TGI BUILD DOCUMENT PACKAGE

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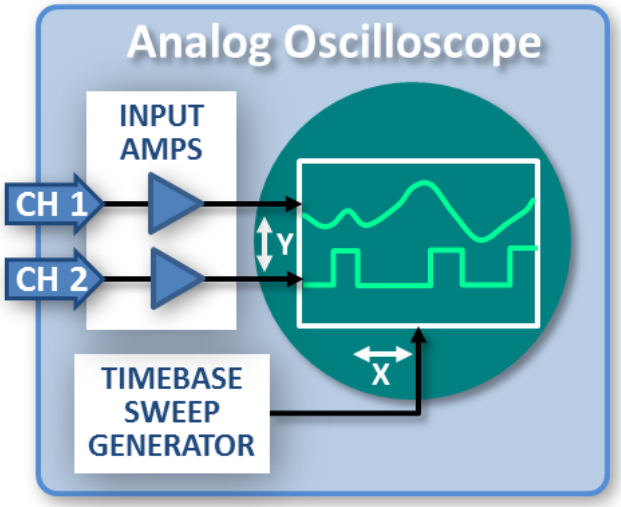
Revision Date	Description
2.0 07-16-2018	Initial Release
3.0 01-05-2020	Correct pin out document errors on Page 22

An Analog Oscilloscope Overview

An oscilloscope accepts a voltage input from a device under test and displays that voltage as a dot on a display screen. A positive voltage into the scope drives the Y-axis of the trace, moving the 'dot' up on the screen, while a negative voltage input moves the 'dot' down. A second, independent voltage is applied to the X-axis of the oscilloscope. In this case, a positive voltage moves the dot to the right along the X-axis while a negative voltage moves the dot to the left.



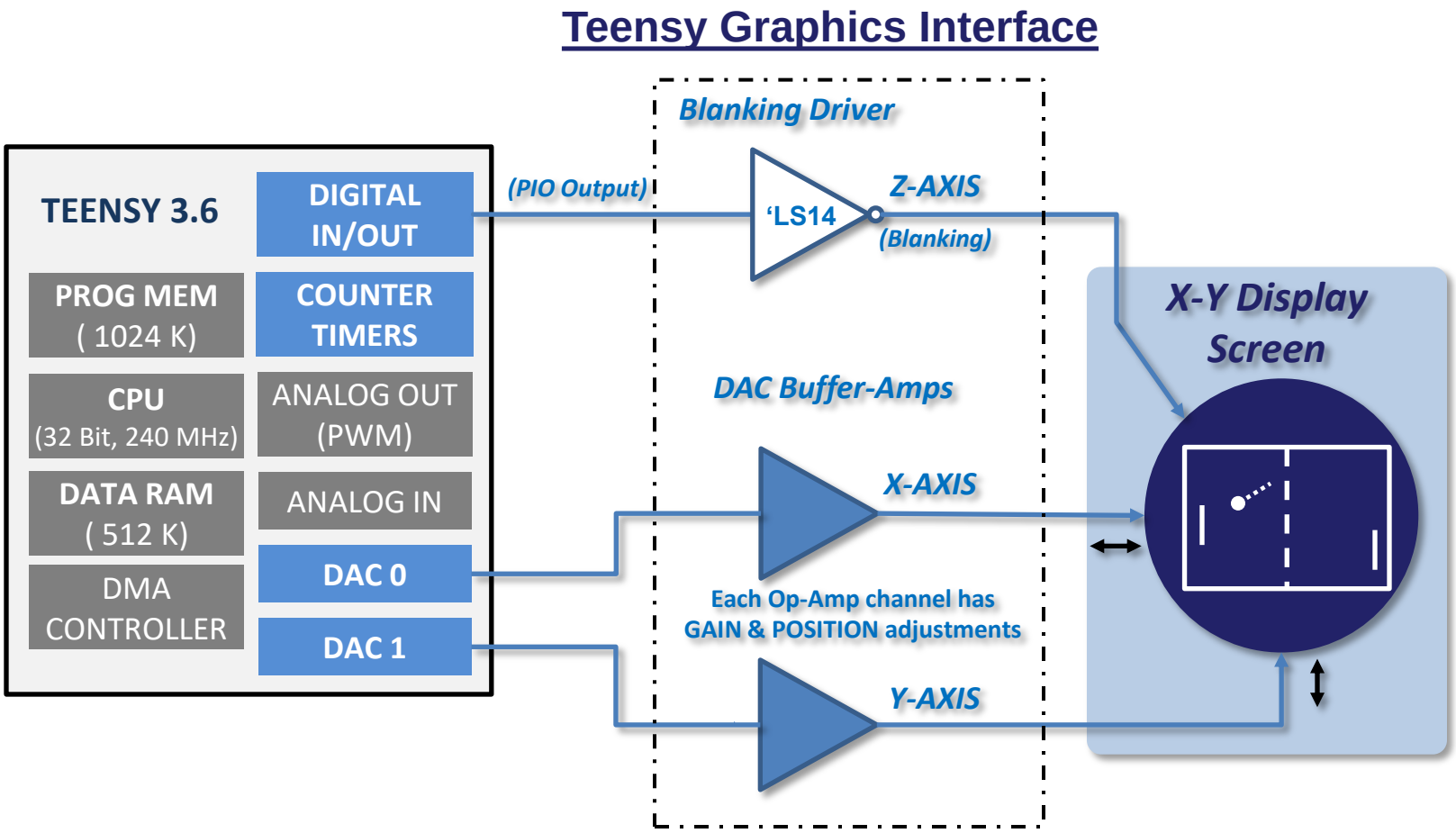
By applying the unknown test voltage into the Y-axis and a linear ramp waveform into the X-axis, the dot will graphically show how the unknown test voltage changes over time.

The linear ramp waveform driving the X-axis waveform is created inside the oscilloscope by an internal time base sweep generator circuit. Two (or four) channel oscilloscopes allow multiple signals to be simultaneously traced across the screen. With careful calibration of the time base and input amplifiers of the scope, precise amplitude and time measurements are made.

The earliest computer graphics and radar displays (circa: 1940-1970's) used CRTs driven in an X-Y fashion to show monochrome vector graphic displays.

This project side steps the internal Time Base seep generator of the oscilloscope and drives by the X & Y axis with a microprocessor. In this way we can show high resolution, vector-art graphic images on an oscilloscope screen.

TGI Block Diagram



THIS DOCUMENT CONTAINS PROJECT SPECIFIC DOCUMENTATION Made by: E. Andrews Date: 12-05-2020	First Made For Arduino Teensy Graphics Interface	Filename 20180627R0 BUILD DOC (Rev 3 TEENSY).pptx	Revision 3 Printed 1/5/2020 13:29	Page 3	AMC Brookfield, WI USA

Parts List – TGI Project

Item	Ref Designators	QTY	Description/Values/Notes	Manufacturer	Mfg PN	Alternate Sources	Additional Notes
1	TGI PCB Assembly	1	--	--	--	--	See build PCB Documentation beginning on page 6.
2	Arduino TEENSY 3.6 Processor Board	1	ARDUINO TEENSY 3.6	PJRC.COM	See Web Site	Digikey, PJRC, eBay, & others	
3	BNC to BNC Cables	2	BNC to BNC, 50Ohm Cable, 3-5Ft Length, TGI to Oscilloscope Interconnect	Various	Various	Amazon, eBay, & others	Shielded or Twisted Pair cabling is recommended; Final method & length of XYZ interconnection is BUILDER'S choice
4	+5VDC, +12VDC, -12VDC Power Supply	1	Three output Voltage Regulated Power Supply (Linear Regulator Req'd)	Various	Various	Amazon, eBay, & others	Selection of Power Supply and method of interconnect to TGI PCB is BUILDER'S choice
5	Hookup Wire	AR	Wire for interconnection between TGI and the power supply	Various, As Required	Various	Amazon, eBay, & others	Method of interconnection is BUILDER'S choice
5	Misc Headers to facilitate interconnect	AR	Connectors headers for interconnect between TGI and the power supply	Various, As Required	Various	Amazon, eBay, & others	Method of' interconnection is BUILDERS choice
6	4-40 by x.xx In Long Spacer (Spacer, Nuts, Screws AR)	4	Spacers may be used to mount TGI to a base or into an enclosure	Various	Various	Amazon, eBay, & others	Final mounting method is BUILDER'S choice
7	Project Enclosure	1	As Required, BUILDER'S choice	Various	Various	Amazon, eBay, & others	Final enclosure method is BUILDER's choice
8	Analog Oscilloscope with XYZ Drive Capability	1	Analog Oscilloscope is required as the final display device. *Note: DIGITAL scopes will not work.*	Various	Various	Amazon, eBay, & others	See OSCILLOSCOPE REQUIREMENTS page to qualify possible oscilloscope candidates.

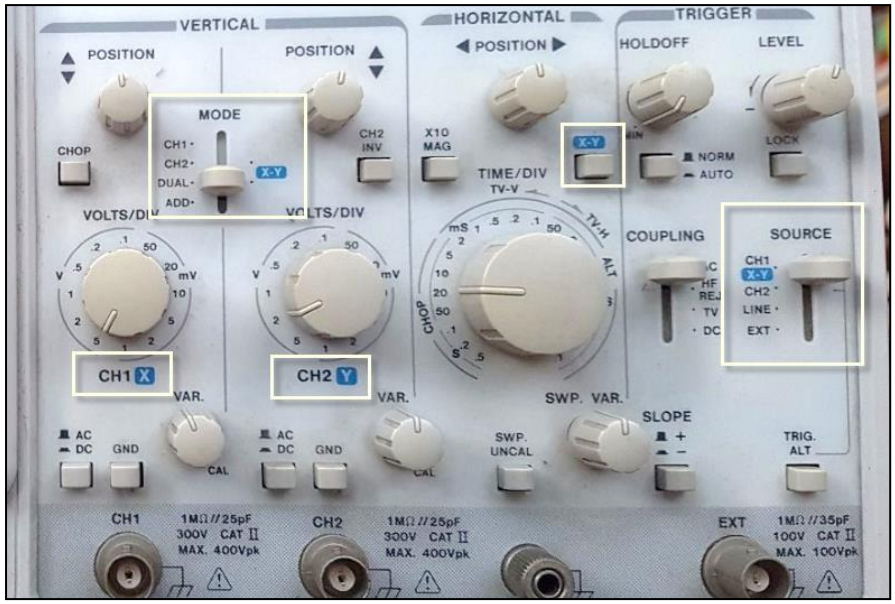
TGI Oscilloscope Requirements

Overall graphics quality is influenced by the quality and performance of the oscilloscope and CRT used. This project works well only with ANALOG Oscilloscopes; Digital scopes will only produce poor looking output.

There are many analog scopes manufactured by Tektronix, HP, Phillips, BK, Leader, GW-Instek and others that will work well.
Look for these key features to find a suitable scope for this project:

- ✓ **Screen size: Larger is better!**
- ✓ **For best display quality, scope frequency response should be 10 MHz or more**
- ✓ **Scope must support an X-Y Mode**
  - ➢ Scopes that support XY mode typically have panel markings that clearly show XY inputs and settings.
- ✓ **Scope must have a Z-AXIS "Intensity Drive" input**
  - ➢ Check the rear panel of the scope to find this feature.

Typical Scope Front Panel View showing XY Operation Controls



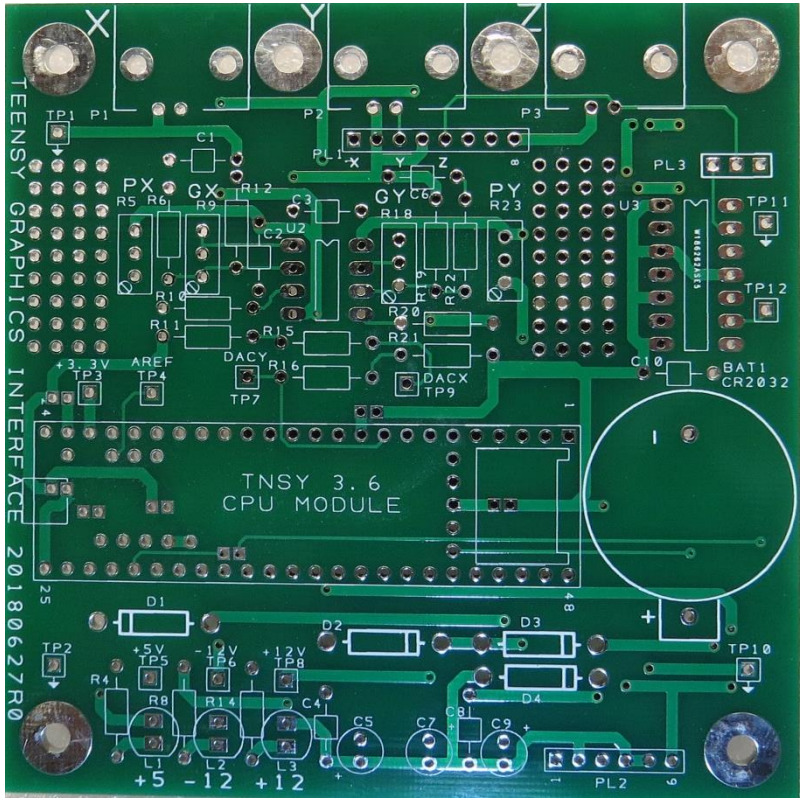
Typical Scope Rear Panel View showing Z-AXIS INPUT connector

Parts List – TGI PCB Parts List

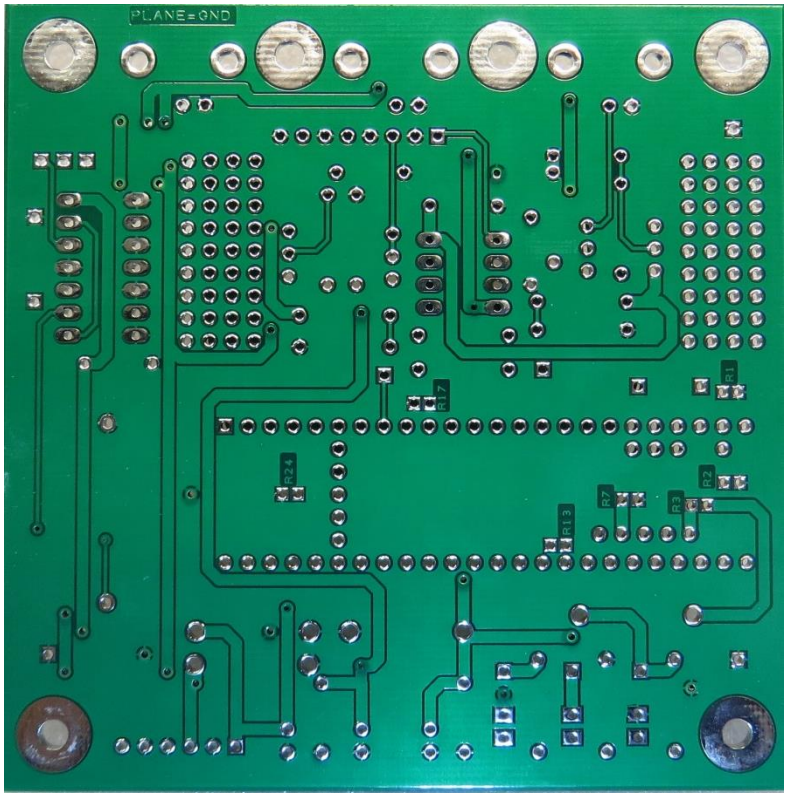
Item #	Ref Designators	QTY	DESCRIPTION	Value	Sourcing Info (DK = Digikey PN Part Num)
1	R24,R3,R7,R17,R1, R2,R13	7	USE JUMPER WIRE - SEE BUILD DOC FOR PLACEMENT & OPTIONS	0_ohm	N/A
2	TP11,TP10,TP2,TP1, TP7,TP9,TP12,TP6, TP8,TP5,TP3,TP4	12	1 PIN .025" SQ. MALE TEST POINT	FOR TEST USE ONLY. CAN USE SHORT WIRES OR .025 SQ PINS CUT FROM PIN STRIPS	DK: SAM11363-ND
3	PL3	1	3 PIN .025" SQ. MALE .100 SIP TIN	OPTIONAL - CAN USE JUMPER WIRE	DK: SAM9525-ND
4	PL2	1	6 PIN .025" SQ. MALE .100 SIP TIN	CONN HEADER 6POS .100" SNGL TIN	DK: SAM1035-06-ND
5	PL1	1	8 PIN .025" SQ. MALE .100 SIP TIN	ONLY USED W/CHASSIS MOUNT BNCs	DK: SAM1035-08-ND
6	R5,R23	2	10-TURN OP ADJ,10K OHM 0.5W TH	10K	DK: 490-2875-ND
7	R9,R18	2	10-TURN OP ADJ, 100K OHM 0.5W TH	100K	DK: 490-2876-ND
8	U3	1	IC HEX SCHMITT-TRIG INV 14-DIP	74LS14	DK: 296-1643-5-ND
9	D1,D2,D3,D4	1	DIODE GEN PURP 400V 1A DO41	1N4004 - ONLY INSTALL D1 OMIT D2, D3 & D4!	DK: 1N4004-TPMSTR-ND
10	L3,L2,L1	3	3 MM LED, 0.1" LD SPACING (Shows ON-status for each voltage)	PCB MOUNT 3MM LED .100 LS COLOR IS BUILDERS CHOICE	VARIOUS
11	P1,P2,P3	3	PCB MOUNT RT ANG BNC	USE CHASSIS MOUNT BNCs IF DESIRED	DK: A97555-ND
12	C8,C10,C2,C4,C3	5	CAP CER 0.1UF 50V AXIAL	.1uf, 50V Ceramic	DK: 587-5501-1-ND
13	U2	1	IC OPAMP GP 4.5MHZ 8DIP	CA3240	DK: CA3240EZ-ND
14	C7,C5,C9	3	CAP ALUM 47UF 20% 50V RADIAL	47uf, 50 V .1" LS	DK: P10321-ND
15	BAT1	1	BAT HOLDER	FOR CR2032 BATTERY	DK: BS-D-ND
16	R14,R4,R8	3	RES 1K OHM 1/4W 1% AXIAL	1K	DK: 1.00KXBK-ND
17	R11,R21,R12,R19	4	RES 4.7K OHM 1/4W 5% AXIAL	4.7K	DK: 4.7KQBK-ND
18	R6,R15,R16,R22	4	RES 10K OHM 1/4W 1% AXIAL	10K	DK: 10.0KXBK-ND
19	R10,R20	2	RES 68K OHM 1/4W 1% AXIAL	OMIT - ONLY REQ'D WHEN USING UNIPOLAR OP-AMP PWR SUPPLY.	DK: 68.0KXBK-ND
20	U1	1	TEENSY 3.6 CPU MODULE	TEENSY 3.6 CPU	DK:1568-1442-ND
21	BATTERY	1	CR2032	3.3V Lithium Battary	DK: P121-ND
22	8-PIN DIP IC SKT	1	SOCKET FOR U2	OPTIONAL BUT RECOMMENDED	VARIOUS
23	14-PIN DIP IC SKT	1	SOCKET FOR U3	OPTIONAL BUT RECOMMENDED	VARIOUS
24	FEMALE SKT STRIPS	3	40 PIN .025" FEMALE SOCKET STRIP	CUT & FILE AS NEEDED FOR U1	VARIOUS
25	6 PIN WIRE HARNESS CONNECTOR	1	6 PIN .025" SQ FEMALE CONNECTOR	PART OF WIRE HARNESS BETWEEN TGI PCB AND POWER SUPPLY	VARIOUS
26	2 PIN FEMALE JUMPER	1	JUMPER FOR USE ON PL2 TO SELECT BLANKING POLARITY	2-PIN JUMPER; CAN USE WIRE-WRAP WIRE OR SOLDERED JUMPER WIRE	VARIOUS
27	BNC M-M CABLE	3	BNC (M) to BNC (M) COAX CABLE	LENGTH DEPENDS ON PHYSICAL SETUP	VARIOUS
28	BLANK PCB BOARD	1	20180627R0 (Rev 0)	BLANK PCB	NUTS & VOLTS STORE

Bare Printed Circuit Board – Rev 0

TOP SIDE VIEW



BOTTOM SIDE VIEW



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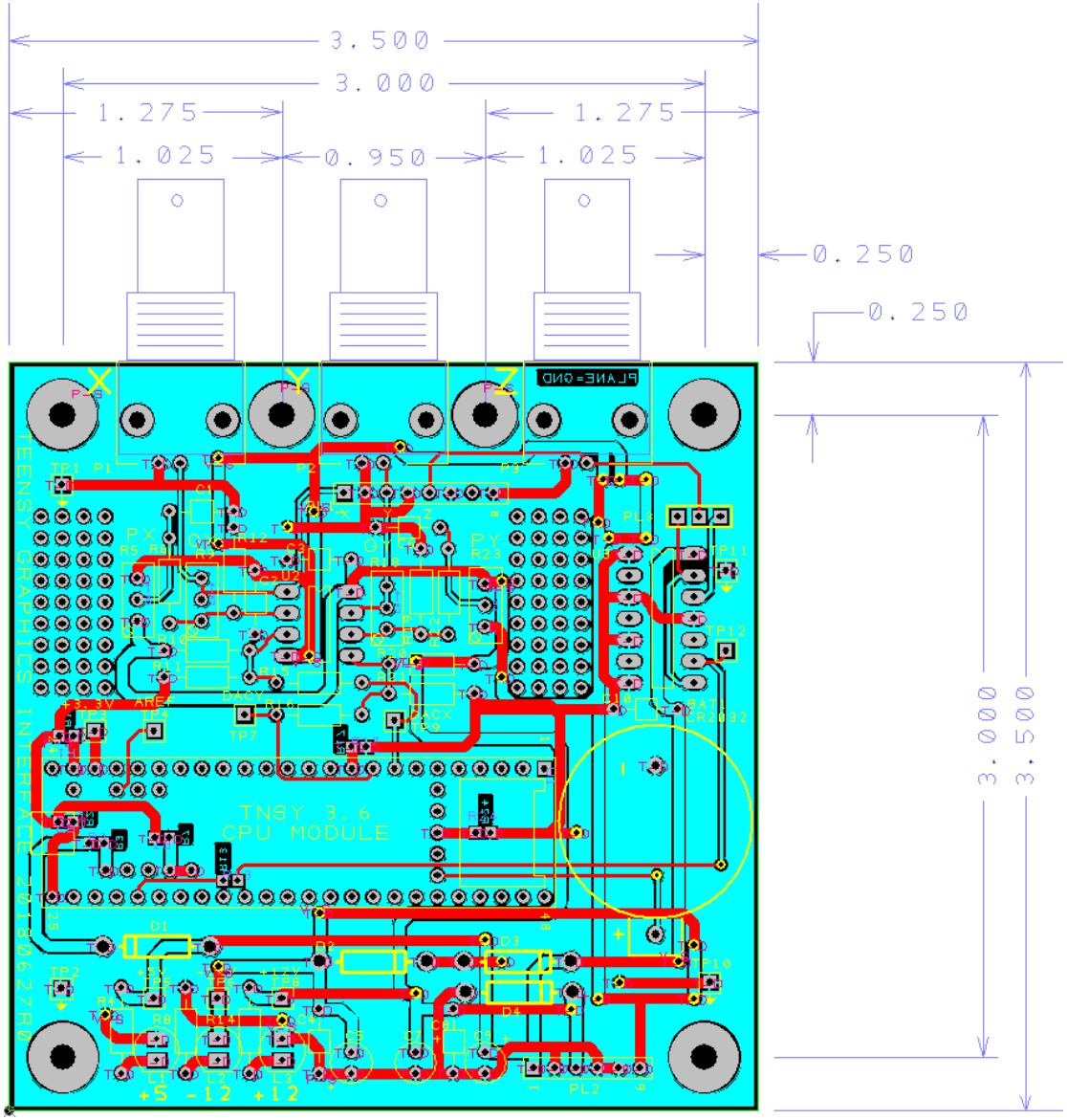
Made by: E. Andrews Date: 12-05-2020			Printed: 1/5/2020 13:29	AMC Brookfield, WI USA

TGI PCB Dimensions



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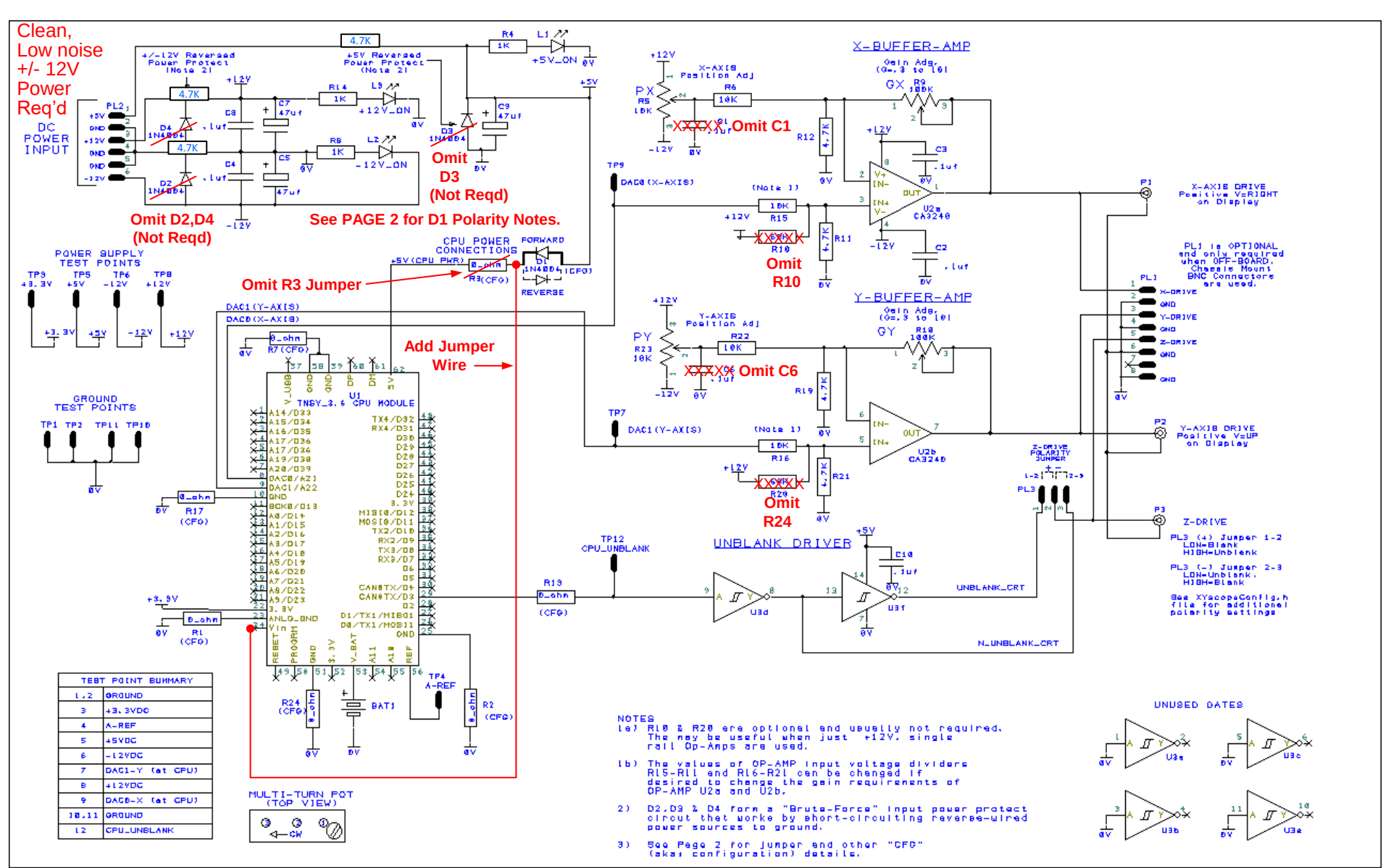


TEST POINT SUMMARY	
1,2	GROUND
3	+3.3VDC
4	A-REF
5	+5VDC
6	-12VDC
7	DAC1-Y (at CPU)
8	+12VDC
9	DAC0-X (at CPU)
10,11	GROUND
12	CPU_UNBLANK

NOTES

1a) R10 & R20 are optional and usually not required. They may be useful when just +12V, single rail Op-Amps are used.

1b) The values of OP-AMP input voltage dividers R15-R11 and R16-R21 can be changed if desired to change the gain requirements of OP-AMP U2a and U2b.

2) D2,D3 & D4 form a "Brute-Force" input power protect circut that works by short-circuiting reverse-wired power sources to ground.

3) See Page 2 for jumper and other "CFG" (aka: configuration) details.

4	3	2	1	0 VENDOR RELEASE 20180629	Drawn E. Andrews 6-15-2018	Check E. Andrews 6-29-2018	Title: AGI:ARDUINO-TNSY GRAPHICS INTERFACE
Drn	Drn	Drn	Drn	First Made For: AGI GRAPHICS INTER'FC			E. ANDREWS
Chk	Chk	Chk	Chk	PN:20180627R0 (PCB)			SEE LAST PAGE FOR REVISON HISTORY

Drawing No.

AMC Consulting Brookfield, WI USA

Filename: TEENSY_XYscope_Ver_00_pg_.sch, TEENSY_XYscope_Ver_00.pcb

Sheet 1 of 1

CONFIGURATION TABLE

REF	DESCRIPTION	NORMAL CONFIG	NOTES
R1	CPU ANLG GND	SHORTED	When SHORTED, ties ANLG-GND to INTFC BOARD GND When OPEN, isolates ANLG-GND from INTFC BOARD GND
R2 R7 R17 R24	CPU DIG-GND #1 CPU DIG-GND #2 CPU DIG-GND #3 CPU DIG-GND #4	SHORTED	When SHORTED, ties DIGITAL-GND to INTFC BOARD GND When OPEN, isolates DIGITAL-GND from INTFC BOARD GND
R3	+5V CPU PWR	~~SHORTED~~	~~Provides +5V path between CPU and INTFC BOARD~~
D1	CPU PWR POLARITY	FORWARD	FORWARD polarity = +5 V is sourced from INTFC BOARD goes to CPU. REVERSE polarity = +5V sourced FROM CPU and goes to INTFC BOARD
R12	CPU UNBLANK PIN	SHORTED	When SHORTED, uses CPU D3 will drive UNBLANK signal When OPEN, wire must be added to desired CPU pin

See Schematic Mark-up – DO NOT install R3; Follow detailed Build Instructions for REV 0 Board

X&Y POTENTIOMETER ADJUSTMENT

1)Put Scope on P1 X-axis Output.

2)Adjust X-Axis R5 CENTER & R8 GAIN untill desired amplitude and offset voltages at FULL SCALE output (0/4095) is achieved.

3)Put Scope on P2 Y-axis Output.

4)Repeat process to make Y-axis R23 CENTER & R18 GAIN adjustments.

DIODE D1 INSTALLATION NOTES - There are two installation options for D1 depending on how the TEENSY and TGI are to be powered.

1. If you always supply +5, +12, and -12 VDC through the main TGI power connector (PL2), install D1 in the FORWARD orientation (as shown on the PCB silk-screen). This is the USUAL WAY to power the TGI and TEENSY BOARD.
2. If you always supply +5V through the TEENSY Micro-USB connector, that is only +/- 12VDC is connected to the main TGI power connector PL2, then install diode D1 in the REVERSE orientation (opposite to the pattern on the PCB silk screen).

4	3	2	1	0 VENDOR RELEASE 20180629	Drawn E.Andrews 6-15-2018	Check E.Andrews 6-29-2018	Title: AGI:ARDUINO-TNSY GRAPHICS INTERFACE E. ANDREWS
Drn	Drn	Drn	Drn	First Made For: AGI GRAPHICS INTER'FC			
Chk	Chk	Chk	Chk	PN:20180627R0 (PCB)			

Drawing No.

AMC Consulting Brookfield, WI USA

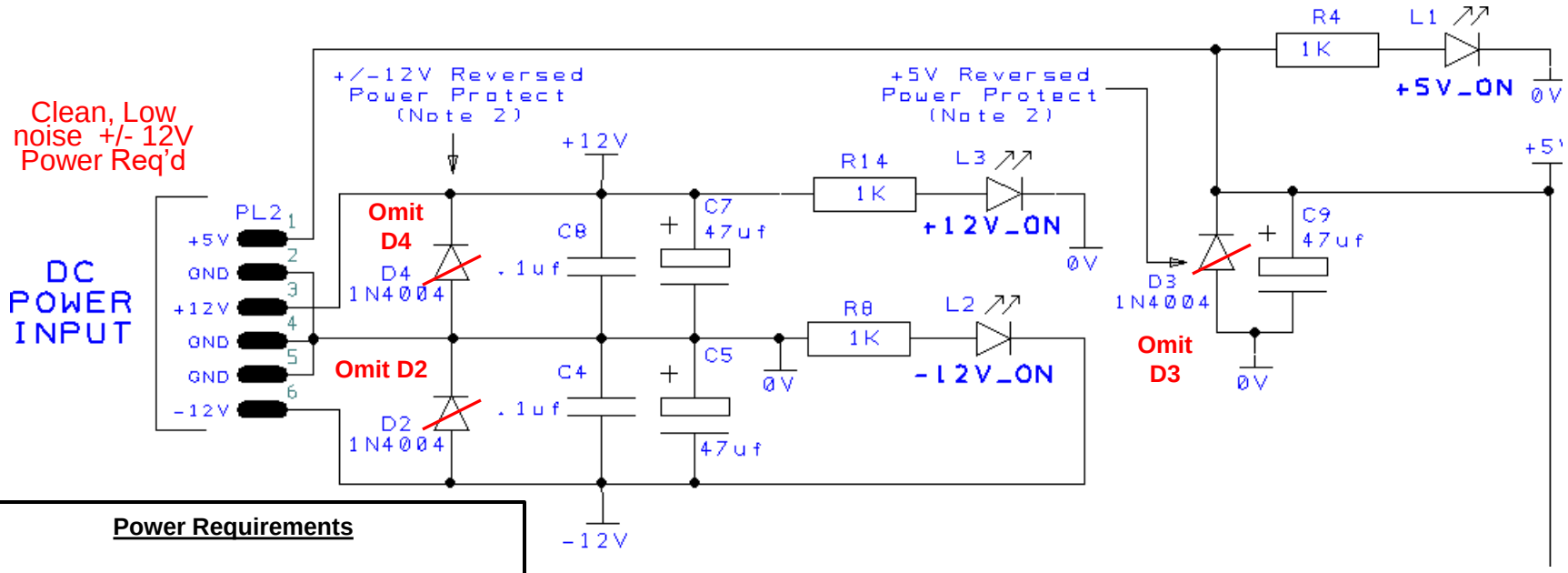
Filename: TEENSY_XYscope_Ver_00_pg_.sch
TEENSY_XYscope_Ver_00.pcb

Sheet 2 of 2

Schematic Details – PG 1

TEST POINT SUMMARY	
1.2	GROUND
3	+3.3VDC
4	A-REF
5	+5VDC
6	-12VDC
7	DAC1-Y (at CPU)
8	+12VDC
9	DAC0-X (at CPU)
10.11	GROUND
12	CPU_UNBLANK

PAGE 1: POWER SUPPLY CIRCUITS



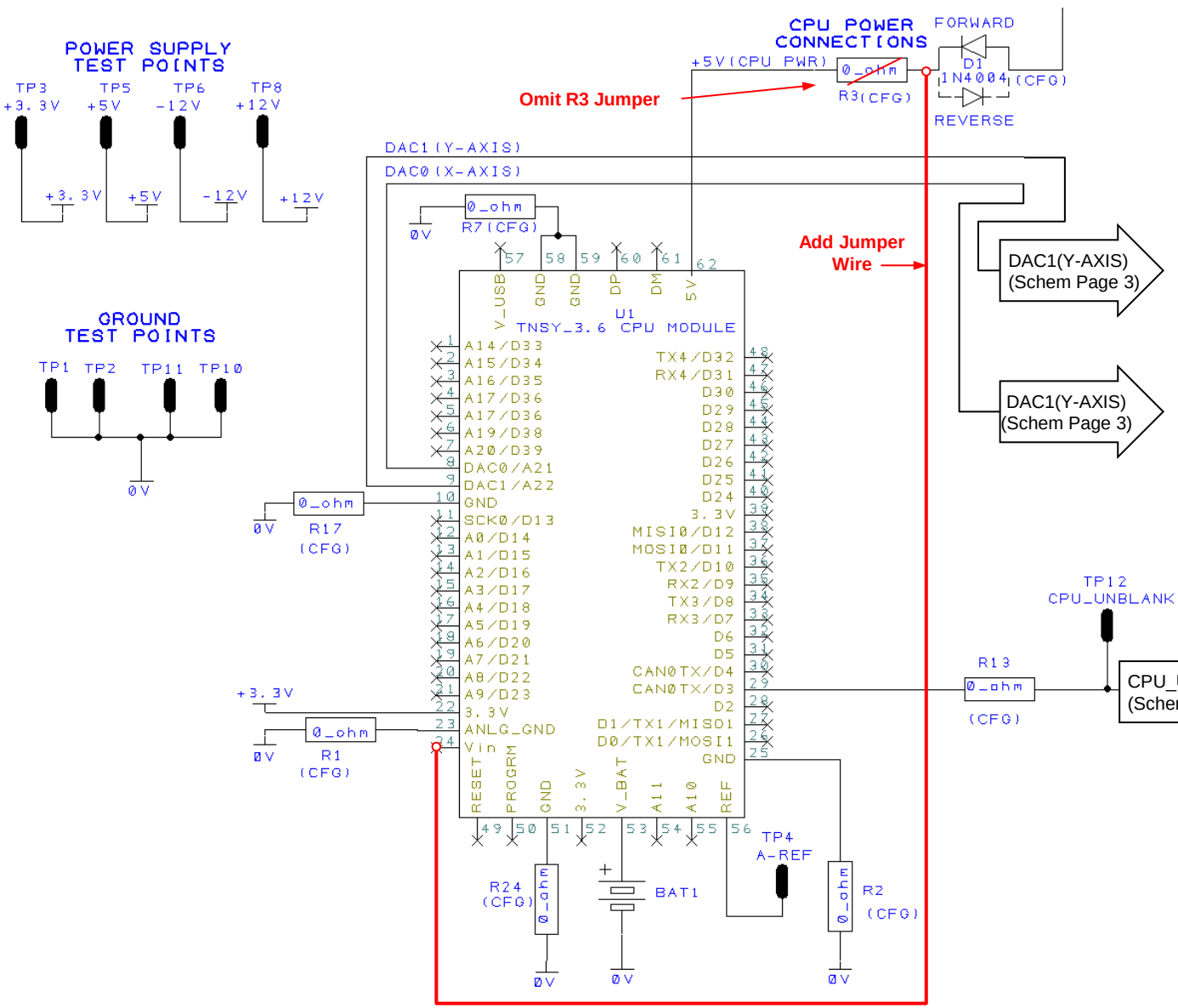
Power Requirements

+5VDC	@ ~500	ma Regulated Power
+12VDC	@ ~50	ma Linear Regulation
-12VDC	@ ~50	ma Linear Regulation

NOTES:

1. TEENSY requires 5V at ~ .5 Amp
2. Linear, low noise power is REQUIRED for +/- 12VDC volt supplies.

PAGE 2: DATA CLOCK TIMING AND BLANKING SYNCHRONIZATION



DIODE D1 INSTALLATION NOTES

- There are two installation options for D1 depending on how the TEENSY and TGI are to be powered.

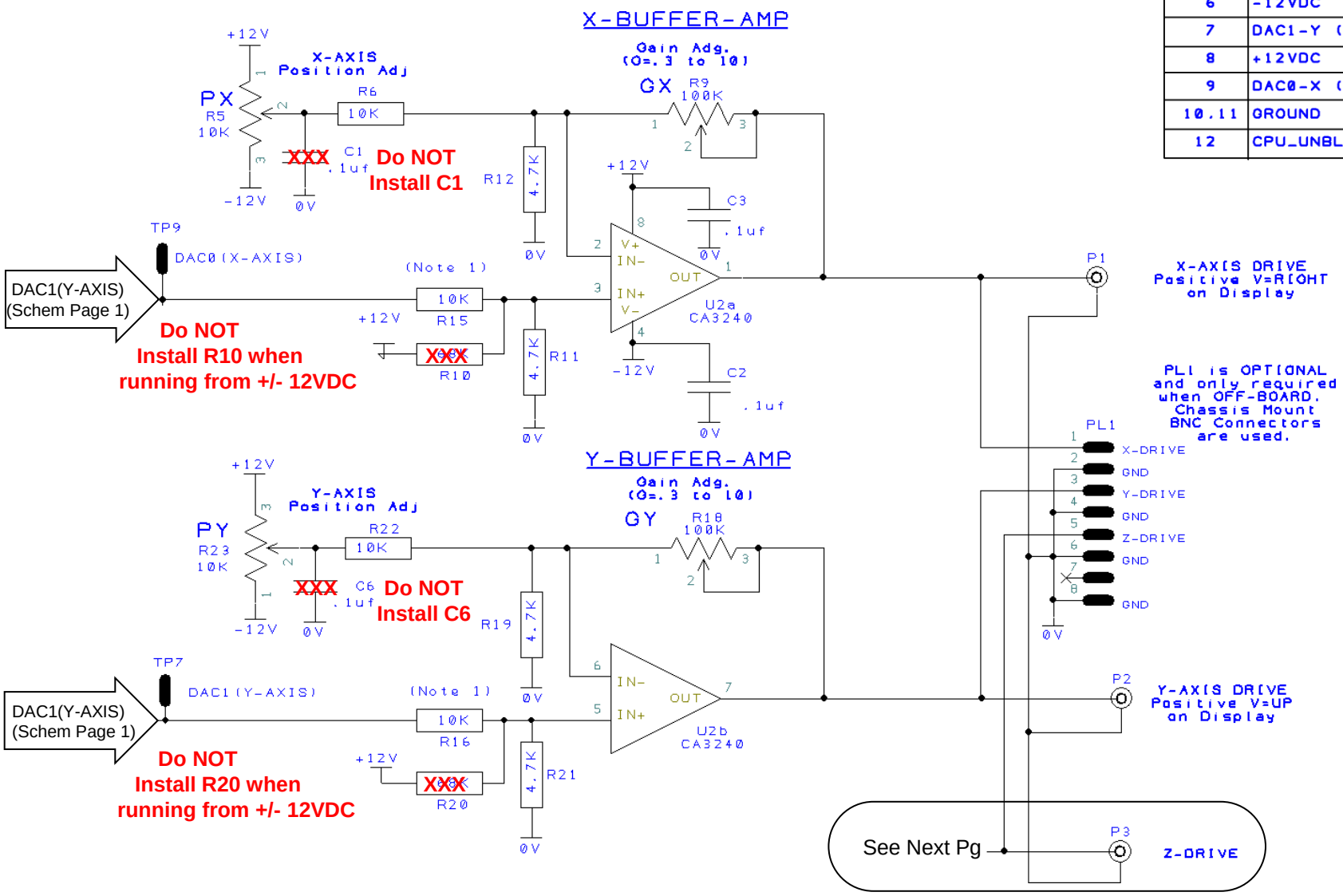
1. **RECOMMENDED:** If you always supply +5, +12, and -12 VDC through the main TGI power connector (PL2), install D1 in the FORWARD orientation (as shown on the PCB silk-screen).

2. **OPTIONAL:** If you always supply +5V through the TEENSY Micro-USB connector and only supply +/- 12VDC through the main TGI power connector PL2, then install diode D1 in the REVERSE orientation (opposite to the pattern on the PCB silk screen).

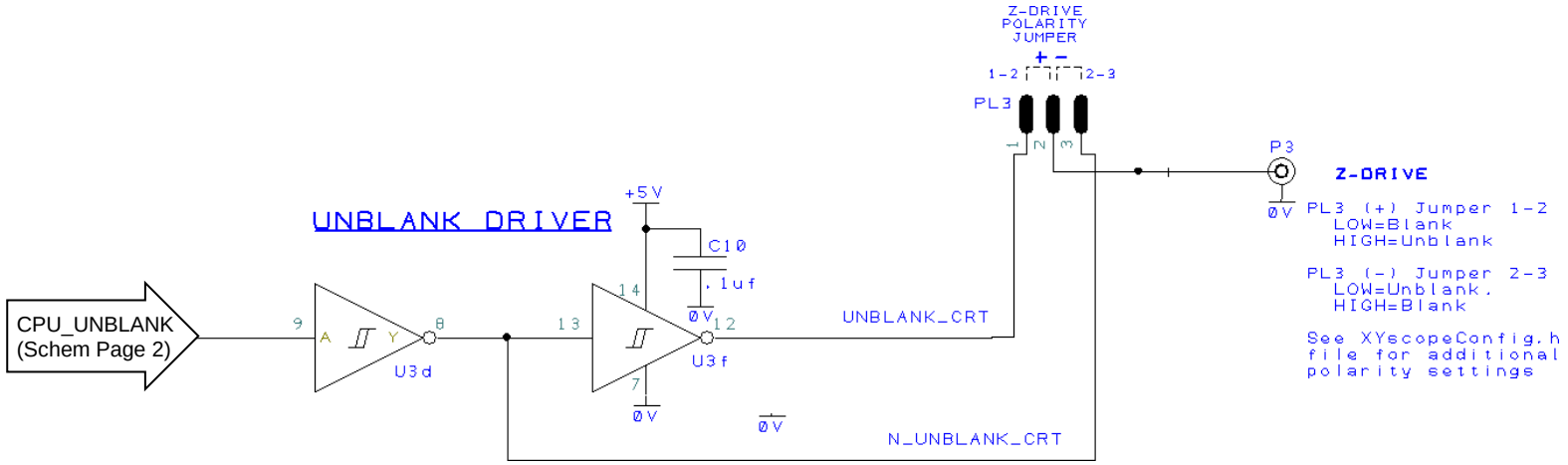
TEST POINT SUMMARY	
1,2	GROUND
3	+3.3VDC
4	A-REF
5	+5VDC
6	-12VDC
7	DAC1-Y (at CPU)
8	+12VDC
9	DAC0-X (at CPU)
10,11	GROUND
12	CPU_UNBLANK

TEST POINT SUMMARY	
1,2	GROUND
3	+3.3VDC
4	A-REF
5	+5VDC
6	-12VDC
7	DAC1-Y (at CPU)
8	+12VDC
9	DAC0-X (at CPU)
10,11	GROUND
12	CPU_UNBLANK

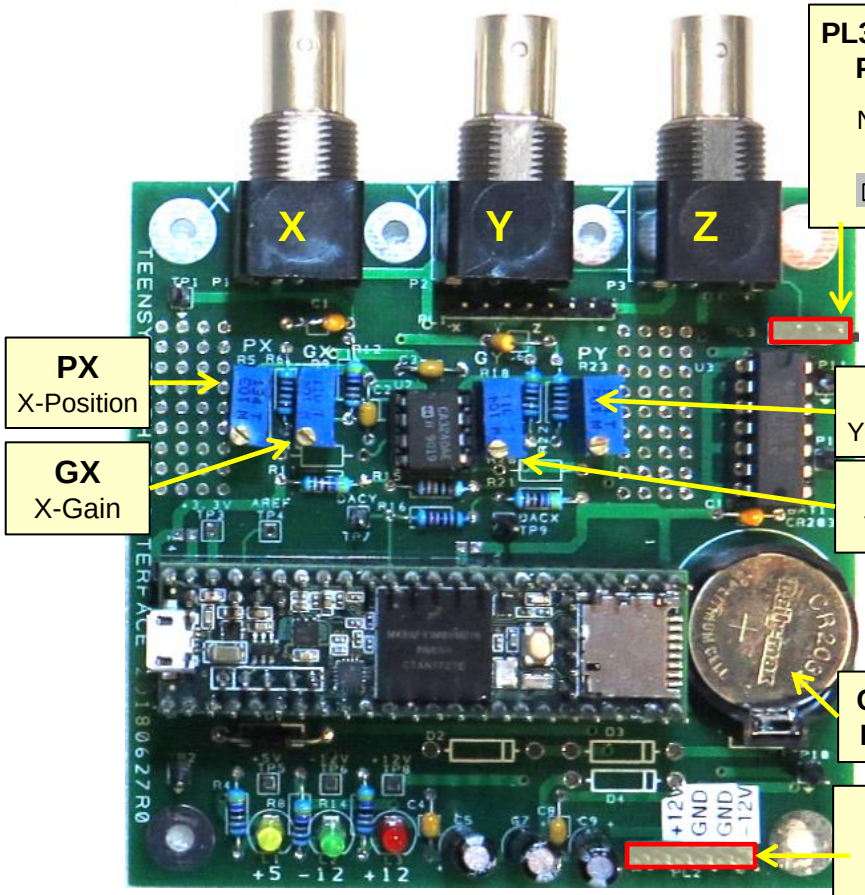
PAGE 3: X-Y ANALOG BUFFER-AMPLIFIERS



PAGE 4: Z-AXIS DRIVER



TGI Assembly Overview & Connectors



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Load Parts: .1uf Capacitors, 1N4004 Diode

BEFORE YOU BEGIN ASSEMBLY

Use and OHM METER to verify the following:

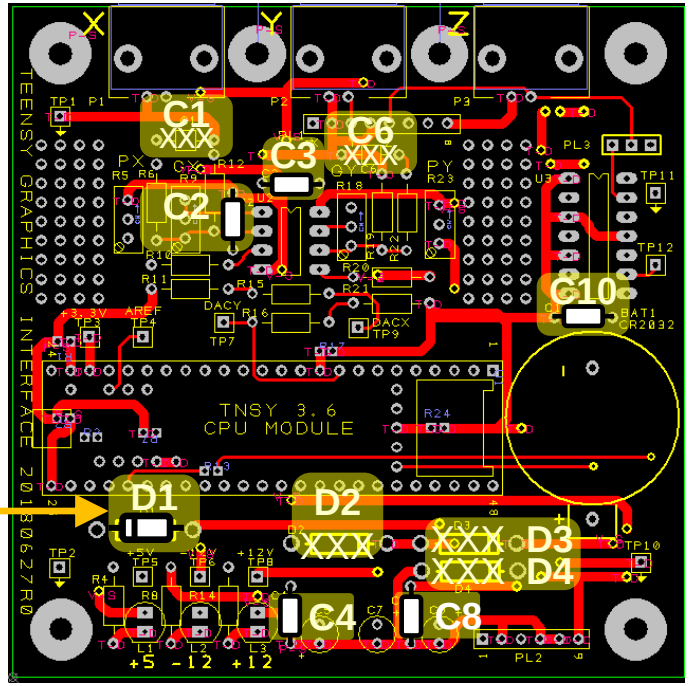
1. +5V bus is NOT SHORTED TO GROUND.
2. +5V bus is NOT SHORTED TO +12V bus.
3. +5V bus is NOT SHORTED TO -12V bus.
4. +12V bus is NOT SHORTED TO GROUND.
5. +12V bus is NOT SHORTED TO -12V bus
6. -12V bus is NOT SHORTED TO GROUND.

INSTALL CAPACITORS & DIODES

Ref Name	Qty	Value
C1	~~1~~	~~.1uf~~ ← XXX - *DO NOT INSTALL!*
C10	1	.1uf
C2	1	.1uf
C3	1	.1uf
C4	1	.1uf
C6	~~1~~	~~.1uf~~ ← XXX - *DO NOT INSTALL!*
C8	1	.1uf
D1	1	1N4004 ←SEE Installation Note Below
D2	~~1~~	~~1N4004~~
D3	~~1~~	~~1N4004~~
D4	~~1~~	~~1N4004~~ ← D2,3,4 NOT REQ'D

5

4 ←Observe Polarity!



DIODE D1 INSTALLATION NOTES

There are two installation options for D1 depending on how the TEENSY and TGI are to be powered.

1. If you always supply +5, +12, and -12 VDC through the main TGI power connector (PL2), install D1 in the FORWARD orientation (as shown on the PCB silk-screen). This is the 'normal' and recommended power connection scheme. To avoid a conflict with the host PC during programming or Serial Monitor use, be sure that the **+5VDC provided through PL2 *NEVER EXCEEDS 5.0VDC***.

2. If you prefer to always supply +5V through the TEENSY Micro-USB connector and only use PL2 to connect the +/- 12VDC supplies, then install diode D1 in the REVERSE orientation (opposite to the pattern on the PCB silk screen); the REVERSE orientation will then power inverter chip U3, from the TEENSY/USB power feed.

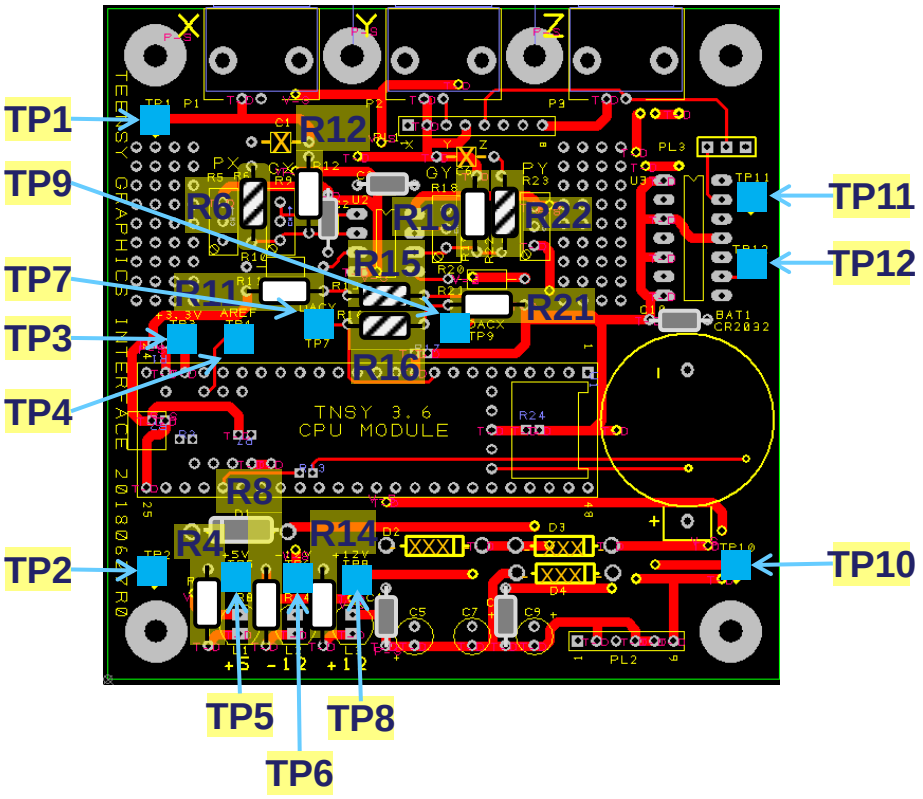
Load Parts: Resistors, Test Points

INSTALL FIXED RESISTORS

Ref Name	Qty	Value	
R10	~~1~~	~~68K~~	← XXX - *DO NOT INSTALL!*
R15	1	10K	2
R16	1	10K	
R20	~~1~~	~~68K~~	← XXX - *DO NOT INSTALL!*
R22	1	10K	2
R6	1	10K	
R14	1	4.7K	
R4	1	4.7K	
R8	1	4.7K	
R11	1	4.7K	7
R12	1	4.7K	
R19	1	4.7K	
R21	1	4.7K	

INSTALL TEST POINTS (Optional)

Ref Name	Qty	Value	
TP1	1	Optonal, 1 POS MALE HDR	
TP10	1	Optonal, 1 POS MALE HDR	
TP11	1	Optonal, 1 POS MALE HDR	
TP12	1	Optonal, 1 POS MALE HDR	
TP2	1	Optonal, 1 POS MALE HDR	
TP3	1	Optonal, 1 POS MALE HDR	12
TP4	1	Optonal, 1 POS MALE HDR	
TP5	1	Optonal, 1 POS MALE HDR	
TP6	1	Optonal, 1 POS MALE HDR	
TP7	1	Optonal, 1 POS MALE HDR	
TP8	1	Optonal, 1 POS MALE HDR	
TP9	1	Optonal, 1 POS MALE HDR	



Load Parts: Caps, LEDs, Sockets, BNCs, Bat. Holder

INSTALL BAT. HOLDER, ELECTROLYTIC CAPS, LEDs

Ref Name	Qty	Value
BAT1	1	BATTERY HOLDER ←Note Orientation
C5	1	10uf/50V (3) ←Observe Polarity!
C7	1	
C9	1	
L1	1	3MM LED .100 LS
L2	1	3MM LED .100 LS (3) ←Observe Polarity!
L3	1	3MM LED .100 LS

INSTALL IC SOCKETS & BNC CONNECTORS

Ref Name	Qty	Value
U3	1	74LS14 Install 14-Pin Socket ←Observe Polarity!
U2	1	CA3240 Install 8-Pin Socket
P1	1	RT ANG BNC
P2	1	RT ANG BNC
P3	1	RT ANG BNC

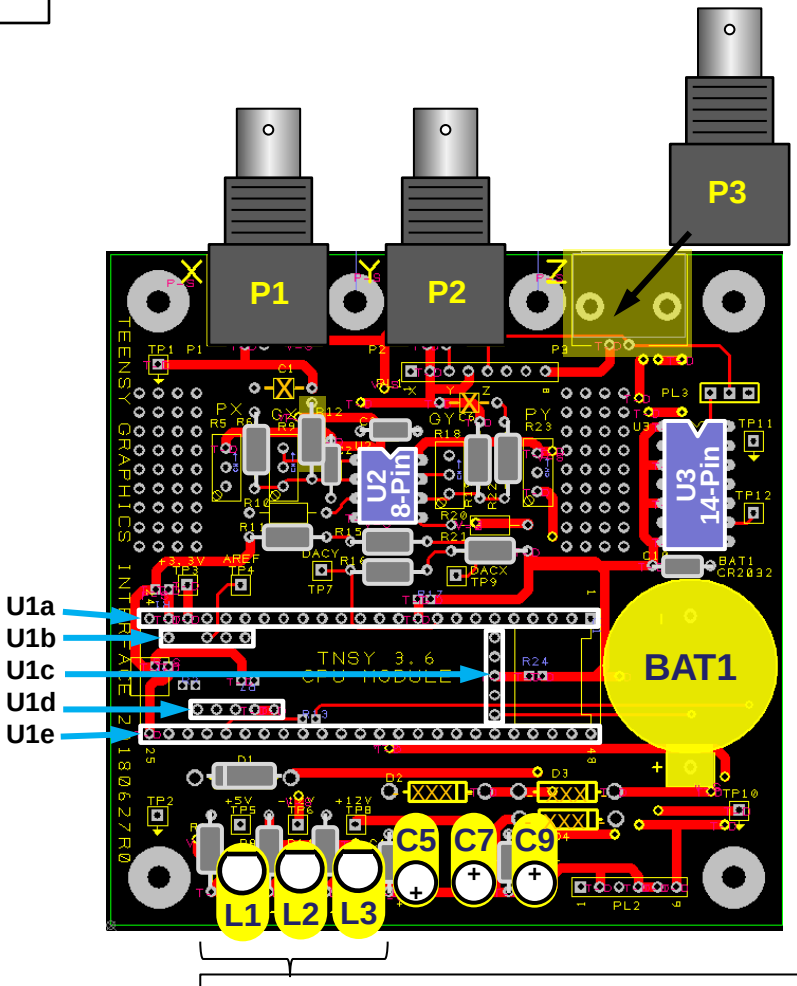
INSTALL TEENSY CPU SOCKETS PINS

Ref Name	Qty	Value
U1	1	TEENSY 3.6 CPU Female Socket Strips

REF	QTY	DESC
U1a U1e	2	24 pin female socket strip
U1b	1	5 pin female socket strip, pin 2 removed
U1c U1d	2	5 pin female socket strip

Socket Pin Fabrication Note:

TEENSY CPU socket pins can be made from 40 Pin strips by cutting to length as required. Cut ends should be hand filed/sanded as required to remove excess material from cut edges (particularly important for U1c).



Right Angle BNC PCB connectors

LED NOTES:

1. *Any color (Builders Choice) 3mm x .1" Lead Space LEDs may be used.*
2. *LED L1, L2, L3 silk screen pattern on Rev 0 PCB is **incorrect**. – Install with orientation shown in this diagram!*

Load Parts: Pots, Headers

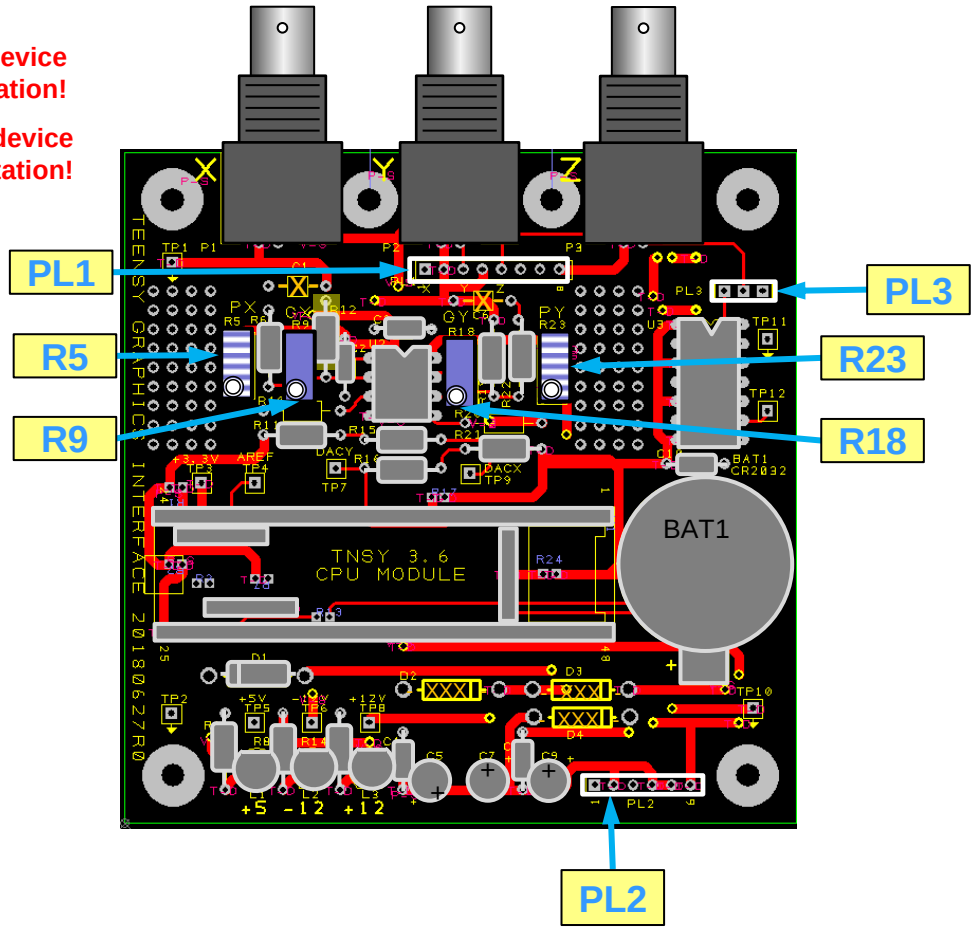
INSTALL POTENTIOMETERS

Ref Name	Qty	Value		
R9	1	100K POT	10 Turn Potentiometer	←Note device orientation!
R18	1	100K POT		
R23	1	10K POT	10 Turn Potentiometer	←Note device orientation!
R5	1	10K POT		

INSTALL HEADERS

Ref Name	Qty	Value	
PL3	1	CONN HDR 3POS.1" SIP	
PL2	1	CONN HDR 6POS .1"SIP	
PL1	1	CONN HDR 8POS .1"SIP	←OPTIONAL

NOTE: PL1 is OPTIONAL and only required for test purposes OR to wire to OFF-PCB-BOARD chassis mounted BNC connectors.



Install Jumper Wires

INSTALLATION OF 0-OHM JUMPER WIRES

Various jumpers are provided in the PCB layout so the experimenter may try different power supply grounding alternatives. These are identified on the schematic and parts list as "0_ohm" components and have a "R*nn*" designation. In order to complete these circuits with a 0_ohm value, a short length of wire or simply a small 'solder blob' must be placed across the two pads at each location. This is best done on the BACK SIDE of the PCB as shown in the figure to the right.

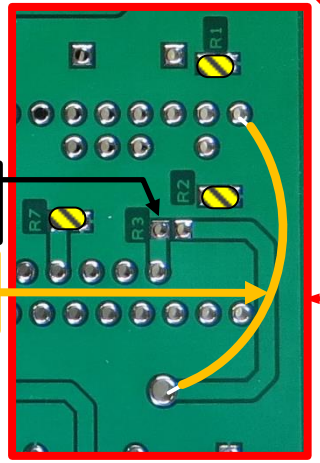
Ref Name	Qty	Value
R1	1	0-OHM Jumper Wire
R13	1	0-OHM Jumper Wire
R17	1	0-OHM Jumper Wire
R2	1	0-OHM Jumper Wire
R24	1	0-OHM Jumper Wire
R3	~~1~~	~~0-OHM Jumper Wire~~ DO NOT INSTALL!
R7	1	0-OHM Jumper Wire

ADD +5VDC JUMPER WIRE

Rather than use a switched USB power pin on the CPU module, the TGI +5V feed should be connected to the CPU "Vin" pin. To do this, a jumper wire needs to be added.

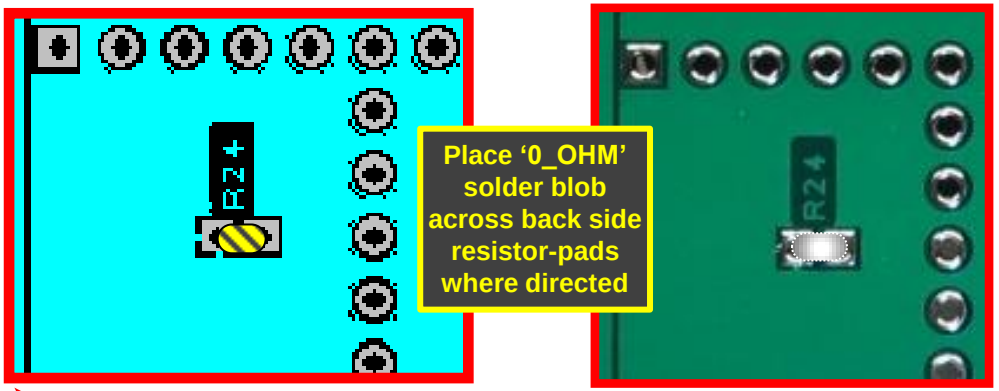
DO NOT install jumper solder-blob at R3

Add jumper wire to back side of PCB as shown.

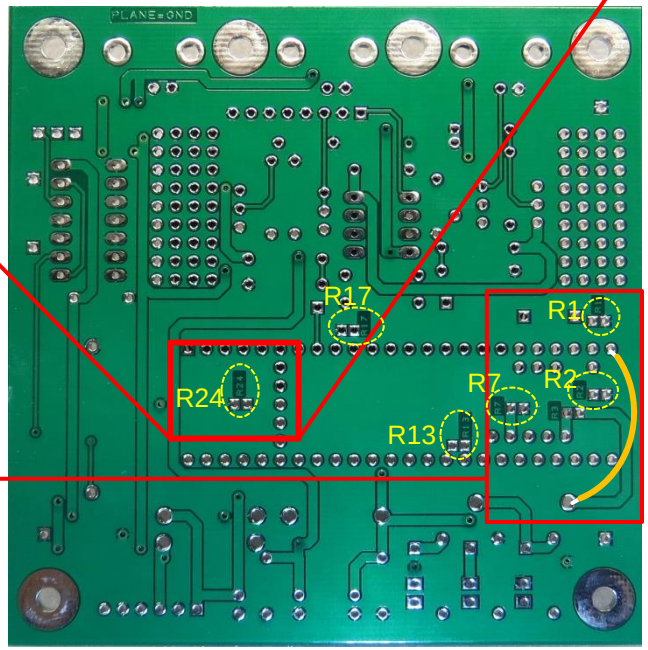


This wire will supply +5VDC *from* the TEENSY CPU Vin pin (normally +5VDC), to the TEENSY GRAPHICS INTERFACE PCB.

Magnified detail to show how to add solder blob to to back side jumper pads to create 0_OHM jumpers



REAR VIEW

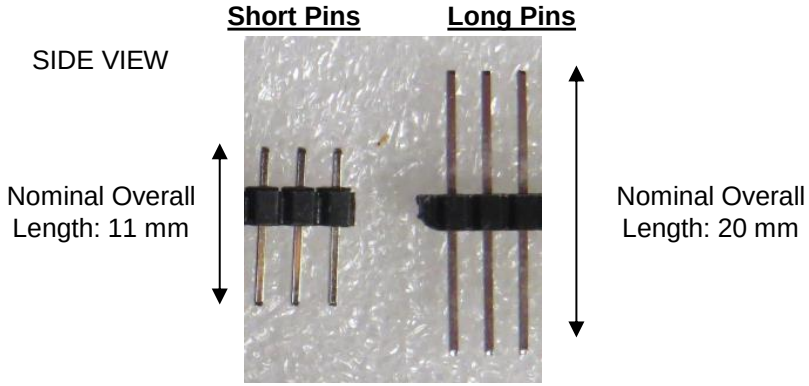


Prepare Teensy 3.6 CPU for Installation

TEENSY 3.6 PREP

Socket pins must be installed into the TEENSY for use with the TGI interface. If you intend to "plug the TEENSY" into the TGI board, it is necessary to install male pins into the TEENSY 3.6 board with which external connections can be made.

Male Pin Options - Several styles of male pins are available. Two styles which are commonly available in 40-pin strips are what I will call "Short-pins" or "Long pins".

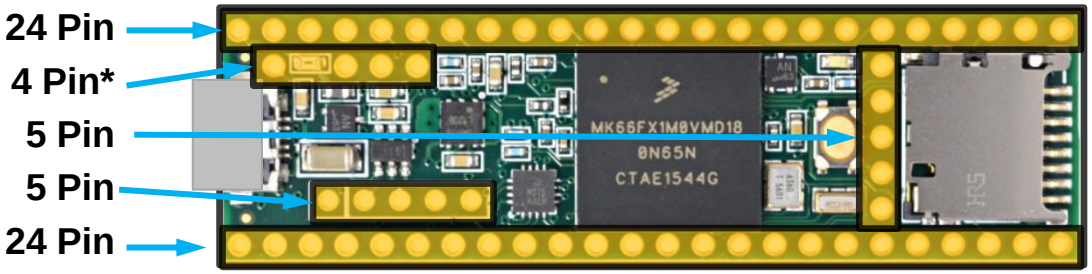


While either pin style will work for most applications, if Long Pins are installed, connections to the TEENSY from the *bottom* (ie: the TGI PCB or a different shield board), as well as the *top* of the TEENSY (ie: using wires with female socket-pins) is achieved and results in the most flexibility.

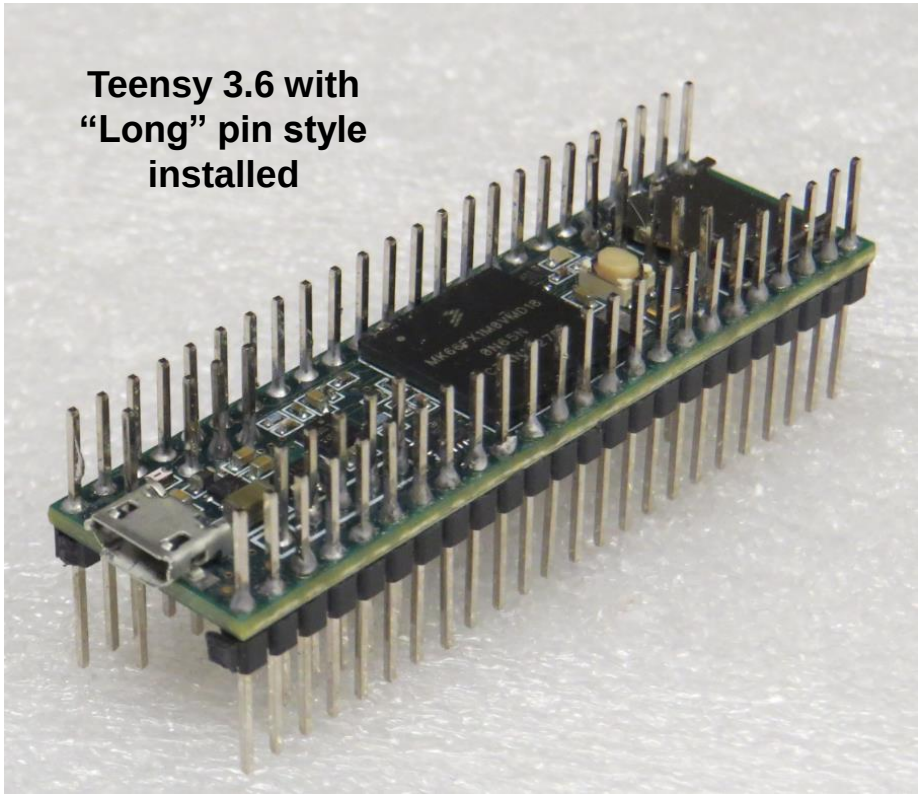
INSTALL PINS INTO TEENSY CPU

If pins have not yet been previously installed into the TEENSY CPU, select the desired pin style, cut pins from pin-strips to the correct pin count & configuration, and install pins into the TEENSY 3.6 board.

ConstructionTip: *Insert the pins into the blank TGI interface board and then place the TEENSY onto the pins. Now the pins will be properly aligned while soldering the pins from the top side of the TEENSY.*



NOTE: 4 Pin = 5 position Header with only 4 pins present (pin #2 removed).*



Final Power Supply Checks & Install ICs

VERIFY POWER SUPPLY

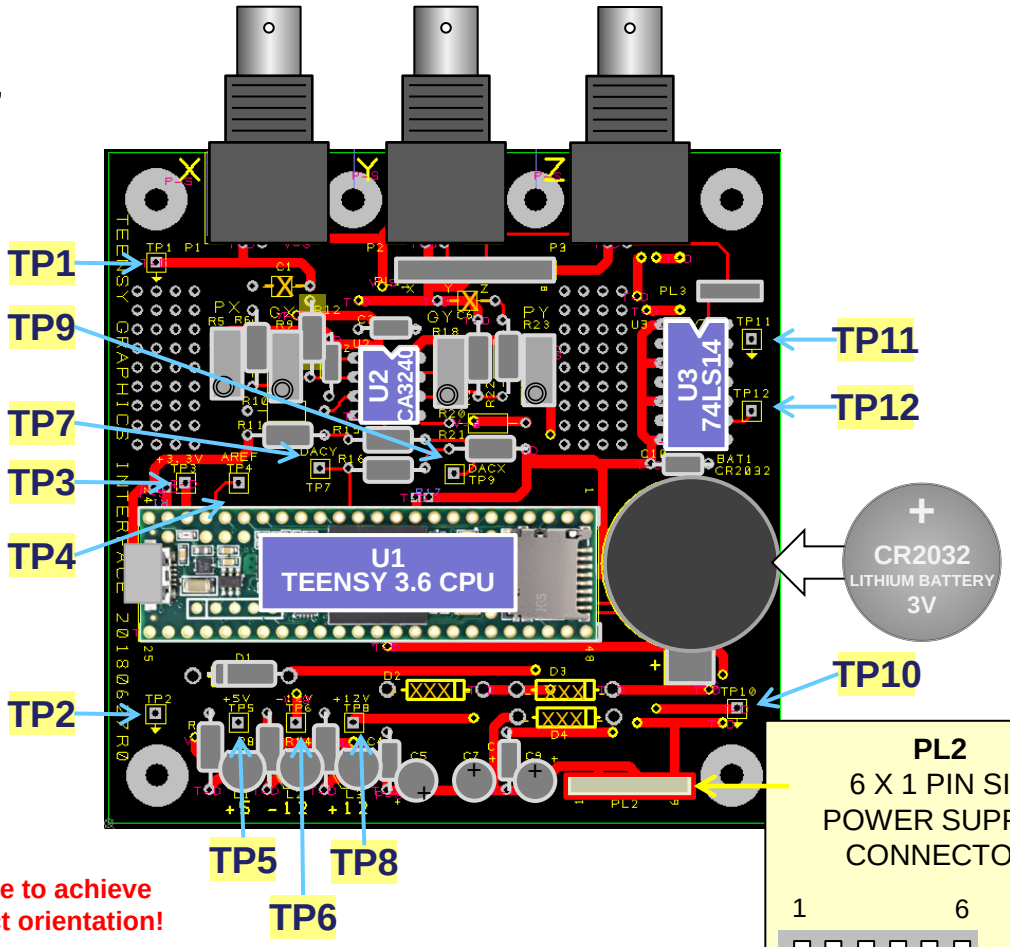
CAUTION: BEFORE INSTALLING U1,2,3
CHECK POWER SUPPLY!

1. BEFORE installing the TEENSY CPU (U1), OP-AMP (U2), or INVERTER (3) ICs, apply +5V, +12V & -12V power to TGI BOARD via PL2.

   a) OBSERVE < 20 MA current draw from all power supplies.
   b) OBSERVE LED L1,L2, & L2 are illuminated.

2. With the BLACK "ground" lead of digital voltmeter clipped to TP1, use the RED DVM lead to read:
   a) +5VDC on TP5
   b) -12VDC on TP6
   c) +12VDC on TP8
   d) +5VDC at PIN 14 of U3 (74LS14)
   e) +12VDC at Pin 8 of U2 socket (CA3240)
   f) -12VDC at Pin 4 of U2 socket (CA3240)
   g) +5VDC at Pin 2 of U1 socket (TEENSY)

3. Remove power from TGI & install U1, U2, & U3 per table below.



PLUG ICs INTO SOCKETS

Ref Name	Qty	Value
U3	1	74LS14
U2	1	CA3240
U1	1	TEENSY 3.6 CPU

Install ICs into into sockets

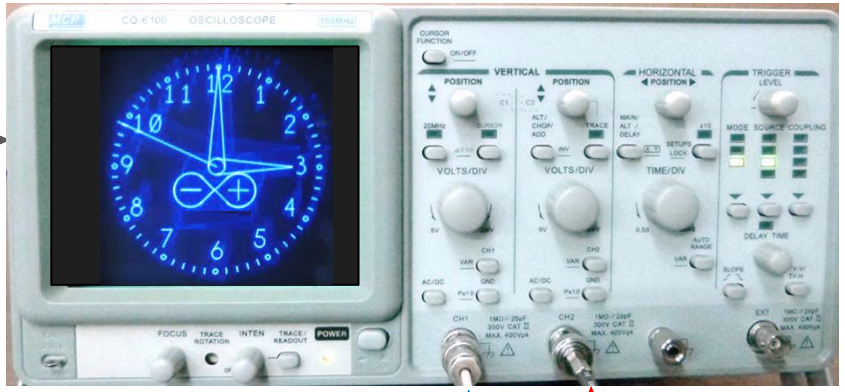
←Be sure to achieve correct orientation!

INSTALL CR2032 BATTERY INTO HOLDER

4. Apply +5, +12V, -12V power to TGI through PL2 and once again and observe proper voltage levels on TP5, 6, & 8 for all voltages. Teensy should operate and execute its stored program.

CAUTION: Take care to be sure that the power supply connector and wiring is correct. Damage to the TEENSY and or TGI board will result if power supplies are mis-connected!

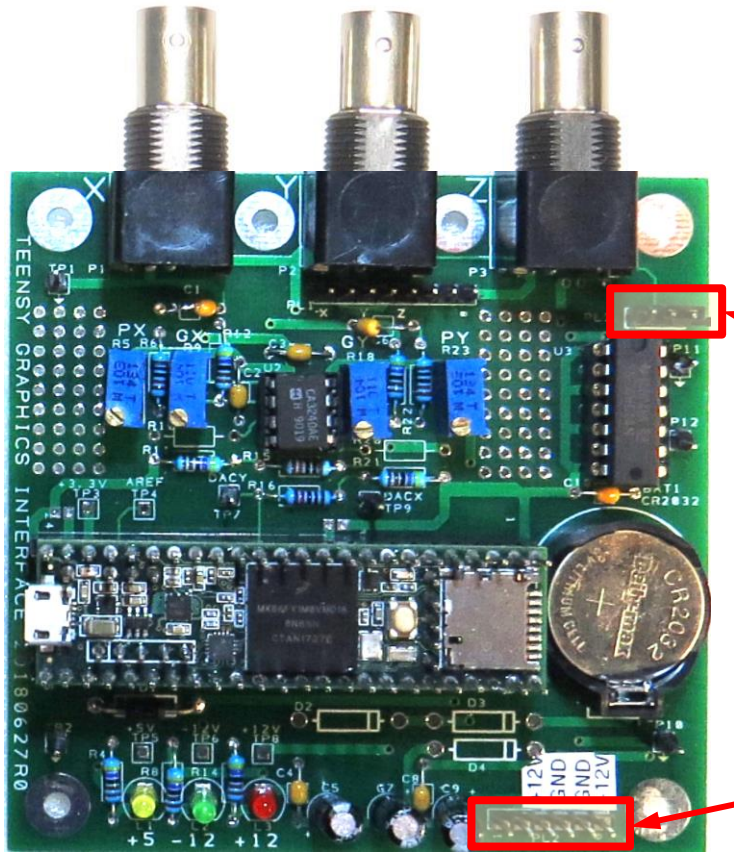
Power, Blanking Select & O'scope Wiring



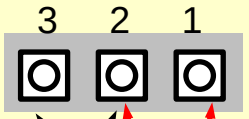
Z-Input
(Typically on Back Panel)

X-Input *(Typically CH 1)*

Y-Input *(Typically CH 2)*



PL3 Blanking Select

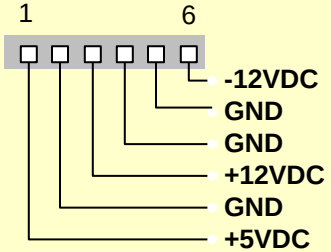


POSITIVE Z-AXIS LOGIC
Jumper position **1-2** for
Logic 1= UNBLANK

NEGATIVE Z-AXIS LOGIC
Jumper position **2-3** for
Logic 0 = UNBLANK

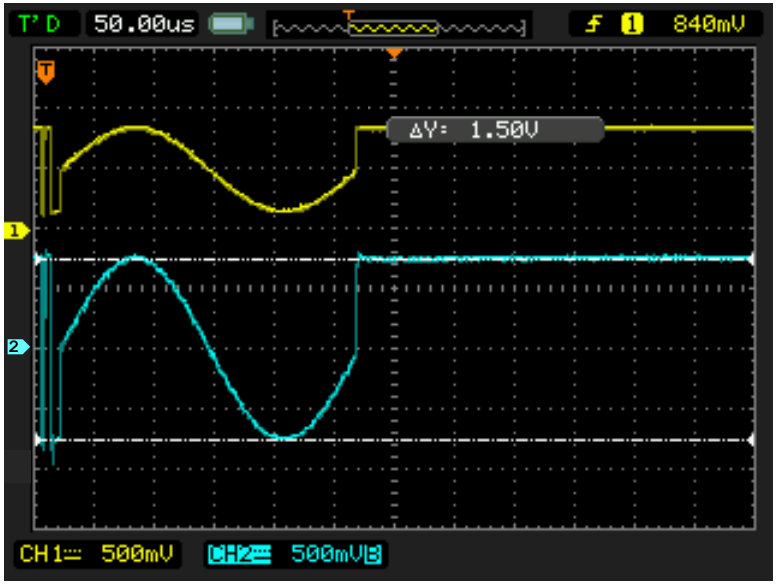
PL2 DC Power

6 X 1 PIN SIP
POWER SUPPLY
CONNECTOR



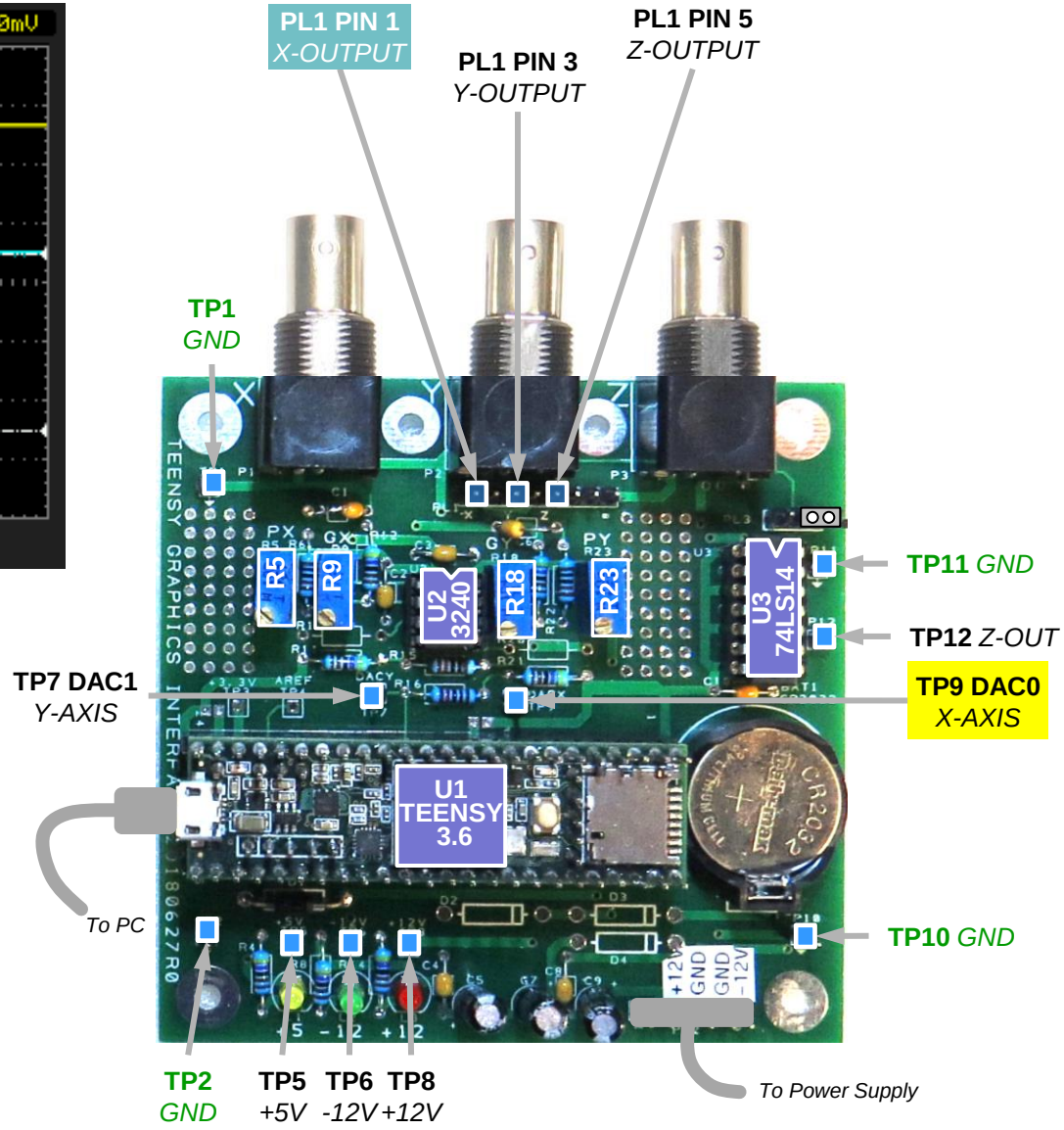
THIS DOCUMENT CONTAINS PROJECT SPECIFIC DOCUMENTATION	First Made For	Filename	Revision 3	Page	**AMC**
Made by: E. Andrews Date: 12-05-2020	Arduino Teensy Graphics Interface	20180627R0 BUILD DOC (Rev 3 TEENSY).pptx	Printed 1/5/2020 13:29		Brookfield, WI USA

X-Axis Gain and Position Adjust

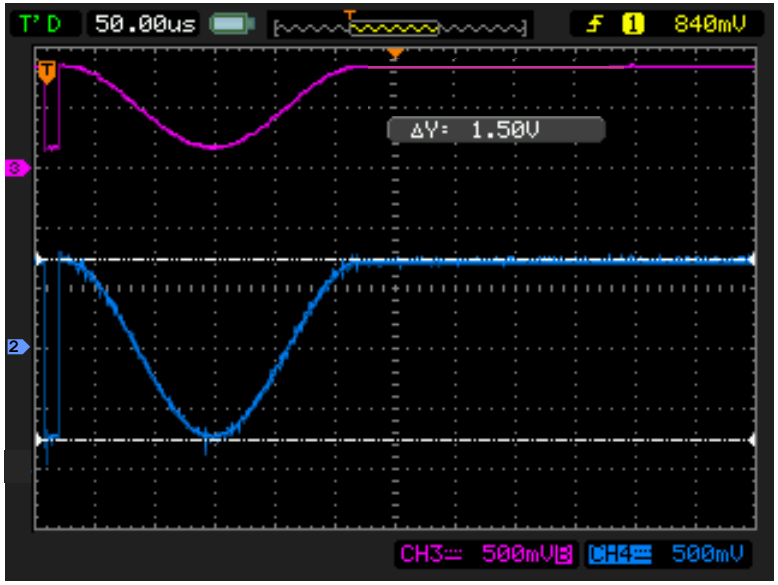


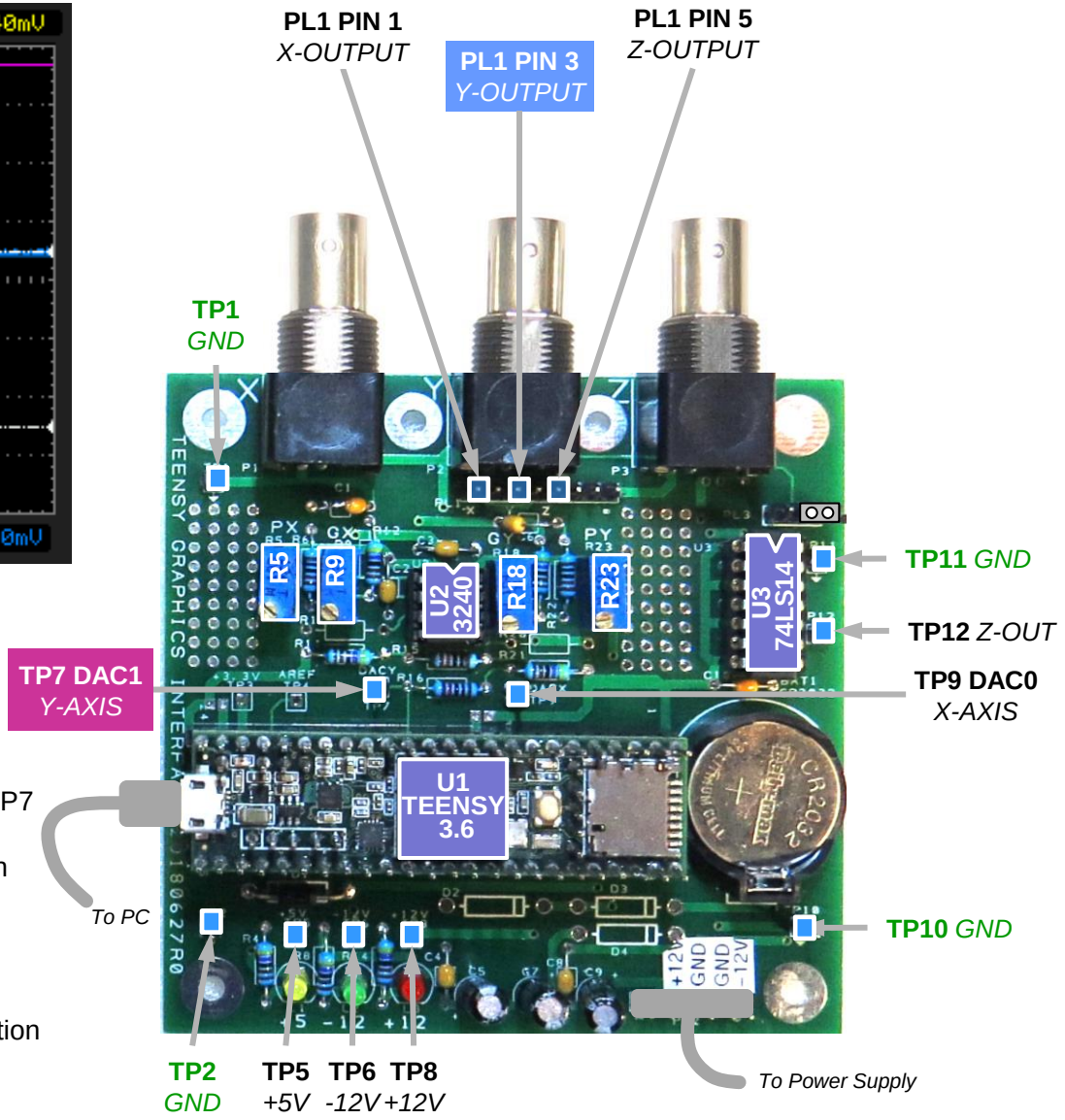
X-Gain & Offset Adjustment – Initial 1.5V P-P Setup

1. Interconnect TGI to PC and apply power to board.
2. Using Arduino IDE, Load and start CRT_SCOPE. Open a Serial Port (Baud=115200, NONE).
3. Select Option '0P' ; this outputs a sine-wave segment on DAC0/DAC1 that draws a circle to the screen.
4. Connect an oscilloscope to TP9 & PL1-Pin 1; Trigger on TP9 as shown.
5. TP9 (X-AXIS): Observe sine wave, approx. .7 V P-P (when Vref set to run at 1.5V).
6. Adjust GAIN_X (R5) and POSITION_X (R9) pots until PL1_1 (X-OUTPUT) displays approximately 1.5V P-P centered about ground.



Y-Axis Gain and Position Adjust





Y-Gain & Offset Adjustment – Initial 1.5V P-P Setup

1. Interconnect TGI to PC and apply power to board.
2. Using Arduino IDE, Load and start CRT_SCOPE. Open a Serial Port (Baud=115200, NONE).
3. Select Option '0P' ; this outputs a sine-wave segment on DAC0/DAC1 that draws a circle to the screen.
4. Connect an oscilloscope to TP7 & PL1-Pin 3; Trigger on TP7 as shown.
5. TP7 (Y-AXIS): Observe sine wave, approx. .7 V P-P (when Vref set to run at 1.5V).
6. Adjust GAIN_Y (R18) and POSITION_Y (R23) pots until PL2_3 (Y-OUTPUT) displays approximately 1.5V P-P centered about ground.
7. Connect & Place Scope in XY mode and final adjust position and gain pots in concert with scope gain and positions controls for proper XY display of a circle.
8. **SETTLING TIME DELAYS** and **UNBLANK** pulse widths are set in SOFTWARE; See **Teensy CRT_SCOPE_CLOCK User Manual** for this procedure.

Test Pattern Descriptions

Program Revision Level

```
========= CRT_SCOPE_CLOCK(3.00)  =========
 H/h/? = Show HELP Screen & plotting STATS
---- TEENSY Hardware Settings & Control -----
  nn S = Set LARGE-step DAC SETTLING (nn=count,0-100)
  nn s = Set SMALL-step DAC SETTLING (nn=count,0-100)
nnnn L = Set LARGE-step Threshold LIMIT (nnnn=count,0-4095)
  nn U = Set UNBLANK Width (nnn=count,0-50)
     I = Show current HW settings on Scope Screen
---- SCREEN SAVE Test routines
     W = Wakeup from SCREEN SAVE
 nnn W = Change Screen Save Timeout (nnn=Seconds)
---- TEXT Test routines
     m = Toggle Text Spacing Mode, Mono<-->Prop
     M = Toggle FONT Select, Vector<-->Hershey
 nnn t = Set TEXT Intensity to 1-250%
---- GRAPHICS Test Routines ----
 nnn G = Set GRAPHICS Intensity 1-250%
     K = CLEAR Display
xxxx,yyyy Z = ADD a point at X,Y to Display List
---- TEST Patterns & Demos ----
     P = Display 'Show Test Patterns' sub Menu
  nn P = Display Test Pattern Number 'nn'
---- CPU Performance Benchmarks ----
     d = Run DHRYSTONE Test (can take >60 Sec)
---- SET TIME & DATE ----
 h,m,s T = Set time values (hours,min,sec)
 m,d,y D = Set date values (month,date,year)
==========================================
```

Display this HELP screen

Hardware timing settings

Set/Reset screen saver function

Set text fonts, text spacing mode, and text brightness

Set graphics brightness/Clear Display Memory

Run various test patterns
(See Next Page for details)

Run CPU performance benchmarks

Set clock

Note: Menus and functions are subject to periodic changes and updates and as such, may vary from this illustration.

CRT_SCOPE_CLOCK – Patterns Menu

Display this Sub-Menu

Display test patterns that are helpful for gain and centering adjustment as well as general display clarity and timing setup

Patterns that demonstrate variious number formats and text optons

Patterns that demonstrate various graphics functions

Simple demo displays

Display a CRT clock using TEENSY RTC

```
========= TEST PATTERNS Sub-Menu =========
      P = Show Test Pattern Sub Menu
    0 P = XY Sine/Cosine OpAmp Gain Setup Pattern
    1 P = Centering Test Pattern
    2 P = Just Corner Dots Test Pattern
    3 P = Vert Stair-Case Test Pattern
    4 P = Vert Peak-To-Peak Test Pattern
    5 P = Horiz Peak-To-Peak Test Pattern

   11 P = Show Rand Nums, various formats
   12 P = Show Rand Nums w/Underline
   13,n P = Show Text Set; n=Switch to Font_0 or Font_1
   14,s,a P = Show Character; ssss=Size,aaa=Ascii Code
              (omit ssss and size=3000, omit aaa for ALL chars)
   15,n,m P = Show Random Points; n=Num_of_Points,omit=10K,m=loop count
   16,n,m P = Show Random Vectors; nnnnn=Num_of_Points,omit=10K,m=loop count
   17,n,m P = Show Random Rectangles; nnnnn=Num_of_Points,omit=10K,m=loop count
   18,n,m P = Show Random Circles; nnnnn=Num_of_Points,omit=10K,m=loop count
   19,n,m P = Show Random Ellipses; nnnnn=Num_of_Points,,m=loop countomit=10K

   20 P = Demo: Animated Logo Plot
   21 P = Demo: AGI Coordinate System
   22 P = Demo: Graphics Plot
   23,h,m P = Demo: Clock Plot, h=Hours,m=Minutes (omit h,m = Random time)
   24 P = Demo: PONG
   25 P = Demo: CLOCK II
==========================================
```

Note: Menus and functions are subject to periodic changes and updates and as such, may vary from this illustration.

Rev 0 PCB Known Issues

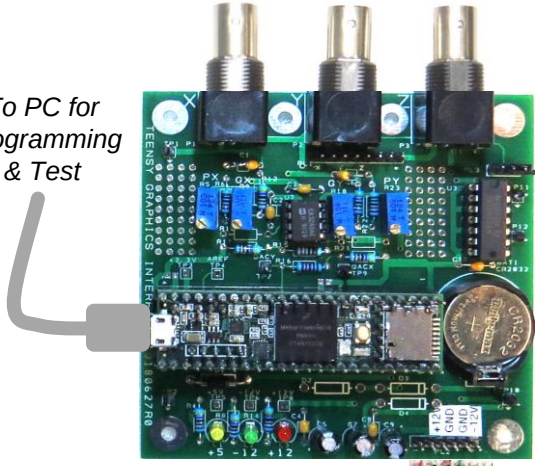
Ref Num	Issue Description	Severity	Status	Evaluation/Solution/Work-Around/Other Actions Taken
1	**TGI LED SILK SCREEN PATTERN ERROR** The top side silk screen patter for LEDs L1, L2, L3 are incorrect.	LOW	OPEN DATE: 20180618	**EVALUATION:** Pattern wrong in PCB library. **RECOMMENDATION:** Build per assembly guide where correct orientation is shown. Fix on future revision of PCB.
2	**+5V BUS BETWEEN TEENSY & TGI ERROR** Copper trace to TGI +5 bus routed incorrectly.	LOW	OPEN DATE: 20180618	**EVALUATION:** BUS routing incorrect. **RECOMMENDATION:** Build per assembly guide, add one jumper wire to correct REV 0 board. Fix on future revision of PCB.

Appendix 1: Power Suggestion, Option 1

Bench Supply -- OR --

TGI Circuit Board w/TEENSY 3.6

To PC for Programming & Test

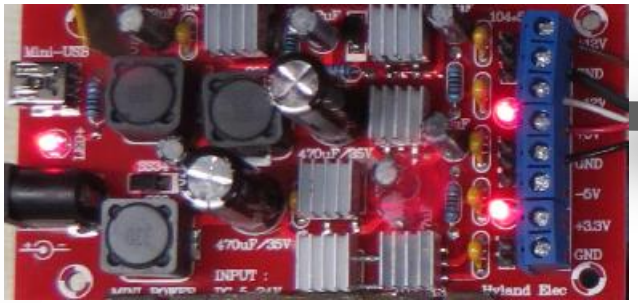


PL2 DC Power
6 X 1 PIN SIP POWER SUPPLY CONNECTOR

1 6

- -12VDC
- GND
- GND
- +12VDC
- GND
- +5VDC

Multi Output Supply With Linear Output Regulators



+5VDC IN

Arduino 5 VDC @ 1.5A Power Supply

See Next Page for Power Supply Kit Sourcing Suggestion

Note: TGI can operate well from any linear regulated voltage from +/- 9 VDC to +/- 12VDC

CAUTION: Take care to be sure that the power supply connector and wiring is correct. Damage to the TEENSY and or TGI board will result if power supplies are mis-connected!

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Made by: E. Andrews Date: 12-05-2020			Printed: 1/5/2020 13:29	AMC Brookfield, WI USA

Appendix 1: Power Suggestion, Option 1

This circuit has a wide range of single power supply input(5-24V, if the output current is small, use 3.7V lithium batteries as input can also provide normal output), then convert to multiple positive and negative regulated output converter. It's suitable for most of electronic required test.

Features:
Mini in size, convenient for use.
Single wide range input voltage: 5-24V DC.
With mini USB interface, the input with current limiting protection.
Multi-channel linear regulated voltage dual output.
Can meet most of experiments needs.

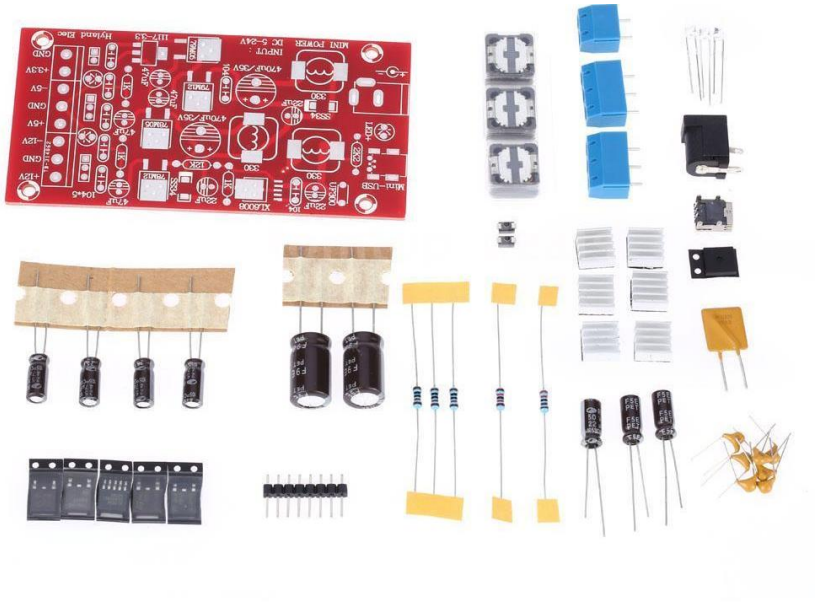
Note:
1. According to the output power requirements, please select input power with a sufficient output current, or it may not start. Output power = output voltage from various quarters * total output current, input power should be at least> Output power /0.9. For example, a standard power supply 5V, 1A, and to power the unit, it can provide up to about 4.5W of output power.
2. The total output power of machine should not exceed 10W, when single output, can provide short-term high current, but this time must pay attention to the heat sink temperature, not too high so as not to damage the IC. If you do not have experience, please control the output current of each channel to less than 0.2A. Excessively large output current may cause damage to the IC overheat.
3. Each output of the IC have protection, but please avoid a short circuit, all output wiring connections should be completed and then turn on the power.

Specifications:
Input Voltage: 5-24V DC
Output Voltage: + 12V, -12V, + 5V, -5V , +3.3V.
Output Current: 300mA (per channel)
PCB Board Size: 98 * 50mm
Package Size: Approx. 11 * 8.5 * 1cm
Package Weight: 55g / 1.96oz

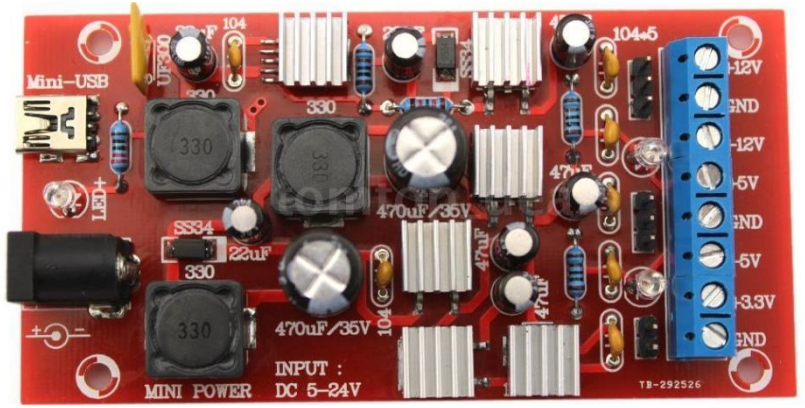
Package List: E1715
1 * Linear Regulated Power Supply DIY Kit

Price: $6.99 + $1.29 Shipping (from China)

Comes as a Kit of Parts



After Assembly



Ebay Link: https://www.ebay.com/itm/DIY-New-Boost-Single-Turn-Dual-Power-Supply-Linear-Regulator-w-Multi-Output-V2H8/282098798234?ssPageName=STRK%3AMEBIDX%3AIT&_trksid=p2057872.m2749.l2649

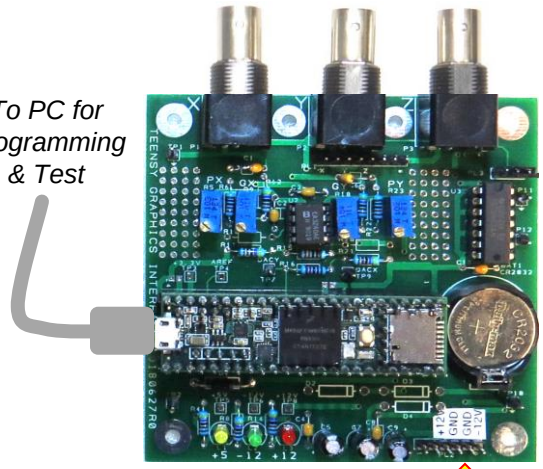
Amazon Link: https://www.amazon.com/KKmoon-Single-Supply-Regulator-Multiple/dp/B077PXWKKV/ref=sr_1_29?ie=UTF8&qid=1538677929&sr=8-29&keywords=Dual-Power-Supply-Linear-Regulator9

Appendix 2: Power Suggestion, Option 2

Bench Supply -- OR -- Arduino 5 VDC @ 1.5A Power Supply

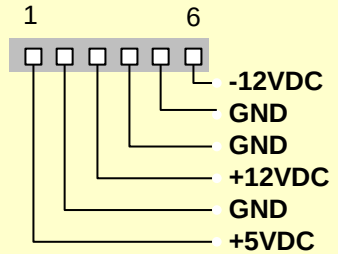
TGI Circuit Board w/TEENSY 3.6

To PC for Programming & Test



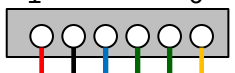
Note: TGI can operate well from any linear regulated voltage from +/- 9 VDC to +/- 12VDC

PL2 DC Power
6 X 1 PIN SIP POWER SUPPLY CONNECTOR



Switching Dual Output Supply Pre-Regulator

Linear 'Clean-Up' Regulator



+5VDC →

-12VDC

79L09
Vin Vout
GND

-9VDC

+12VDC

78L09
Vin Vout
GND

+9VDC

See Next Page for +/-12VDC Inverter Power Supply Sourcing Suggestions

NOTE: The Linear CLEAN UP regulator is required with this option!

CAUTION: Take care to be sure that the power supply connector and wiring is correct. Damage to the TEENSY and or TGI board will result if power supplies are mis-connected!

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Made by: E. Andrews Date: 12-05-2020			Printed: 1/5/2020 13:29	AMC Brookfield, WI USA

Appendix 2: Inverter for Power Option 2

One way to provide +/- 12VDC to the TGI is by purchasing an inverter which accepts +5VDC as an input, and provides +/-12VDC outputs. One such power supply is seen below. Note that a the second stage, linear regulator (as noted on the preceding page) is also required to eliminate switching power supply noise aritifacts from degrading the traces appearing on the oscilloscope display screen..

LINK: https://www.ebay.com/itm/Negative-Voltage-Dual-DC12V-12V-Power-Supply-Module-5-12V-to-12V-For-Amplifier/171788980821?epid=18006616672&hash=item27ff6bd255%3Ag%3A8AAAAOSw6BtVVEiv&_sacat=0&_nkw=Dual+Power+Supply+Module&_from=R40&rt=nc&LH_TitleDesc=0%7C0

Negative Voltage Dual DC12V -12V Power Supply Module 5-12V to ±12V For Amplifier

★★★★★ 2 product ratings

Condition: **New**

Quantity: 1 More than 10 available
219 sold / See feedback

Price: **US $6.58**

Buy another

Add to cart

Best Offer: Make Offer

Watching

2-year protection plan from SquareTrade - $5.99

100% buyer satisfaction	219 sold	More than 86% sold

Shipping: **FREE** ePacket delivery from Hong Kong | See details
See details about international shipping here.
Item location: Hong Kong, Hong Kong
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Delivery: Estimated between **Wed. Aug. 1 and Wed. Aug. 15**
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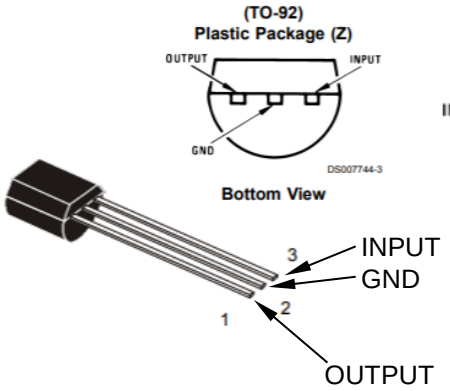
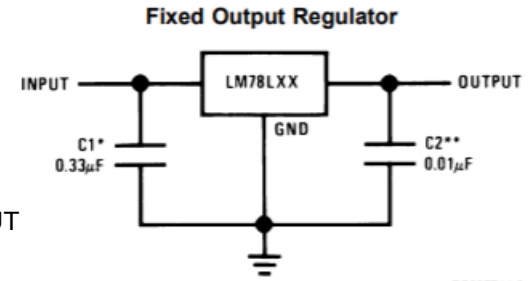
Appendix 3: Linear Regulators for Option 2





*Required if the regulator is located more than 3" from the power supply filter.
**See (Note 4) in the electrical characteristics table.

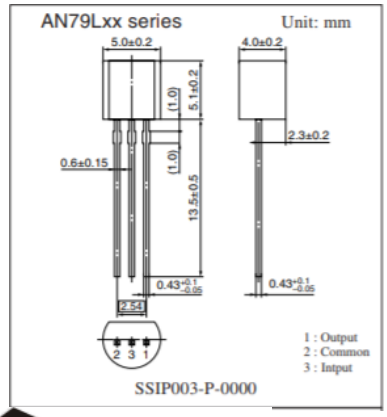
Note 4: Recommended minimum load capacitance of 0.01 µF to limit high frequency noise

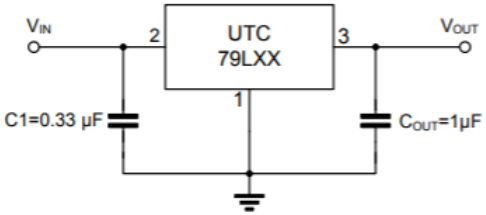
LM78L09AC

Unless otherwise specified, V_{IN} = 15V

Symbol	Parameter	Conditions	Min	Typ	Max	Units
V_O	Output Voltage		8.64	9.0	9.36	V
		11.5V ≤ V_{IN} ≤ 24V 1 mA ≤ I_O ≤ 40 mA (Note 3)	**8.55**		**9.45**	
		1 mA ≤ I_O ≤ 70 mA (Note 3)	**8.55**		**9.45**	
ΔV_O	Line Regulation	11.5V ≤ V_{IN} ≤ 24V		100	200	mV
		13V ≤ V_{IN} ≤ 24V		90	150	
ΔV_O	Load Regulation	1 mA ≤ I_O ≤ 100 mA		20	90	
		1 mA ≤ I_O ≤ 40 mA		10	45	
I_Q	Quiescent Current			2	5.5	mA
ΔI_Q	Quiescent Current Change	11.5V ≤ V_{IN} ≤ 24V			**1.5**	
		1 mA ≤ I_O ≤ 40 mA			**0.1**	
V_n	Output Noise Voltage			70		µV
$\frac{\Delta V_{IN}}{\Delta V_{OUT}}$	Ripple Rejection	f = 120 Hz 15V ≤ V_{IN} ≤ 25V	38	44		dB
I_{PK}	Peak Output Current			140		mA
$\frac{\Delta V_O}{\Delta T}$	Average Output Voltage Tempco	I_O = 5 mA		−0.9		mV/°C
V_{IN} (Min)	Minimum Value of Input Voltage Required to Maintain Line Regulation			10.7		V

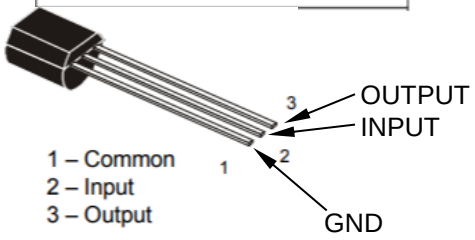
■ APPLICATION CIRCUIT





Typical C_{OUT} = 0.1uf

Connect CI of 2µF when the input line is long. CO improves the transient response. 1µF



Caution: Pinout is consistent, but Pin Number assignments are inconsistent between manufactures

■ Electrical Characteristics at T_a = 25°C (continued)

• AN79L09, AN79L09M (−9V type)

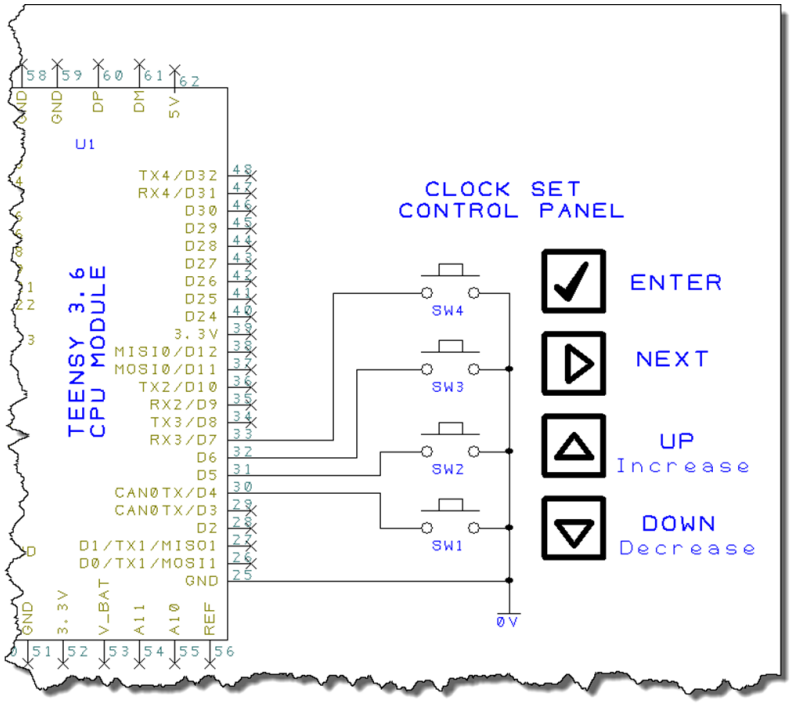
Parameter	Symbol	Conditions	Min	Typ	Max	Unit
Output voltage	V_O	T_j = 25°C	−8.64	−9	−9.36	V
Output voltage tolerance	V_O	V_I = −12 to −24V, I_O = 1 to 70mA	−8.55	—	−9.45	V
Line regulation	REG_{IN}	V_I = −11 to −25V, T_j = 25°C	—	—	160	mV
		V_I = −12 to −22V, T_j = 25°C	—	—	80	mV
Load regulation	REG_L	I_O = 1 to 100mA, T_j = 25°C	—	16	90	mV
		I_O = 1 to 40mA, T_j = 25°C	—	8	50	mV
Bias current	I_{Bias}	T_j = 25°C	—	3	5	mA
Bias current fluctuation to input	$\Delta I_{Bias(IN)}$	V_I = −12 to −24V, T_j = 25°C	—	—	0.5	mA
Bias current fluctuation to load	$\Delta I_{Bias(L)}$	I_O = 1 to 40mA, T_j = 25°C	—	—	0.1	mA
Output noise voltage	V_{no}	f = 10Hz to 100kHz, T_a = 25°C	—	58	—	µV
Ripple rejection ratio	RR	V_I = −12 to −22V, f = 120Hz, T_a = 25°C	53	—	—	dB
Minimum input/output voltage difference	$V_{DIF(min)}$	T_j = 25°C	—	0.8	—	V
Output short-circuit current	$I_{O(Short)}$	V_I = −35V, T_j = 25°C	—	200	—	mA
Output voltage temperature coefficient	$\Delta V_O/T_a$	I_O = 5mA, T_j = 0 to 125°C	—	− 0.6	—	mV/°C

Note 1) The specified condition T_j = 25°C means that the test should be carried out within so short a test time (within 10ms) that the characteristic value drift due to the chip junction temperature rise can be ignored.
Note 2) Unless otherwise specified, V_I = −15V, I_O = 40mA, C_I = 2µF, C_O = 1µF, T_j = 0 to 125°C (AN79L09) and T_j = 0 to 100°C (AN79L09M)

Appendix 4: 4-Button Control Panel

Starting with V3.20 code, optional push buttons may be connected to the TEENSY and used to set the clock (While in CLOCK MODE) or vary selected timing parameters (when in TEST & DEMO MODE).

Buttons should be wired as shown to the right.



TEST & DEMO MODE OPERATION

The following values when in Non-Clock-Mode:

- Small_Step Settling time
- Large_Step_Settling time
- UnBlank_time

To activate a button, select the value you wish to adjust by typing (via monitor keyboard):

- s↵ Small_Step_Settling time value
- S↵ Large_Step_Settling time value
- U↵ Unblank time

TEST & DEMO MODE Example:

If you wish to adjust the Unblank time with the control buttons then just type **_U↵** into the Monitor keyboard.

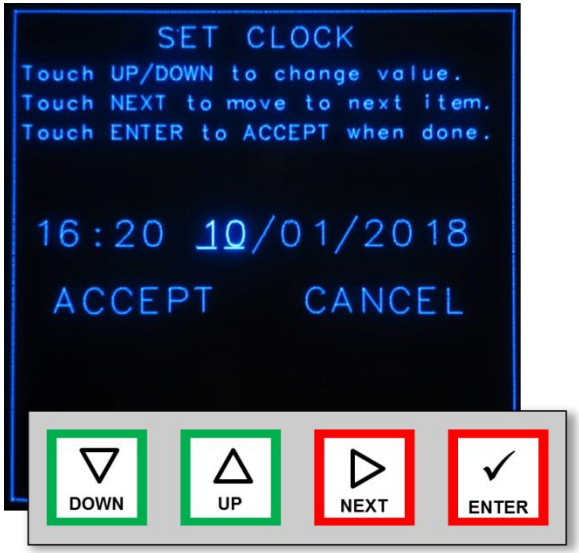
Now, pressing the UP/DOWN buttons will vary the UNBLANK value. The changed UNBLANK value instantly used and will be displayed on the screen as well.

Press and HOLD a UP/DOWN button to auto repeat (step) the value up or down.

In this way, you can watch the display screen or watch timing waveforms change in 'real time'

SAVE Timing Values to EEPROM

Use the SAVE to EEPROM option to save the changes to EEPROM where they will be automatically restored upon power up.



CLOCK MODE OPERATION

If you touch any key while in CLOCK MODE, the SET CLOCK screen will appear. Follow the instructions on the screen to set time and date. Select ACCEPT then touch ENTER to set the clock to the new values; Select CANCEL and then touch ENTER to leave the SET CLOCK screen *without* changing the current time or date.

Document Revision Log

Rev	Date	Change Summary
0	20180716	Initial Release, focus on Rev 0 PCB build
1	20180831	Add Power Supply suggestions and sourcing
2	20181004	Omit D2,3,4, Update BOM, Add 4-button control panel wiring diagram, minor document cleanup