS232 level converter.

- The Oscilloscope mode uses a simple sweep generator with a range up to a few hundred kilohertz. The oscilloscope is good for simple waveform monitoring and experiments. Basic triggering is an included feature of the oscilloscope.

- The TV mode will display a basic picture on the CRT screen with a composite video input. This mode is not a full television receiver that decodes over-the-air, VHF, or digital signals. It utilizes the same sweep generator used for the oscilloscope in addition to another sweep generator for the vertical deflection to create a raster (scanning pattern) on the screen. The circuitry is quite simple so the picture is visible but not fantastic.

These are all the features available with a fully populated PCB, but the board could be partially built for fewer features such as a standalone scope clock. The PCB was designed to run solely off a transformer for isolation purposes to provide some additional safety. More importantly, the PCB contains high voltage circuitry where the largest potential difference is at around 1000 volts, so extra care should be taken when building, handling, and operating the board.

All the details on assembly and parts are included in this manual. This manual is written under the assumption that the reader has some experience with soldering and mounting components.

PARTS LIST

The PCB and a small Clock parts kit are only supplied components of the CRT Clock/TV/Scope kit. All the other parts will have to be obtained at the discretion of the builder. The parts list is separated in five sections: essentials, clock, scope, TV, and miscellaneous. The essentials are the parts required for the PCB to do anything useful, that is, a basic XYZ scope display. The Clock, Oscilloscope, and TV parts may be added to extend the capability of the PCB to include that feature. Due to the integration of circuits for multiple functions, the TV feature requires all the parts under Oscilloscope except for those denoted with an asterisk. The miscellaneous parts are not required for the PCB, but rather for external wiring or other functions detailed under Notes and at the Page number. All the parts come with a suggested part number for Digikey (DK), Mouser (MR), STF-Electronics (STF), SparkFun (SF), NKC Electronics (NKC), or other sources.

A small parts kit is available from Dutchtronix (www.dutchtronix.com) that will cover all the parts listed under Clock and jumpers JP1-4 for $17.50.

Many components often come in different packages and dimensions. The information listed under Package describes the case or dimensions of the component that will fit on the PCB. Other dimensions may work but likely will not fit as neatly on the PCB. Several components have numbers under Package that describes the physical dimensions as follows:

- For the battery, ceramic disc capacitors, and crystals: the number refers to the spacing between the leads.
- For electrolytic capacitors: the first digit before the dash is the spacing between the leads and the last digit after the dash is the tubular body diameter. For example, a 3.5 - 5 package means 3.5mm spacing between leads of a capacitor with a 5mm body diameter.

Essentials

Part	Value	Description	Package	Suggested Part Number
CRT	(See CRT Notes on Page 8)			
C1	0.001uF 2kV	ceramic disc	5	DK# 478-4289-1-ND
C15	10uF 450V	radial electrolytic	5 – 13	DK# P13671-ND
C16	1uF 450V	radial electrolytic	3.5 – 8	DK# P5340-ND
C17	2.2uF 450V	radial electrolytic	5 - 10.5	DK# P5341-ND
C18	2.2uF 450V	radial electrolytic	5 - 10.5	DK# P5341-ND
C19	100uF	radial electrolytic	2 - 5	DK# P5137-ND
C20	470uF	radial electrolytic	3.5 - 8	DK# P5141-ND
C21	1000uF	radial electrolytic	5 - 10.5	DK# P5142-ND
C22	470uF	radial electrolytic	3.5 - 8	DK# P5141-ND
D3	1N4007	1000V 1A diode	DO-41	DK# 1N4007-TPMSCT-ND
D4	1N4007	1000V 1A diode	DO-41	DK# 1N4007-TPMSCT-ND
D5	1N4007	1000V 1A diode	DO-41	DK# 1N4007-TPMSCT-ND
D6	1N4007	1000V 1A diode	DO-41	DK# 1N4007-TPMSCT-ND
D7	1N4004	400V 1A diode	DO-41	DK# 1N4004-TPMSCT-ND

D8	1N4004	400V 1A diode	DO-41	DK# 1N4004-TPMSCT-ND
IC1	TL082	dual op-amp	DIP-8	DK# 296-1780-5-ND
IC4	78L05	5V 100mA regulator	TO-92	DK# MC78L05ACPGOS-ND
IC5	79L05	-5V 100mA regulator	TO-92	DK# MC79L05ACPGOS-ND
JP1-4		0.1" header 20 pos		MR# 538-22-28-4203
		Shunts for jumpers		MR# 151-8000
T2	ZTX458	400V 0.5A NPN	TO-92	DK# ZTX458-ND
T3	ZTX458	400V 0.5A NPN	TO-92	DK# ZTX458-ND
T4	ZTX458	400V 0.5A NPN	TO-92	DK# ZTX458-ND
T5	ZTX458	400V 0.5A NPN	TO-92	DK# ZTX458-ND
T9	ZTX458	400V 0.5A NPN	TO-92	DK# ZTX458-ND
R1	2.2K 1/4W	resistor		DK# CF1/42.2K5%RCT-ND
R2	56K 1/4W	resistor		DK# CF1/456K5%RCT-ND
R3	56K 1/4W	resistor		DK# CF1/456K5%RCT-ND
R4	4.7K 1/4W	resistor		DK# CF1/44.7K5%RCT-ND
R5	4.7K 1/4W	resistor		DK# CF1/44.7K5%RCT-ND
R6	56K 1/4W	resistor		DK# CF1/456K5%RCT-ND
R7	56K 1/4W	resistor		DK# CF1/456K5%RCT-ND
R8	4.7K 1/4W	resistor		DK# CF1/44.7K5%RCT-ND
R9	2.2K 1/4W	resistor		DK# CF1/42.2K5%RCT-ND
R10	10K 1/4W	resistor		DK# CF1/410K5%RCT-ND
R11	470K 1/4W	resistor		DK# CF1/4470K5%RCT-ND
R12	10K 1/4W	resistor		DK# CF1/410K5%RCT-ND
R13	10K	YPOS potentiometer		MR# 531-PT10MH-10K
R14	100K	XSIZE potentiometer		MR# 531-PT10MH-100K
R15	10K	XPOS potentiometer		MR# 531-PT10MH-10K
R16	100K	YSIZE potentiometer		MR# 531-PT10MH-100K
R17	1Meg 1/4W	resistor		DK# CF1/41M5%RCT-ND
R18	4.7K 1/4W	resistor		DK# CF1/44.7K5%RCT-ND
R33	1Meg	ASTIG potentiometer		MR# 531-PT10MH-1M
R34	47K 1/4W	resistor		DK# CF1/447K5%RCT-ND
R35	1Meg	INTEN potentiometer		MR# 531-PT10MH-1M
R36	1Meg	FOCUS potentiometer		MR# 531-PT10MH-1M
SOCKET		CRT Socket (See Notes on Page 11)		
TRAFO	270X	Hammond (See Transformer Notes on Page 8)		STF# 270X

Clock

Part	Value	Description	Package	Suggested Part Number
BATTERY	3 volt	lithium cell	5	MR# 614-CR1225FV-LF
C23	0.1uF	ceramic disc	5	DK# 478-1831-ND
C24	0.1uF	ceramic disc	5	DK# 478-1831-ND

C25	22pF	ceramic disc	5	MR# 140-50N2-220J-RC
C26	22pF	ceramic disc	5	MR# 140-50N2-220J-RC
C27	0.1uF	ceramic disc	5	DK# 478-1831-ND
C28	10uF	radial electrolytic	1.8 – 4	DK# ECA-1CM100B-ND
D9	BAT42	schottky diode		DK# 497-2495-1-ND
D10	BAT42	schottky diode		DK# 497-2495-1-ND
D12	1N4148	signal diode		DK# 1N4148T-73CT-ND
D13	1N4148	signal diode		DK# 1N4148T-73CT-ND
IC6	ATMEGA168-20	preprogrammed CPU	DIP-28 (See Page 8)	MR# 556-ATMEGA168-20PU
IC7	AD7302	DAC	DIP-20	DK# AD7302BNZ-ND
IC8	PCF8563	RT clock/calendar	DIP-8	DK# PCF8563PN
IC6 socket	For ATMEGA168-20		DIP-28	MR# 571-3902619
IC7 socket	For AD7302		DIP-20	MR# 571-3902616
IC8 socket	For PCF8563		DIP-8	MR# 649-DILB8P-223TLF
Q6	32.768MHz	clock crystal	2.5	DK# XC967-ND
Q7	20MHz	crystal	5	DK# CTX062-ND
R37	10K 1/4W	resistor		DK# CF1/410K5%RCT-ND
R38	10K 1/4W	resistor		DK# CF1/410K5%RCT-ND
R39	10K 1/4W	resistor		DK# CF1/410K5%RCT-ND
R40	4.7K 1/4W	resistor		DK# CF1/44.7K5%RCT-ND
R41	1K 1/4W	resistor		DK# CF1/41K5%RCT-ND
R42	10K 1/4W	resistor		DK# CF1/410K5%RCT-ND
R43	1K 1/4W	resistor		DK# CF1/41K5%RCT-ND
R44	330Ω 1/4W	resistor		DK# CF1/43305%RCT-ND
R45	10K 1/4W	resistor		DK# CF1/410K5%RCT-ND
S1		tactile switch		MR# 688-SKHHBW
T1	2N3904	NPN transistor	TO-92	DK# 2N3904GOS-ND

Oscilloscope

Part	Value	Description	Package	Suggested Part Number
C2	0.001uF	ceramic disc	5	DK# P4060A-ND
C3 *	0.01uF	ceramic disc	5	DK# P4300A-ND
C4 *	0.1uF	ceramic disc	5	DK# 478-1831-ND
C5 *	1uF	radial electrolytic	1.8 - 4	DK# P5174-ND
C6 *	10uF	radial electrolytic	1.8 - 4	DK# ECA-1CM100B-ND
C7 *	47uF	radial electrolytic	1.8 - 4	DK# P5137-ND
C9	0.1uF	ceramic disc	5	DK# 478-1831-ND
D2	1N4148	signal diode		DK# 1N4148T-73CT-ND
IC2	556	dual timer	DIP-14	DK# LM556CNFS-ND

R19	10K 1/4W	resistor		DK# CF1/410K5%RCT-ND
R20	100K 1/4W	resistor		DK# CF1/4100K5%RCT-ND
R21	470K 1/4W	resistor		DK# CF1/4470K5%RCT-ND
R23	100K 1/4W	resistor		DK# CF1/4100K5%RCT-ND
R28	250K	HSYNC potentiometer		MR# 531-PT10MH-250K
T6	2N3906	PNP transistor		DK# 2N3906GOS-ND

1-pole 6-position switch (See Oscilloscope Mode Setup and Usage on Page 14)

TV

*(all parts under Oscilloscope except for those with an * are required for this feature)*

Part	Value	Description	Package	Suggested Part Number
C8	0.22uF	radial electrolytic	1.8 - 4	DK# P821-ND
C10	0.1uF	ceramic disc	5	DK# 478-1831-ND
C11	0.1uF	ceramic disc	5	DK# 478-1831-ND
C12	0.1uF	ceramic disc	5	DK# 478-1831-ND
C13	0.1uF	ceramic disc	5	DK# 478-1831-ND
C14	0.1uF	ceramic disc	5	DK# 478-1831-ND
D1	1N4148	signal diode		DK# 1N4148T-73CT-ND
IC3	LM1881	sync separator	DIP-8	DK# LM1881N-ND
R22	680K 1/4W	resistor		DK# CF1/4680K5%RCT-ND
R24	10K 1/4W	resistor		DK# CF1/410K5%RCT-ND
R25	100K 1/4W	resistor		DK# CF1/4100K5%RCT-ND
R26	470K 1/4W	resistor		DK# CF1/4470K5%RCT-ND
R27	250K	VSYNC potentiometer		MR# 531-PT10MH-250K
R29	100K 1/4W	resistor		DK# CF1/4100K5%RCT-ND
R30	4.7K 1/4W	resistor		DK# CF1/44.7K5%RCT-ND
R31	4.7K 1/4W	resistor		DK# CF1/44.7K5%RCT-ND
R32	47K 1/4W	resistor		DK# CF1/447K5%RCT-ND
T7	2N3906	PNP transistor	TO-92	DK# 2N3906GOS-ND
T8	2N3904	NPN transistor	TO-92	DK# 2N3904GOS-ND

Miscellaneous

Part	Notes	Page	Suggested Part Number
DIP-8 socket	For TL082	10	DK# A24807-ND
DIP-8 socket	For LM1881	10	DK# A24807-ND
DIP-14 socket	For 556	10	DK# AE9989-ND
4pole 3pos rotary switch	Primary circuit	10	DK# EG1957-ND
Slow blow fuse	Primary circuit	10	(See notes on Page 10)

Fuse holder	Primary circuit	10	
Power cord	Primary circuit	10	DK# Q114-ND
Power switch	Primary circuit	10	
USB RS232 board	RS232 level shifter	15	SF# BOB-00198
RS232 to TTL board	RS232 level shifter	15	NKC# KIT-0004

AVR Notes

The ATMEGA168-20 AVR must be programmed in order for the Clock mode to work and is only available with a small Clock parts kit from Dutchtronix (www.dutchtronix.com). In case of future software upgrades that are made available on the Dutchtronix website, more information on programming the AVR can be found on Page 15. The firmware for the AVR incorporates long-term time correction using mains frequency, which is a feature not available on the original Dutchtronix scope clocks so all the firmware for the original clocks are incompatible.

Transformer Notes

The PCB was designed to operate off a wide variety of common power transformers similar to the Hammond 270X. The requirements for the secondaries are as follows:

1. 350VCT to 550VCT at 0.04A
2. 6V at 0.6A
3. 5V at 0.6A

The secondary current ratings listed above are minimum values for proper operation. Transformers with higher current capabilities on any one of the three secondaries will work as long as the voltage is close to the required specifications. The primary winding may be chosen to suit the AC mains supply of choice, for instance, 120VAC for the USA. The 350VCT secondary is sufficient for the PCB to operate most 2" and 3" CRTs, but likely too low for any 5" CRTs. A 550VCT secondary is a bit high for 2" CRTs, but works nicely for 3" and some 5" CRTs.

CRT Notes

Below is a non-exhaustive list of CRTs that have been tested on the PCB. Some CRTs require an extra connection from the B+ on the PCB to the anode cap, which is detailed in the assembly instructions on Page 12. Most American CRTs use a straightforward numbering system in which the first digit is the screen size and the number after P is the phosphor type. To list a few common phosphors: P1 is the generic green phosphor, P4 is white, and P7 is long persistence typically used for radar. The long persistence phosphor can create interesting afterglow effects that may be desirable. Refer to Appendix A on Page 26 for more information on phosphor types.

Most of the round electrostatic oscilloscope CRTs are difficult to find but are often found new old stock (NOS) from various tube suppliers or ebay.

The PCB is not designed for magnetically deflected CRTs.

Type	Size	Works	Color	Notes
2AP1	2” round	Yes	Green	Bright and sharp
3AP1	3” round	No	Green	Requires extensive modification to PCB
3BP1	3” round	Yes	Green	Bright
3JP1	3” round	Yes	Green	Bright, anode cap connects to B+.
3JP7	3” round	Yes	Blue (yellow afterglow)	Long persistence phosphor version of 3JP1
3RP1	3” round	Yes	Green	Bright
5BP1	5” round	Yes	Green	Dim picture, won’t work for TV mode
5UP1	5” round	Yes	Green	Dim picture, won’t work for TV mode
902A	2” round	No	Green	Requires extensive modification to PCB
913	1” round	No	Green	Requires extensive modification to PCB

ASSEMBLY

Populating the PCB

Once all the parts are gathered, the first step in assembly is to populate the PCB with all the parts listed under Essentials and other categories if more features are desired. All the components under Miscellaneous with the exception of IC sockets are not used on the PCB so ignore them. It is easier to mount a few smaller components at a time while soldering them in place. The idea is to have smaller components mounted first so when the board is upside-down, the surface of the table or workbench will keep the components pressed against the board. Gradually advance from smaller to larger components until the board is fully populated with all the necessary components.

A few things to keep in mind while mounting and soldering components in place:

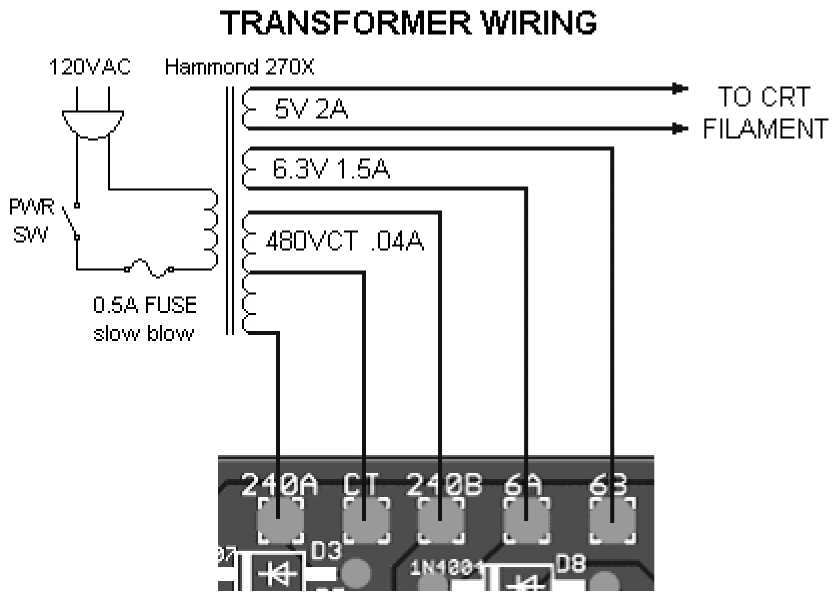
- Ensure that the diodes are installed in the correct direction indicated on the PCB. 1N4004 and 1N4007 diodes have a gray-white band that indicates the cathode end of the diode, so check that the band matches the white band on the diode outline on the PCB. This also applies to other diodes.
- Take great care to ensure that all the electrolytic capacitors, especially the high voltage ones, are installed in the correct polarity. Ceramic capacitors may be installed in either direction.
- Whether the builder prefers to use IC sockets or soldering the IC in place, ensure that the notch or recessed area on the IC package matches the notch in the outline of the IC on the PCB. IC sockets are strongly recommended for the AVR microcontroller so it is easily removable for future software upgrades. The PCB does not offer on-board programming.
- When installing the battery, the positive terminal is inserted in the hole nearest D10, and the negative terminal in the hole nearest Q6. Bend the unused tabs on the battery to prevent any risk of shorting.
- Jumper pins may be replaced with a rotary mode selector switch if preferred. Details are in the User Manual under Mode Selection at Page 16.

Transformer Wiring

Once the PCB is completed, the next step is to wire the transformer to the PCB and the CRT. The high voltage winding of the transformer feeds into the 240A and 240B solder pads and the center tap into the CT solder pad. The 6A and 6B solder pads are for the low voltage winding of the transformer, preferably the 6V 0.6A winding. The 5V 0.6A winding is recommended for operating the CRT filament. Although most CRT filaments operate off 6V 0.6A, running it at 5V runs the filament slightly cooler for longer life. However, if preferred the 5V 0.6A winding may be fed into 6A and 6B and the CRT filament may run off the 6V 0.6A winding instead.

On the following page (Page 11) is a wiring diagram of the transformer connections to the PCB. The transformer used in this diagram is a Hammond 270X, but any other transformer with similar specifications as described on Page 8 should work fine. Note that the primary circuit has a 0.5A slow blow fuse for the Hammond 270X, but more powerful transformers may require larger fuses. Although the fuse may be eliminated entirely without problems because transformer failure is highly unusual, please use a fuse for additional safety in case of unforeseen failure.

The PCB only deals with the secondary windings of the transformer, so the switch, power cord, and fuse holder for the primary circuit of the transformer are additional components that are listed under the Miscellaneous category on Page 7.



CRT Socket and Wiring

Please refer to Appendix B on Page 27 for a listing of many American CRT pinouts and data. If the CRT of choice is not listed there then the next best bet is to search through online tube datasheet websites. The diagrams reflect the pins of the CRT base. Similarly, CRT socket pins are numbered clockwise when viewed from the bottom solder end.

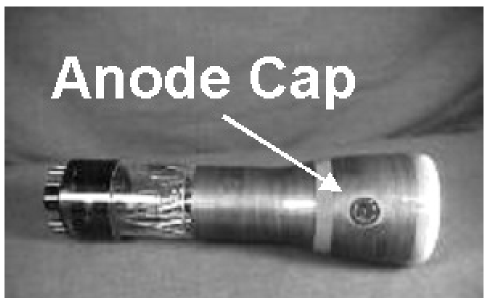
The PCB has 9 solder pads for CRT connections, but for most of the CRTs listed under CRT Notes on Page 8, only 8 of the pads are needed. The older American CRT pinouts shown in Appendix B have a different convention for labeling the pins and are listed under American CRT Pin below. A summary of the solder pads on the PCB and connections are listed below:

PCB pad	Description	American CRT Pin
K	Cathode	K
A1	Anode 1	G3
A2	Anode 2	G2,G4,CL ultor
G1	Grid	G1
X1	Horizontal Deflection 1	DJ1
X2	Horizontal Deflection 2	DJ2
+HV	Anode 3 (if present)	G3,CL post-ultor (anode cap)
Y1	Vertical Deflection 1	DJ3
Y2	Vertical Deflection 2	DJ4

Sockets for older CRTs are difficult to find but makes assembly easier. An alternative is to use individual wires with appropriate pin connectors at the ends. Pin connectors from hard disk drive connectors on PC power supplies work great with most CRT pins.

The pins labeled as H are the filament (heater) pins and connect directly to the transformer as described in Transformer Wiring on Page 10.

If the CRT comes with an anode cap such as the 3JP1 shown in the picture below then it is possible to make the CRT work by connecting the anode cap to the +HV solder pad. Do not attempt to solder a wire to the anode cap as that may damage the CRT. Be creative with a paper clip to create a connector for the anode cap. Other CRTs may require much higher voltages on the anode cap and cannot be used with the PCB. Most electrostatic CRTs do not have an anode cap so the +HV solder pad is left unused.



Final Assembly Steps

Carefully check over the PCB to make sure all components are soldered in place and excess leads are clipped off. Ensure that there are no loose solder blobs or bridges that could cause a short.

Do not attach the shunts to the jumpers so the PCB is in XYZ Scope mode, and do not connect any of the XYZ inputs to a signal source. If a rotary mode selector switch is used as detailed in the User Manual under Mode Selection on Page 16, then set it to XYZ Scope mode.

Rotate the INTEN trimmer potentiometer fully counter-clockwise for full brightness. The ASTIG and FOCUS trimmers should be centered. Leave all the jumpers disconnected so the PCB is in XYZ Scope mode. The XPOS and YPOS trimmers should be centered. XSIZE and YSIZE should be turned fully counter-clockwise for minimal amplifier gain.

If only Oscilloscope mode or Oscilloscope **and** TV modes are used, then refer to Frequency Range Switch Wiring on Page 19 for adding a 1-pole 6-position rotary switch. If TV mode is desired but not Oscilloscope mode, then refer to TV Mode with No Oscilloscope Mode on Page 19 for adding a jumper on solder pad 6 and 7.

Stand-off posts or feet at the corners of the PCB are recommended to keep the PCB bottom off the surface of the table or workbench.

USER MANUAL

Powering Up for the First Time

At this point the PCB should be populated with all the components under Essentials plus additional features, and wired to the transformer and CRT. Carefully check that the transformer has been correctly wired to the PCB and CRT. Make sure the primary circuit including the power cord are adequately insulated and not in contact with the secondary circuit including the PCB and transformer. This is essential for isolation and safety.

The PCB carries potentially lethal voltages with the largest potential difference at around 1000 volts. Try to refrain from using both hands when making adjustments or measurements on the PCB and use only one hand at all times when possible. If for any reason the PCB has to be powered off, the high voltage capacitors will still hold dangerous charges. Do not attempt to manually discharge any of the capacitors with a screwdriver or a jumper of some sort as that may damage the circuit. Anytime the term **power off** appears, remove power and wait a few minutes for the capacitor charges to bleed off before handling the PCB. Moreover, the metal terminals on ASTIG, FOCUS, and INTEN have 200 to 400 volts across them so be very careful not to touch those terminals when the PCB is powered.

In the next few steps, the PCB will be powered up for the first time. If any unexpected problems arise in the next few steps then **power off** and refer to Troubleshooting starting on Page 23.

Now for the moment of truth, apply power to the transformer. The CRT filament should slowly come to a dim yellow-orange glow. After about 15 seconds to a minute, depending on CRT age and wear, a dot should appear somewhere on the CRT screen. The dot will usually be out of focus so adjust the INTEN trimmer slightly clockwise until the dot is slightly dimmer. Then adjust the FOCUS trimmer until the dot is sharper and smallest. Depending on the transformer used, the dot sharpness may vary from 0.5mm to 3mm. Finally, adjust the ASTIG trimmer until the dot is as round as possible. Minor readjustments may be necessary later.

The next check to perform is to adjust the XPOS and YPOS pots and the dot should move horizontally and vertically respectively. The CRT itself may need to be rotated until the dot movements match the descriptions. This checks that the deflection amplifiers are correctly operating without a signal input.

Now apply a sinusoidal signal within ±5V at a frequency around 100Hz to 5KHz on the center pin of XSEL (JP2). The dot should turn into a horizontal line. Likewise, apply the same signal to the center pin of YSEL (JP1) and the dot should turn into a vertical line. XSIZE and YSIZE will adjust the line size.

If desired, attenuation potentiometers may be added to the inputs to allow a wider range of input voltages that are not limited by the ±5V supply of the op-amp. Refer to Signal Input Limitations and Workarounds on Page 18 for more information.

The final few steps depend on what features were added to the PCB and are described next.

Clock Mode Setup and Usage

If the Clock feature was added, then **power off** and proceed to add the jumper shunts for this mode using Mode Selection on Page 16 for instructions. If a rotary mode selection switch was used then rotate the switch to Clock mode. Apply power again. A clock face should appear on the screen after the CRT warms up. If the picture appears backwards then **power off** and flip the wires leading to X1 and X2, then power on. Similarly, if the picture appears upside-down then **power off** and flip the wires leading to Y1 and Y2, then power on.

Adjust XPOS and YPOS until the clock display appears roughly centered on the screen, then adjust XSIZE and YSIZE until the clock fits the CRT face with about 0.25 inches of border from the edge of the CRT face. Adjust ASTIG until the whole picture appears relatively sharp everywhere. FOCUS and INTEN may need minor readjustment until the picture looks clean. Depending on the CRT, there may be some small visible blurs or retrace lines, which is normal due to the simplicity of the deflection circuitry and the internal capacitances of the CRT. Moreover, the CRT is sensitive to its orientation due to the Earth's magnetic field so XPOS and YPOS readjustment may be necessary when moving the clock to a different location.

Once the CRT adjustments are complete and picture quality is good, the clock operates exactly like the original Scope Clock available on www.dutchtronix.com. The pushbutton switch (S1) at the front of the PCB is used to change the clock settings. Refer to the Dutchtronix website for operating instructions. However, note that this PCB lacks a LED and a RS232 level shifter. The AVR still can be programmed with the aid of an external RS232 level shifter board. Refer to Programming the AVR on Page 15 for further details. Do not try to add a LED to the circuit because it causes fluctuations in the low voltage supply and interferes with the picture.

Oscilloscope Mode Setup and Usage

If the Oscilloscope feature was added, then **power off.** If not done so, follow instructions under Frequency Range Switch Wiring on Page 19. Then proceed to add the shunts on the jumpers for this mode using Mode Selection on Page 16 for instructions. If a rotary mode selection switch was used then rotate the switch to Oscilloscope mode. Apply power. A line or a dot should appear on the screen as the CRT warms up. Adjust XSIZE to vary the width of the sweep (horizontal line). Due to basic triggering and lack of retrace blanking, XSIZE should be adjusted so the beginning of the sweep is off screen for a cleaner sweep trace. Adjust XPOS if necessary to center the horizontal line. Adjust YPOS to center the line vertically.

Apply a signal that is no larger than ±5V at a low frequency ranging from 100Hz to 10KHz to the middle pin of YSEL (JP1) or to the input of the rotary selector switch if that is used. Use the Frequency Range selector switch to change resolution to see the signal better. Adjust YSIZE to vary the amplitude of the signal on the screen, and this will also improve triggering. Adjust HSYNC until the trace is clear and stable. Refer to Page 18 under Signal Input Limitations and Workarounds for more information on suitable signals to feed into the oscilloscope.

TV Mode Setup and Usage

First, **power off** the PCB. If the TV feature minus the Oscilloscope feature is desired, then skip this paragraph. If the TV feature **and** the Oscilloscope feature were desired, then if not done so, follow instructions under Frequency Range Switch Wiring on Page 19 to add a switch. Then proceed to add the shunts on the jumpers for this mode using Mode Selection on Page 16 for instructions. If a rotary mode selection switch was used then rotate the switch to TV mode. Finally, proceed to set the Frequency Range switch to the highest frequency setting.

If the TV feature minus the Oscilloscope feature is desired instead, then if not done so, follow instructions under TV Mode with No Oscilloscope on Page 19 for adding a jumper. Then proceed to add the shunts on the jumpers for this mode using Mode Selection on Page 16 for instructions. If a rotary mode selection switch was used then rotate the switch to TV mode.

The composite video input is fed into the PCB through the VIN solder pad. Use the GND solder pad to connect to the ground shield of the video connector. The PCB was not designed for a PCB-mounted RCA jack, so a loose video connector or cable will have to be used.

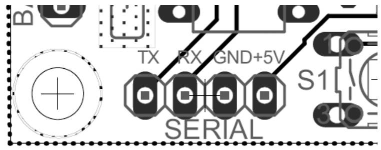
Composite video may be obtained from a video camera, a DVD player, a VCR that is either playing a tape or tuned to a TV station, or the new DTV converter boxes. Feed a composite video signal into VIN then apply power to the PCB. A raster (scanning pattern) should appear on the screen as the CRT warms up. Depending on the deflection settings, the picture may be blown up. Adjust XSIZE and YSIZE until the raster is roughly the shape of a square and adjust XPOS and YPOS until the raster reasonably fits in the CRT screen area. The raster may show evidence of flickering. Adjust VSYNC (vertical sync) until the flickering stops. See if overshooting the VSYNC will cause the raster to flicker differently. Too much adjustment in one direction may cause the vertical to collapse and stop oscillation, so adjust it back where a raster is present with no flickering, which is where the vertical is stable.

If no picture is visible, then adjust HSYNC (horizontal sync) until a picture appears. Chances are the picture will appear more than once or with an overlay, so continue to adjust HSYNC until the picture reappears as a single frame.

Readjust XSIZE, YSIZE, XPOS, and YPOS if necessary to center and resize the picture. Adjust INTEN for best picture appearance, and FOCUS to improve sharpness if necessary. Do not expect a picture quality that is comparable to a cheap handheld TV, let alone high definition. On the other hand, congratulations on making an incredibly simple TV video monitor from scratch. Some streaking and blurring of the picture is normal due to simplicity and poor response in the Z-axis circuit.

Programming the AVR Microcontroller for Clock Mode

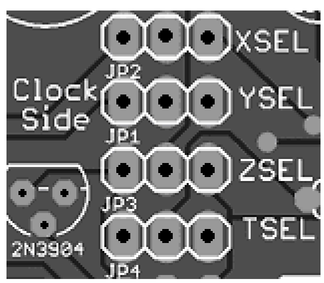
If the Clock mode is used then a preprogrammed ATMEGA168-20 is available from www.dutchtronix.com. If the microcontroller needs to be upgraded to the latest clock software from Dutchtronix, then the PCB comes with a connector at the lower left shown in the following picture that provides all the necessary connections (+5, GND, TX, RX) for an external level shifter board.



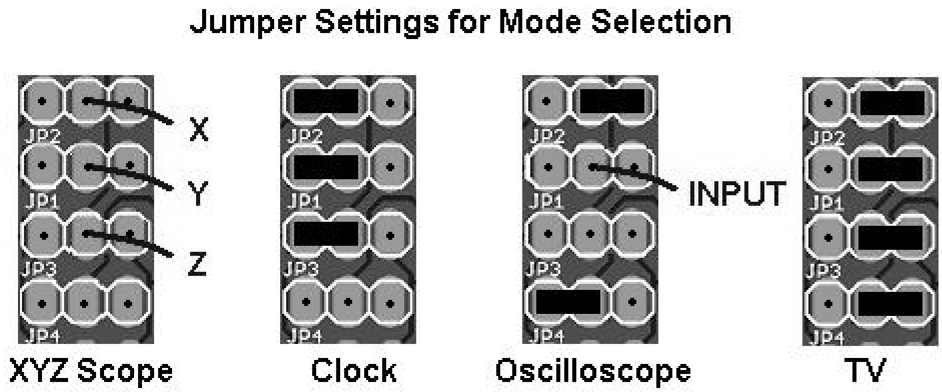
The TX and RX pins on the PCB are TTL levels and incompatible with RS232 signals. An external level shifter is required because RS232 ports typically output ±3 to ±15V, whereas the AVR supports 0 to 5V. The level shifter takes care of the difference in voltage magnitudes, polarity, and ranges. Prefabricated level shifter boards are available to convert RS232 or USB signals to TTL levels, including the Breakout Board for FT232RL USB to Serial at Sparkfun Electronics (www.sparkfun.com) or the RS232 to TTL 3V-5.5V Converter Kit at NKC Electronics (www.nkcelectronics.com).

Mode Selection

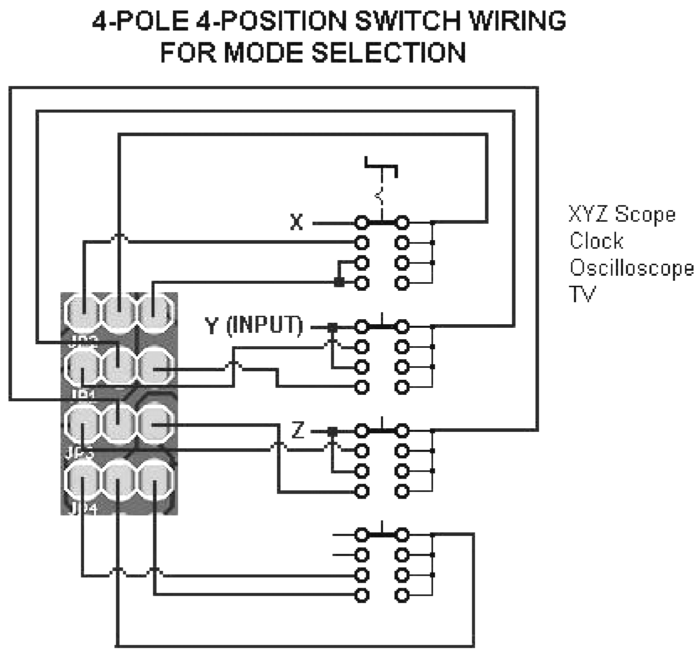
Jumpers JP1 to JP4 are used for selecting a mode, but a switch may be preferred for quick and convenient selection of modes (see Page 17 for more details). If the builder only intends to hardwire a single feature on the PCB then wires may be used in place of the jumper pins. Below is a close up picture of the jumper area at the center of the PCB.



The center pin of XSEL (JP2) and YSEL (JP1) leads to the inputs of the deflection amplifiers. Likewise, the center pin of ZSEL (JP3) leads to the Z-axis circuitry. The left pins on JP1 through JP3 are output signals from the scope clock. The right pins of JP1 and JP2 are from the 556 sweep generators and the right pin of JP3 is video output, all of which are used in both Oscilloscope and TV modes. TSEL (JP4) stands for Trigger Select because half of the 556 timer is used in both Oscilloscope and TV mode. The right pin of TSEL (JP4) is the horizontal sync for TV mode, and the left pin of TSEL is the output of the vertical amplifier for triggering the sweep to the input signal in Oscilloscope mode. Please refer to the following diagram for a summary of the jumper settings. The black rectangles are either shunts or jumper wires. The blue lines refer to external signals that are fed into these pins using a probe or a wire.



If the builder prefers to use a switch for convenient selection of modes then a 4-pole 4-position rotary switch is recommended for easy selection of all four modes. However, these switches are difficult to find, but 4-pole 3-position types are fairly common. Below is a schematic diagram of how a 4-pole 4-position switch can be wired to the PCB in theory. If less features are desired and a switch with fewer positions are used then simply ignore wiring to features that are not used.

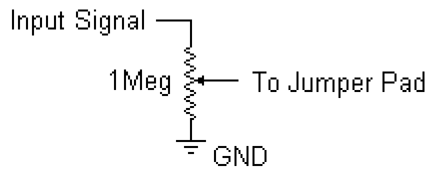


Signal Input Limitations and Workarounds

For XYZ Scope mode, the input signals for X and Y may not exceed ±5V due to the op-amp being limited by the power supply. Moreover, the Z-axis responds to positive signals from around 0.7 to 2 volts by shutting off the beam briefly. For slightly better Z-axis operation and protection of transistor T9, a base resistor in the kilo-ohms range such as 10K is recommended. Likewise, the INPUT signal for Oscilloscope mode may not exceed ±5V. When fed into the deflection amplifiers, signals with amplitudes greater than ±5V will appear on the CRT screen with clipping. Refrain from feeding higher input voltages or circuit damage may result.

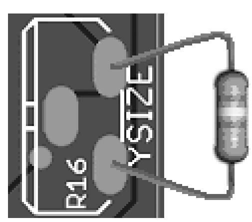
In Oscilloscope Mode, the signal should not be greater than 500KHz because the 556 timer sweep circuit tops out at this speed. Higher frequencies will appear as a thick line.

A 1Meg attenuation potentiometer is recommended to attenuate the input signal to a suitable range for the op-amp and behaves very much like the SIZE potentiometer. A schematic for the input attenuator is shown below:



The op-amp circuit is currently set up with a variable gain range from 1 to 11 with reasonably good response on its high impedance non-inverting input, but the input is limited to ±5V or clipping and possible circuit damage will result. An attenuation potentiometer provides the advantage of a variable voltage divider to reduce input signals with voltages above ±5V to a level suitable for the input of the op-amp, including a range of gains below 1. The ground side of the potentiometer connects to the GND solder pad at the lower right of the PCB near transistor T6.

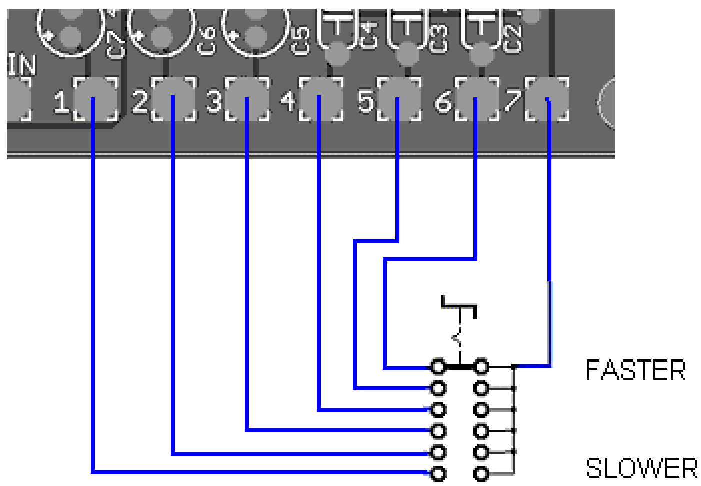
If one wishes to simplify the size controls on the PCB for easier adjustment in Oscilloscope mode at the cost of picture quality for Clock mode, then attenuation potentiometers may be used as the new size controls and a 10K to 100K resistor may be used in place of the XSIZE and YSIZE trimmer resistors (R14 and R16 respectively) on the PCB to give the op-amp a fixed but sufficient gain. The resistor is soldered in place of the two mount holes nearest the edge of the PCB. As an example, the section of the PCB where YSIZE is located is shown below:



Frequency Range Switch Wiring

For Oscilloscope Mode, it is assumed that the builder will want to use panel-mount potentiometers and switches for easy and convenient use. The horizontal sweep generator has 6 capacitors from 0.001uF to 47uF to change the range of sweep speeds. These capacitors are connected to solder pads 1 to 6 on the lower right of the PCB. The common terminal that leads to the sweep generator is at solder pad 7. The following illustration shows how to wire a 1-pole 6-position rotary switch to these pads to provide a range selector switch for the horizontal sweep.

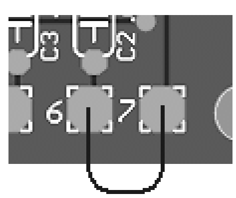
Sweep Frequency Range Switch Wiring



If the builder prefers a simpler alternative, small pins may be mounted to each solder pad and a short wire with a clip from pad 7 may be used to select a range.

TV Mode and No Oscilloscope Mode

If TV mode was built into the board, then Oscilloscope mode comes with TV mode as a free bonus but fixed at a high frequency range due to the lack of C3 to C7. If the builder includes C3 to C7 then the full Oscilloscope mode is included. The horizontal sweep used in Oscilloscope mode is also used in TV mode but remains fixed at a high frequency range to synchronize to the horizontal sync pulses from the input composite video. Rather than a frequency range switch that is not needed for TV mode if Oscilloscope mode will never be used, a short piece of wire may be used as a jumper between solder pad 6 and 7 as illustrated in the following picture.



THEORY OF OPERATION

The schematic is included in Appendix D.

Power Supply

Diodes D3 and D5 performs full-wave rectification on the high voltage secondary of the transformer feeding into 240A-CT-240B. Capacitor C15 filters out the ripples so the +HV line has fairly steady +245 to +385VDC that is essential for the deflection amplifiers.

D4, D6, C16, C17, and C18 creates a voltage doubler circuit off the 240B-CT secondary to create about –490 to –770VDC for the negative supply. The cathode is set very negative so the deflection amplifiers only have to handle a few hundred volts with respect to ground. The Z-axis circuitry uses a coupling capacitor C1 to provide the appropriate bias on the grid to shut off the beam for a short moment when the voltage on the collector of T9 changes. Most of the time, the Z-axis will receive fast-changing signals so the circuit serves its function without resorting to a more expensive DC-coupled design.

D7 creates positive half-wave DC that is filtered heavily by C21, then IC4 regulates the voltage to +5 at 100mA maximum, and the output is filtered again with C20 for a relatively steady +5VDC supply. Similarly, D8 creates negative half-wave DC that is filtered by C22, regulated to –5V at 100mA max by IC5, and the output filtered again by C19. The –5V is only used by the deflection amplifiers, which do not have a heavy current demand so the filter capacitors do not have to be as large as those on the +5V supply for steady –5VDC.

Potentiometers R33, R35, and R36 provide an adjustable range of appropriate voltages to the CRT elements. C17 and C18 are wired in series to make an equivalent capacitor rated at 1uF 900V to handle the highest negative potential of –770V without a problem. R11 serves as an equalizing and bleeder resistor for C17; R35 and R36 serves a similar purpose for C18.

Deflection Amplifiers (XYZ Scope)

T4, T5, R2, R3, R5, R8, and R9 form a transistor difference amplifier for the horizontal with a gain that is governed by the size of R9. The two transistors share emitter currents through R9, so one transistor is affected when the other draws more emitter current. As a result, the collector voltages on both transistors change at the same amount but in different directions, resulting in uniform deflection of the beam. A mechanical analogy of the collector voltage behavior is to visualize a seesaw; as collector voltage 1 goes up, collector voltage 2 must go down at the same “distance” so there is a push-pull effect on the beam by the deflection plates. R15 sets the bias voltage on T5 to change the offset of the collector voltages and thereby control centering. A smaller value for R9 increases the gain, and a larger value decreases the gain. Likewise, T2, T3, R7, R6, R4, R18, and R1 for the vertical serve the same purpose as their respective horizontal deflection counterparts in the horizontal deflection circuit, and R13 sets the positioning for the vertical.

IC1 is a TL082 dual op-amp used in a non-inverting amplifier circuit because of the benefit of high impedances input for XYZ Scope and Oscilloscope modes. R10 and R14 sets up the gain of the horizontal amplifier, and the gain is determined by 1 + (R14/R10). R12 and R16 does the same respective function but for the vertical amplifier. The variable gain controls the output amplitude and thereby the deflection range.

Clock

IC6 is the ATMEGA168 microcontroller running the Dutchtronix Scope Clock code. IC7 is an AD7302 digital-to-analog converter (DAC) that converts parallel digital outputs from IC6 to analog voltage levels for rapidly drawing a picture in XY mode. IC9 is a Real-Time Clock and Calendar (RTC) chip that stores all the time keeping and calendar information. The microcontroller communicates to the RTC through serial communications.

T1, R40, and R41 create an inverting amplifier for the intensity signal from the microcontroller to drive the Z-axis of the Scope.

R43 and R44 is a voltage divider that provides a voltage reference that determines a suitable output voltage range produced by the AD7302 that works well with the XYZ Scope.

D9 and D10 allow either the +5V or the battery to maintain power to the RTC so time and date settings are not lost when power is removed from the PCB.

R37, R38, R39, and R42 serve as pull-up resistors to ensure a clean logic 1. C23, C24, C27, and C28 are all bypass capacitors placed close to the AVR and RTC to filter out noise that may cause erratic operation. C25 and C26 are used to regulate the crystal frequency accuracy for the AVR. Q6 and Q7 are crystals for the RTC and AVR respectively.

The hardware is nothing compared to the software used on the AVR to deal with input settings, graphics, and time keeping. Refer to www.dutchtronix.com for more information.

Oscilloscope

A basic oscilloscope is just one step above a XY Scope. Rather than two inputs for both axes, one axis is fed with a sawtooth signal that indefinitely moves the beam continuously left to right (or backwards) over time then repeats. This allows the screen to display an input signal with respect to time.

IC2 is a 556 dual timer (two 555 timers in one) with only one half used in Oscilloscope Mode. The timer is set up to run in astable (free running) mode due to the feedback resistor R21, and triggering is achieved by C9. When the amplitude of the signal coming off the vertical amplifier (YAMP in the schematic) is not at a certain level, capacitor C9 keeps the timer from restarting so the sweep starts every time the signal reaches the same specific level that allows the timer to start a new sawtooth cycle. The triggering level and slope are not adjustable to maintain simplicity.

R19, R20, R23, R28, and T6 create a roughly variable current source that will charge up one of C2 to C7 for a linear sawtooth output. The 556 timer discharges the capacitor so a new cycle can begin. The range of capacitances C2 to C7 sets the frequency range, from fast to slow. C2 is the smallest value that pushes the 556 at the maximum possible operating frequency of about 500KHz. Larger capacitors may be used beyond the value of C7 for a very slow horizontal frequency that may be desired if a long persistence CRT was used. There are certainly better and faster circuits, but the timer is a classic circuit. The other half of the 556 is unused in Oscilloscope mode, but used in TV mode.

The signal is simply fed into the vertical amplifier while the horizontal amplifier is connected to the output of the 556 sweep generator. R28 (HSYNC) serves as a Fine Frequency control to change the frequency within a small range.

TV

The TV mode is really a simple video monitor that is a step above an oscilloscope. Another sweep generator running at around 60Hz feeds the vertical amplifier. When the horizontal sweep is set at the maximum frequency range using C2, a raster scanning pattern is achieved. R24, R29, R25, R27, and T7 are equivalent in function to R19, R20, R23, R28, and T6 respectively to create a variable current source. C8 was selected so the operating frequency was around 60Hz.

The feedback resistor R26 allows the other half of the 556 to operate in astable mode.

The LM1881 is a nice little sync separator chip that outputs vertical sync pulses on pin 3 and horizontal composite sync pulses on pin 1. The vertical sync is hardwired to the 60Hz sweep portion of the 556 via coupling capacitor C12 for triggering. The horizontal sync connects to the same sweep generator used in Oscilloscope mode, but the trigger selector TSEL connects HSYNC to TRIG signals for TV mode.

R27 and R28 are fine frequency controls labeled VSYNC and HSYNC respectively. The controls are used to both calibrate and fine-tune the sweep frequency to the sync signals.

C13, C14, R30, R31, R32, and T8 create a simple video inverter that worked best for the particular Z-axis circuit in the XYZ Scope. This is an area for future improvement.

TROUBLESHOOTING

This page is intended to be used as a guide with some possible solutions for potential problems that may be encountered during power up or afterwards. Also reading the Theory of Operation starting on Page 20 will provide better understanding of component functions and aid in isolating and repairing problems.

CRT filament does not light.

- Incorrect or bad filament connection.
- Use a meter to check if 5VAC is present on the filament pins. If so, then CRT filament may be open. **Power off** and double-check by disconnecting filament pins and using an ohmmeter to check continuity.
- Fuse in primary circuit is blown. Try a higher rated fuse and make sure it is slow blow.
- If 5V is not present on the filament pins, then check if 5VAC winding of transformer has voltage. If not, winding is open and transformer should be replaced.

CRT filament lights but nothing appears on the screen.

- Rotate the INTEN trimmer completely counter-clockwise for full brightness. Set the mode to XYZ Scope and try to locate a dot by adjusting XPOS and YPOS. If Oscilloscope mode is available then use it because a horizontal sweep would help locate the beam easier.
- Check Appendix C for a list of expected voltage measurements.
- CRT may be either too large, requires a higher accelerating voltage on the anode cap that cannot be provided by the PCB, or weak due to heavy use in the past. Consider obtaining another CRT.

Dot, line, or picture appears on screen but very dim.

- Rotate the INTEN trimmer completely counter-clockwise for full brightness. If the CRT remains dim then the tube is either too large, requires a higher accelerating voltage on the anode cap that cannot be provided by the PCB, or weak due to heavy use in the past. Consider obtaining another CRT.
- Power transformer may not be suitable for the CRT size. 350VCT is sufficient for many 2” and 3” CRTs, but most likely not for 5” CRTs. 550VCT is a bit high for 2” or smaller CRTs but sufficient for 3” and some 5” CRTs.

Dot appears but does not move when XPOS or YPOS trimmers are adjusted.

- Check that the ZTX458 transistors (T2, T3, T4, T5) are installed properly. If accidentally reversed, they are most likely ruined so replacement is recommended.
- Check R1, R9, R5, R4, R8, and R18 to make sure they are soldered in the correct place.
- Use a DC meter with ground probe connected to GND and the other probe on the center pin of the XPOS or YPOS trimmer. Be very careful when handling the board due to high voltages. Always **power off** before handling the board. Meter should read a voltage between +5 and –5. If not, check that the trimmer is soldered in place correctly or replacement is recommended.

Dot appears and is movable, but does not do anything with a signal input.

- TL082 op-amp (IC1) may be installed backwards. Check that the notch on the chip matches the IC outline notch on the PCB.
- TL082 (IC1) may be damaged.
- Use a DC meter with the ground probe connected to GND to check voltages on the TL082 (IC1). There should be +5 on pin 8, and –5 on pin 4.
- Check the XSIZE and YSIZE trimmers to ensure they are soldered in place. Also check R10 and R12 to make sure they are soldered in place correctly.

Dot appears moveable but constrained in an area of the screen. Only a quarter of the clock appears on the screen with a pie shape.

- Position and Gain pots set incorrectly. Turn down XSIZE and YSIZE by rotating completely counterclockwise, then recenter the image via XPOS and YPOS then resize.
- Check R1, R9, R5, R4, R8, and R18 to make sure they are soldered in the correct place.
- Use a DC meter with the ground probe connected to GND to check voltages on the TL082 (IC1). There should be +5 on pin 8, and –5 on pin 4.

Beam moves backwards on X and/or Y-axis, clock face is backwards and/or upside-down.

- Flip the wires leading to X1 and X2 if horizontal is backwards, Y1 and Y2 if vertical is backwards. Be sure to **power off** the PCB before reversing these connections.

Signal does not appear stationary (free running) in Oscilloscope mode.

- Adjust HSYNC to change the fine frequency so the signal appears clearly on the screen.
- Triggering is not working due to incorrect setup of TSEL.
- Triggering is not present due to weak signal. Turn up YSIZE to improve triggering.
- Note that trigger circuitry is basic so not all signals will trigger the sweep nicely.

A line cuts through the signal in Oscilloscope mode with Frequency Range at highest setting.

- This is normal due to lack of retrace blanking. The retrace is visible at higher frequencies.

How to install panel mount potentiometers.

- Use extension wires from the trimmer pins to the potentiometer. Be careful with the ASTIG, FOCUS, and INTEN potentiometers because they carry high voltages. Make sure the metal casing of the potentiometers are not in any way connected to the terminals for insulation.

In TV mode, only a horizontal line appears.

- YSEL (JP1) is incorrectly set up. The right pin should connect to the center pin either through a shunt, wire jumper, or through the mode selection switch.
- Vertical oscillator is not running due to VSYNC being way off. Readjust VSYNC.
- Check that vertical deflection amplifier is functional by feeding a signal no larger than ±5 into the center pin of YSEL (JP1). If not, TL082 (IC1) may need to be replaced.
- Check that the vertical ZTX458 transistors (T2, T3) are installed properly. If accidentally reversed, they are most likely ruined so replacement is recommended.
- Check that 0.22uF (C8) is properly installed.

In TV mode, no picture appears.

- No composite video is present on VIN. Make sure the ground shield of the video cable is connected to GND.
- INTEN may be set too high so readjust for a lower brightness setting.
- Check R34, R17, T9, and C1 to make sure they are soldered in place correctly. If T9 was inserted backwards, it is most likely ruined and replacement is recommended.
- Check C13, C14, R30, R31, R32, and T8 to make sure they are soldered in place correctly.

In TV mode, a picture appears but with horizontal streaking or overlay.

- Readjust HSYNC.
- If there is some streaking and it changes with the video then that is normal due to the simplicity of the Z-axis circuit.

In TV mode, the picture appears totally black and white with no gray in between.

- Adjust INTEN to gain some gray area, but most of this picture quality is normal due to the simplicity of the Z-axis circuit.

+5V reads as 0 on the DC meter.

- Check the 6A and 6B connections on the PCB from the transformer. Use an AC meter with probes on 6A and 6B to check for voltage. Expected voltage should be around 6 to 8 volts AC.
- 78L05 (IC4) may be damaged.
- Check that C20 and C21 are installed in the correct polarity. If not, replace the capacitor. The 78L05 may also be damaged as a result of this so replacement is strongly recommended.

-5V reads as 0 on the DC meter.

- Check the 6A and 6B connections on the PCB from the transformer. Use an AC meter with probes on 6A and 6B to check for voltage. Expected voltage should be around 6 to 8 volts AC.
- 79L05 (IC5) may be damaged.
- Check that C19 and C22 are installed in the correct polarity. If not, replace the capacitor. The 79L05 may also be damaged as a result of this so replacement is strongly recommended.

The CRT image jitters or swims.

- The CRT is too close to the power transformer. Some transformers have poor magnetic shielding while others such as the Hammond 270X has fairly good shielding.
- The best location for the transformer is behind the CRT base to prevent interference.

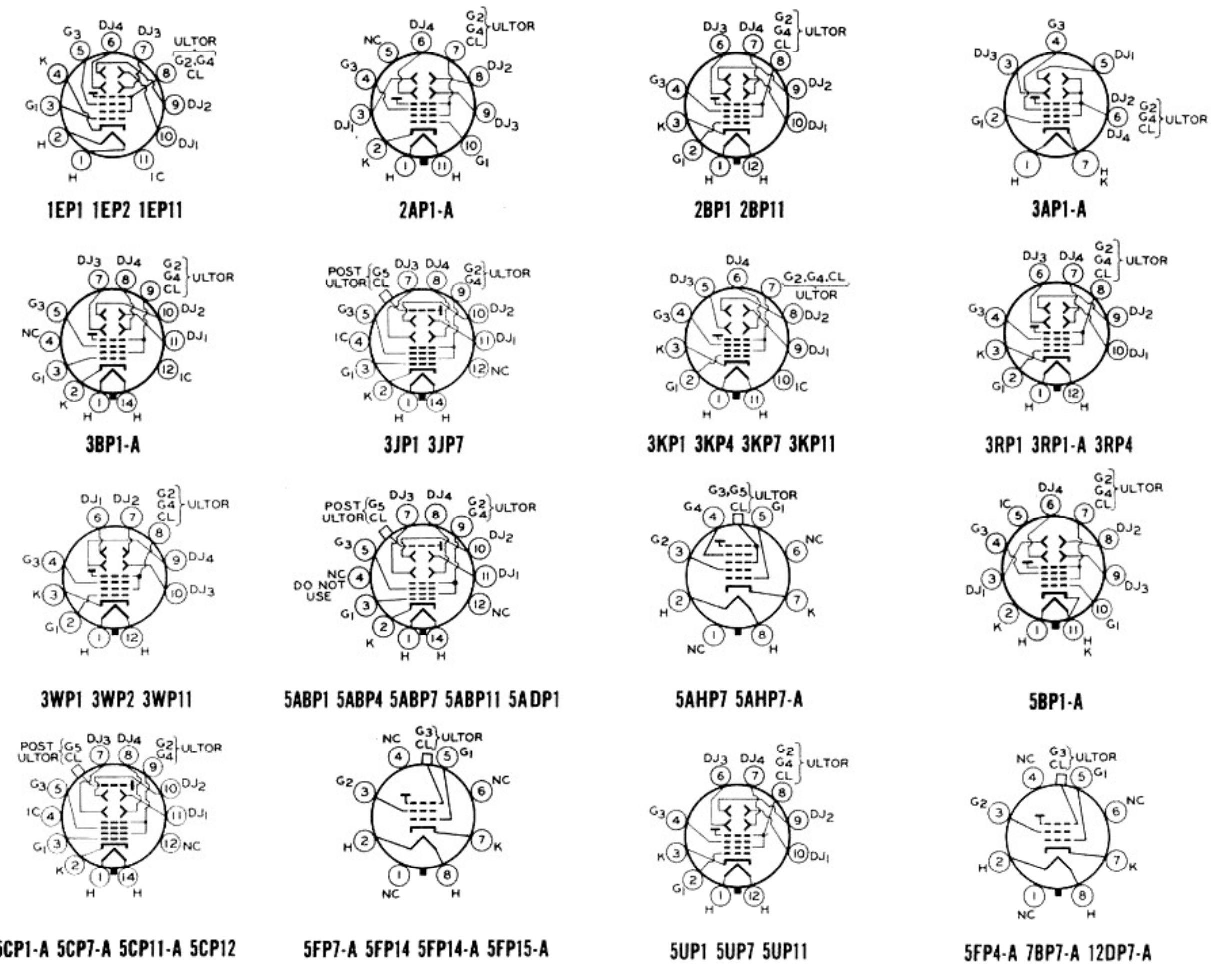
APPENDIX A: STANDARD REGISTERED PHOSPHORS

E.I.A. PHOSPHOR	EMISSION COLOR FLUORESCENCE	EMISSION COLOR PHOSPHORESCENCE	PERSISTENCE	APPLICATION
P-1	Yellowish green	Yellowish green	Medium	Used in cathode ray oscillograph and radar.
P-2	Yellowish green	Yellowish green	Medium	Used in cathode ray oscillographs.
P-3	Yellowish orange	Yellowish orange	Medium	
P-4	White	White	Medium to medium short	Used in monochrome television picture tubes.
P-5	Blue	Blue	Medium short	Photograph recording.
P-6	White	White	Short	Obsolete—Originally used in television receivers.
P-7	White	Yellowish green	Blue—medium short Yellowish green—long	Used for radar.
P-8	Obsolete	replaced by P-7		
P-9	Obsolete			
P-10			Dark trace— very long	Outside source of light is used for observation. Persistence from seconds to several months.
P-11	Blue	Blue	Medium short	Photographic recording.
P-12	Orange	Orange	Long	Used for radar.
P-13	Reddish orange	Reddish orange	Medium	
P-14	Purplish blue	Yellowish orange	Blue—medium short Orange—medium	Used for military displays where repetition rate is 2 to 4 seconds after excitation is removed.
P-15	Green	Green	Visible—short Ultra-violet— very short	Television pick-up of photographs by Flying Spot Scanning.
P-16	Bluish purple	Bluish purple	Very short	Television pick-up of photographs by Flying Spot Scanning.
P-17	Yellow white to blue white	Yellow	Blue—short Yellow-long	Used for military displays.
P-18	White	White	Medium to Medium short	Low frame rate television.
P-19	Orange	Orange	Long	Radar indicators.
P-20	Yellow green	Yellow green	Medium to medium short	High visibility displays.
P-21	Reddish orange	Reddish orange	Medium	
P-22	Tricolor phosphor screen		Medium short	Used for color television.
P-23	White	White	Medium short	Low temperature white—(Sepia) Interchangeable with P-4.
P-24	Green	Green	Short	Used in Flying Spot Scanner tubes.
P-25	Orange	Orange	Medium	Used for military displays where repetition rate is 10 seconds, to 2 minutes after excitation is removed.
P-26	Orange	Orange	Very long	Used for radar display.
P-27	Reddish orange	Reddish orange	Medium	Color Television Monitor Service.
P-28	Yellow green	Yellow green	Long	Used for radar display.
P-29	Two color phosphor screen		Medium	Used as indicator in aircraft instruments.
P-30*	—	—	—	—
P-31	Green	Green	Medium—short	Used in cathode ray oscillographs.
P-32	Purple-blue	Yellow green	Long	Used for radar display.
P-33	Orange	Orange	Very long	Used for radar display.
P-34	Bluish green	Yellow green	Very long	Used for oscillography, radar and visual information storage.

**No data available—not registered as yet with EIA.*

APPENDIX B: CRT BASING DIAGRAMS

BASING DIAGRAMS



APPENDIX C: PCB OPERATING VOLTAGES

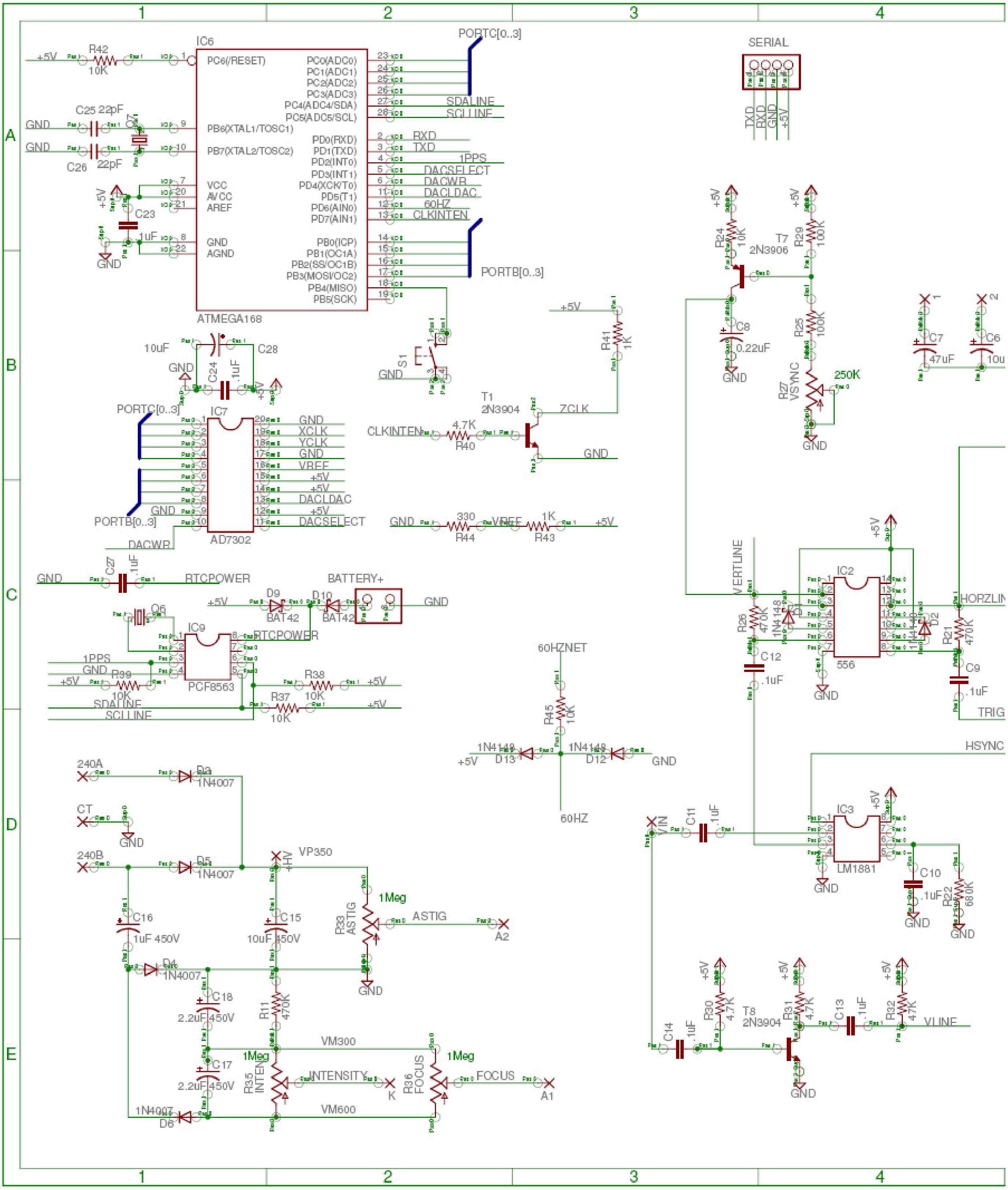
CAUTION: Operating voltages on the PCB are potentially **lethal**. Take great care when making voltage measurements of any kind with power applied to the PCB. Always turn off the power **before** handling the PCB or turning it upside-down for voltage measurements.

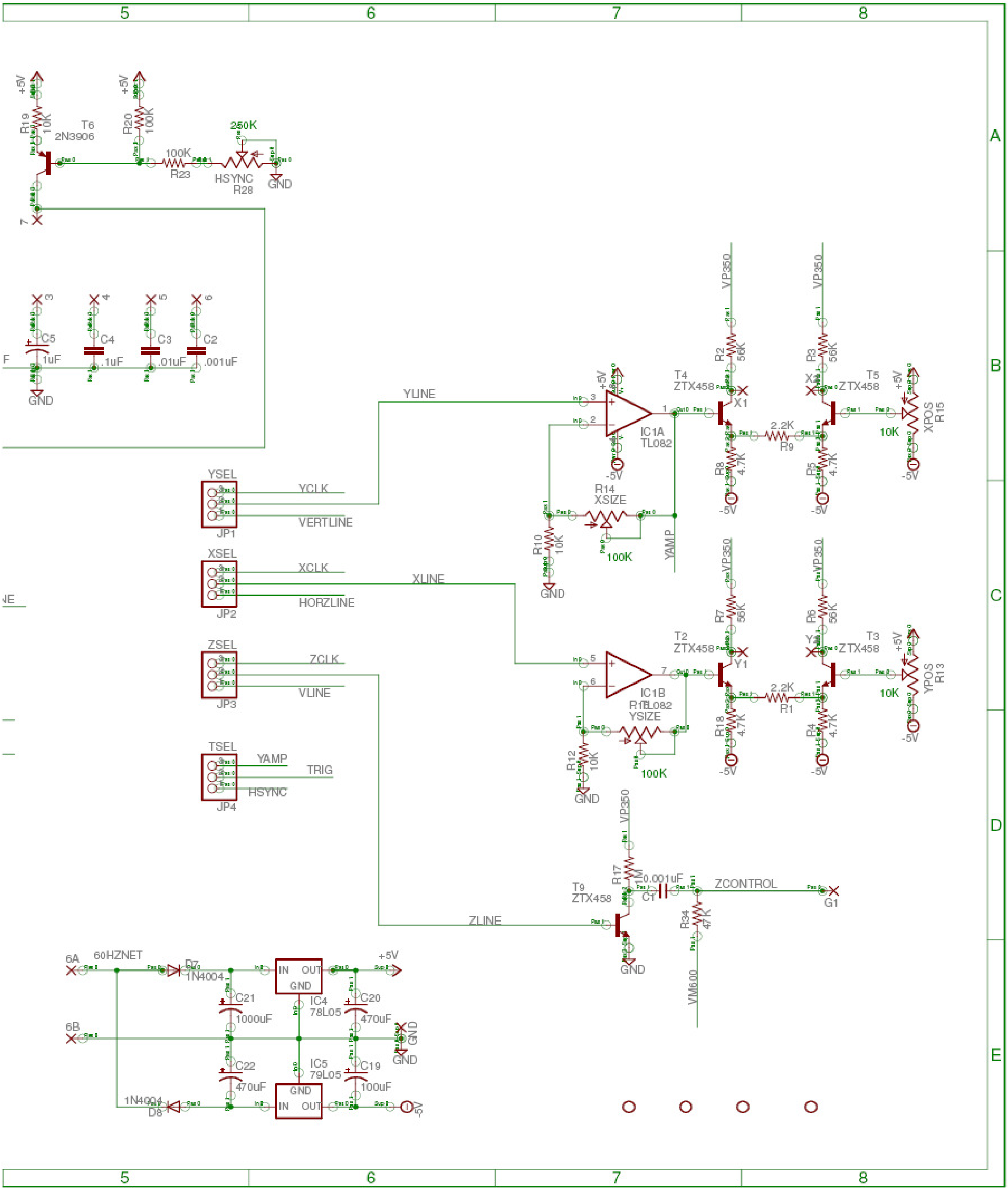
Due to the wide range of power transformers that is compatible with the PCB, the high voltage measurements may vary so lists of voltages are provided for three different transformer secondaries of 350VCT, 450VCT, and 550VCT that feeds into 240A, CT, and 240B. The voltages below are rough approximations and the actual measured voltages may vary but should be reasonably close and follow the pattern of voltages. For instance, K will always read a voltage that is more negative than A1.

Use a DC meter capable of measuring up to 800VDC and connect the ground probe to GND on the PCB near the lower right. Take great care when measuring voltages. Use a well-insulated probe and do **not** make voltage measurements with both hands. Use only one hand to hold the probe and the other hand should be away from anything conductive. If anything has to be powered off, put down the probe and use that same hand to turn off the power. Always power off the PCB and let it sit for a few minutes before handling.

	Expected Voltages		
Solder Pad	350VCT	450VCT	550VCT
G1	-490	-630	-770
K	-470	-610	-740
A1	-350	-470	-570
A2	+120	+150	+180
+HV	+245	+315	+385

APPENDIX D : SCHEMATIC





5
6
7
8
A
B
C
D
E
+5V
R19
10K
T6
2N3906
R20
100K
100K
R23
250K
HSYNC
R28
GND
C5
1uF
C4
.1uF
C3
.01uF
C2
.001uF
GND
YLINE
YSEL
YCLK
VERTLINE
JP1
XSEL
XCLK
XLINE
HORZLINE
JP2
ZSEL
ZCLK
VLINE
JP3
TSEL
YAMP
TRIG
HSYNC
JP4
IC1A
TL082
-5V
R14
XSIZE
100K
R10
10K
GND
YAMP
VP350
R2
56K
T4
ZTX458
X1
2.2K
R9
R8
4.7K
R3
56K
T5
ZTX458
R15
XPOS
10K
R5
4.7K
IC1B
TL082
R16
YSIZE
100K
R12
10K
R7
56K
T2
ZTX458
Y1
R1
R18
4.7K
R6
56K
T3
ZTX458
YPOS
R13
R4
R17
1M
0.001uF
C1
ZCONTROL
G1
T9
ZTX458
ZLINE
R34
47K
VM600
6A
60HZNET
D7
1N4004
IN
OUT
GND
IC4
78L05
C21
1000uF
C20
470uF
6B
C22
470uF
IC5
79L05
C19
100uF
1N4004
D8
-5V