TGI BUILD DOCUMENT PACKAGE

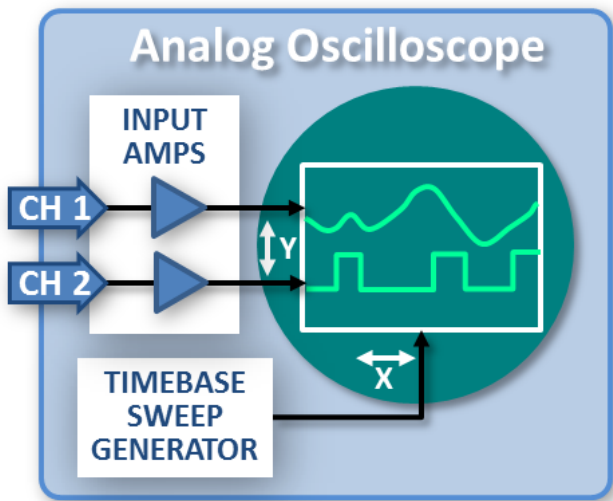## TABLE OF CONTENTS

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.

Teensy Graphics Interface

Blanking Driver

DIGITAL IN/OUT — *(PIO Output)*

'LS14

Z-AXIS *(Blanking)*

TEENSY 3.6

PROG MEM (1024 K)

COUNTER TIMERS

CPU (32 Bit, 240 MHz)

ANALOG OUT (PWM)

DATA RAM (512 K)

ANALOG IN

DMA CONTROLLER

DAC 0

DAC 1

DAC Buffer-Amps

X-AXIS

Y-AXIS

Each Op-Amp channel has GAIN & POSITION adjustments

X-Y Display Screen
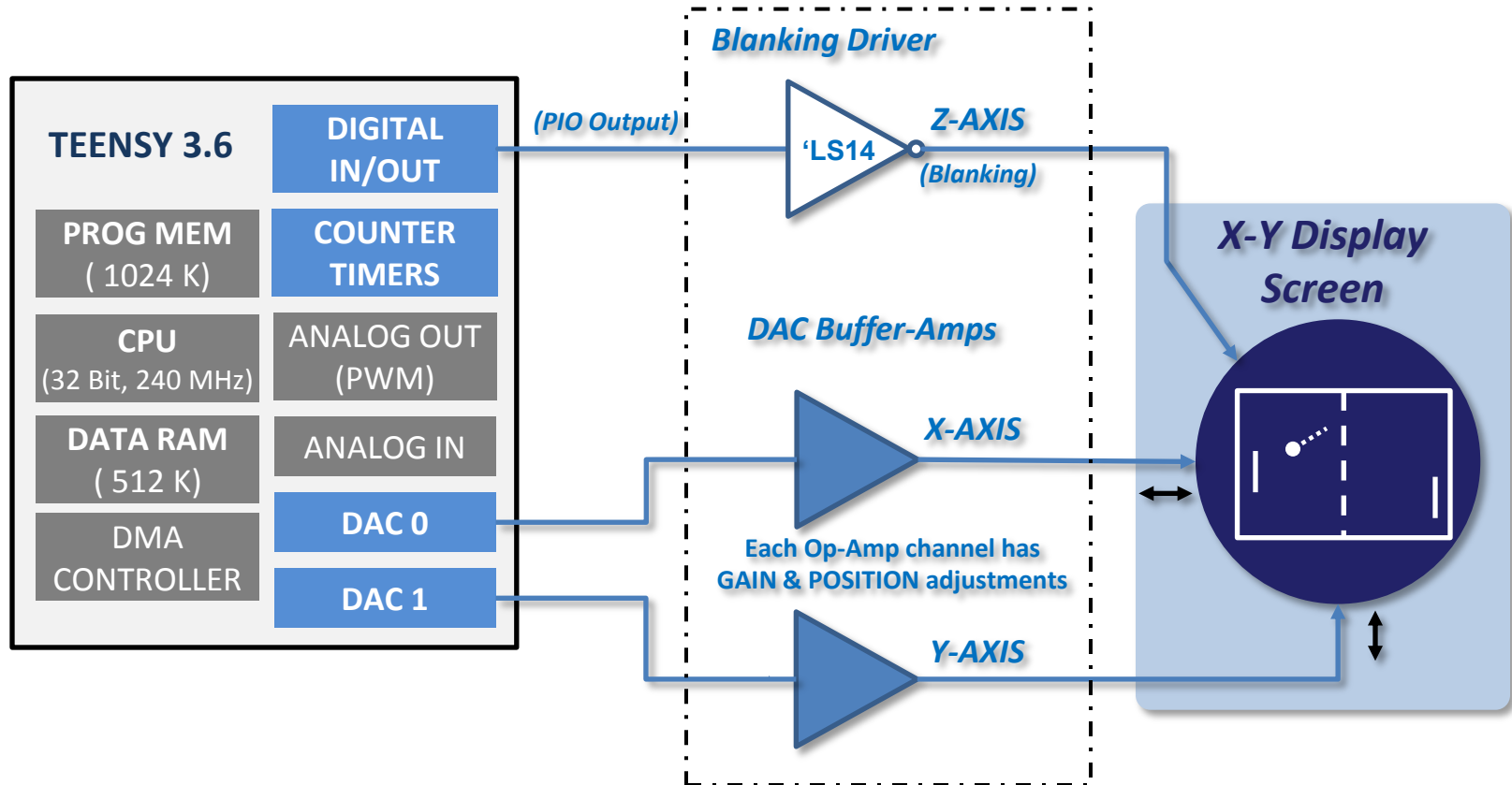
Parts List – TGI Project

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.

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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
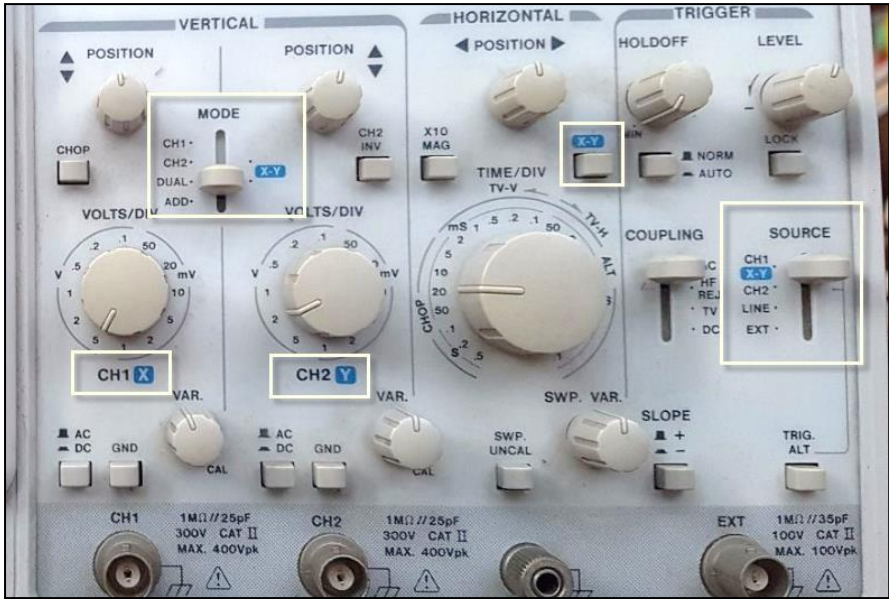
Typical Scope Rear Panel View showing Z-AXIS INPUT connector

Parts List – TGI PCB Parts List

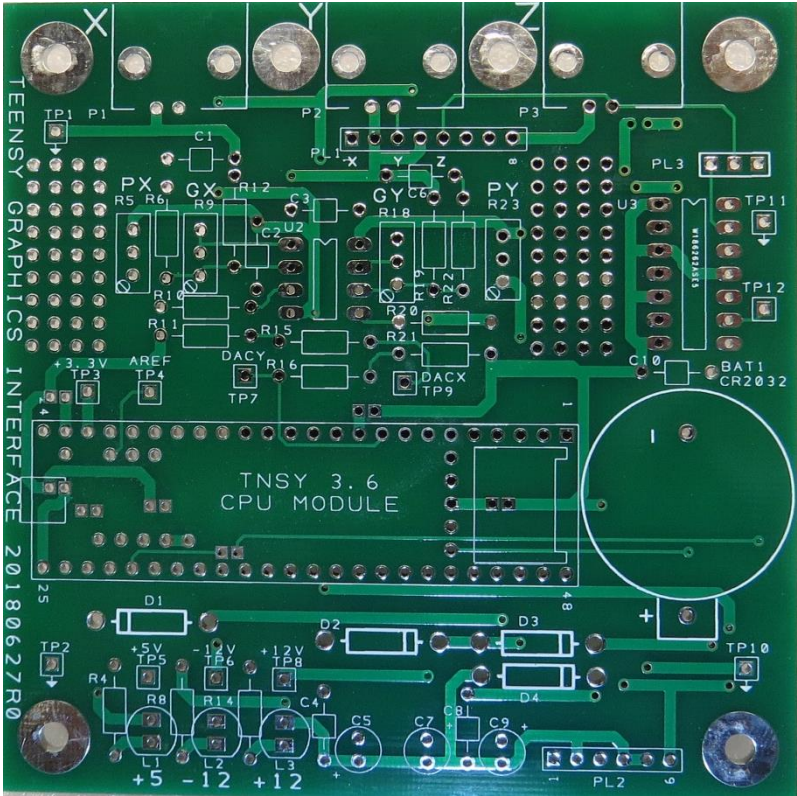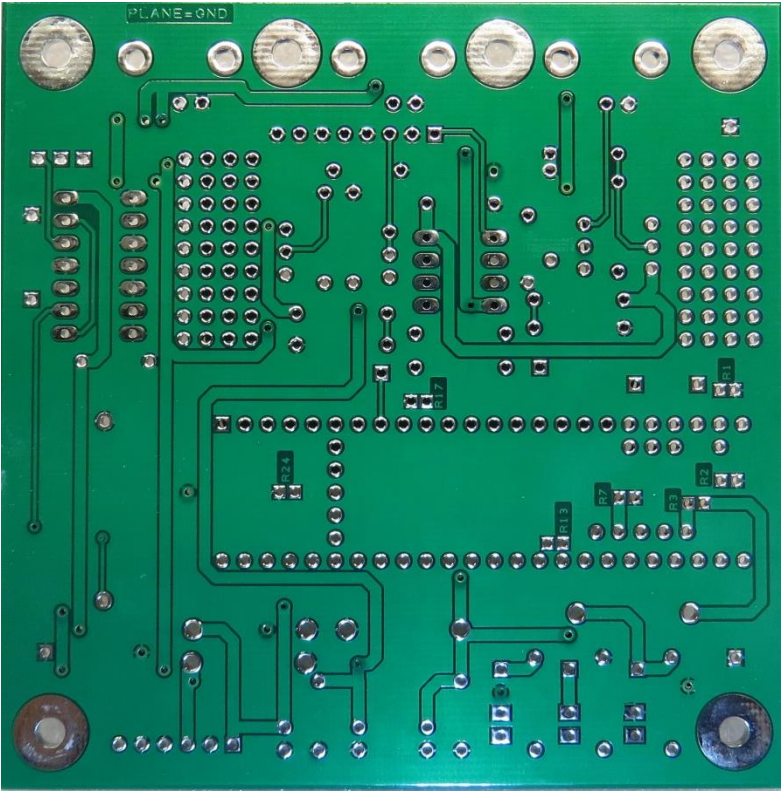| Item #	Ref Designators	QTY	DESCRIPTION	Value	Sourcing Info (DK = Digikey PN Part Num)
1	R24,R3,R7,R17,R1, R2,R13	7	USE JUMPER WIRE - SEE BUILD DOC FOR PLACEMENT & OPTIONS	0_ohm	N/A
2	TP11,TP10,TP2,TP1, TP7,TP9,TP12,TP6, TP8,TP5,TP3,TP4	12	1 PIN .025" SQ. MALE TEST POINT	FOR TEST USE ONLY. CAN USE SHORT 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

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Bare Printed Circuit Board – Rev 0

TOP SIDE VIEW

BOTTOM SIDE VIEW

TGI PCB Dimensions

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Clean, Low noise +/- 12V Power Req'd

DC POWER INPUT

PL2
+5V
GND
+12V
GND
0V
-12V

+/-12V Reversed Power Protect (Note 2)

D4 1N4004
D2 1N4004
Omit D2,D4 (Not Reqd)

+12V
C7 47uf
C8 .1uf
C4 .1uf
C5
47uf

R14 4.7K
L3
+12V_ON
R8 4.7K
L2
-12V_ON

+5V Reversed Power Protect (Note 2)
C9 47uf
D3 1N4004
Omit D3 (Not Reqd)

R4 4.7K
L1
+5V_ON
0V
+5V

See PAGE 2 for D1 Polarity Notes.

POWER SUPPLY TEST POINTS
TP3 +3.3V   TP5 +5V   TP6 -12V   TP8 +12V
+3.3V   +5V   -12V   +12V

GROUND TEST POINTS
TP1 TP2 TP11 TP10
0V

CPU POWER CONNECTIONS
+5V (CPU PWR)
R3 (CFG)   0_ohm
Omit R3 Jumper
FORWARD
D1 1N4004 (CFG)
REVERSE

Add Jumper Wire →

DAC1(Y-AXIS)
DAC0(X-AXIS)

R7 (CFG) 0_ohm
0V

TNSY_3.6 CPU MODULE U1

A14/D33
A15/D34
A16/D35
A17/D36
A17/D36
A19/D38
A20/D39
DAC0/A21
DAC1/A22
GND
BCK0/D13
A0/D14
A1/D15
A2/D16
A3/D17
A4/D18
A5/D19
A6/D20
A7/D21
A8/D22
A9/D23
3.3V
ANLG_GND
Vin
RESET
PROGRM
GND
3.3V
V-BAT
A11
A10
REF

TX4/D32
RX4/D31
D30
D29
D28
D27
D26
D25
D24
3.3V
MISO0/D12
MOSI0/D11
TX2/D10
RX2/D9
TX3/D8
RX3/D7
D6
D5
CAN0TX/D4
CAN0TX/D3
D2
D1/TX1/MISO1
D0/TX1/MOSI1
GND

R17 (CFG) 0_ohm
0V

R1 (CFG) 0_ohm
0V

+3.3V

TP12 CPU_UNBLANK

R13 (CFG) 0_ohm
0V

R24 (CFG)
BAT1
TP4 A-REF
R2 (CFG) 0_ohm
0V

MULTI-TURN POT (TOP VIEW)
← CW

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

X-BUFFER-AMP
Gain Adj. (G=.3 to 10)

+12V
PX R5 10K
X-AXIS Position Adj
R6 10K
-12V   0V
Omit C1 C1 .1uf
R12 4.7K
GX R9 100K

+12V
0V
V+ IN- IN+ V-
U2a CA3240
C3 .1uf
0V
OUT

TP9 DAC0(X-AXIS)
(Note 1)
R15 10K
+12V
Omit R10 R10
R11 4.7K
-12V
C2 .1uf
0V

P1 X-AXIS DRIVE Positive V=RIGHT on Display

PL1 is OPTIONAL and only required when OFF-BOARD Chassis Mount BNC Connectors are used.

PL1
1 X-DRIVE
2 GND
3 Y-DRIVE
4 GND
5 Z-DRIVE
6 GND
7
8 GND
0V

Y-BUFFER-AMP
Gain Adj. (G=.3 to 10)

+12V
PY R23 10K
Y-AXIS Position Adj
R22 10K
-12V   0V
Omit C6 C6 .1uf
R19 4.7K
GY R18 100K

0V
IN- IN+
U2b CA3240
OUT

TP7 DAC1(Y-AXIS)
(Note 1)
R16 10K
+12V
Omit R24 R20
R21 4.7K
0V

P2 Y-AXIS DRIVE Positive V=UP on Display

Z-DRIVE POLARITY JUMPER
+ -
1-2 2-3
PL3
P3 Z-DRIVE

PL3 (+) Jumper 1-2 LOW=Blank HIGH=Unblank
PL3 (-) Jumper 2-3 LOW=Unblank HIGH=Blank
See XYscopeConfig.h file for additional polarity settings.

UNBLANK DRIVER
+5V
C10 .1uf
0V
A U3d
A U3f
UNBLANK_CRT
0V
N_UNBLANK_CRT

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.

UNUSED GATES
A U3a
A U3b
A U3b
A U3a

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	Drawing No. AMC Consulting Brookfield, WI USA
Drn	Drn	Drn	Drn	First Made For AGI GRAPHICS INTER'FC				
Chk	Chk	Chk	Chk	PN:20180627R0 (PCB)			SEE LAST PAGE FOR REVISON HISTORY	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).
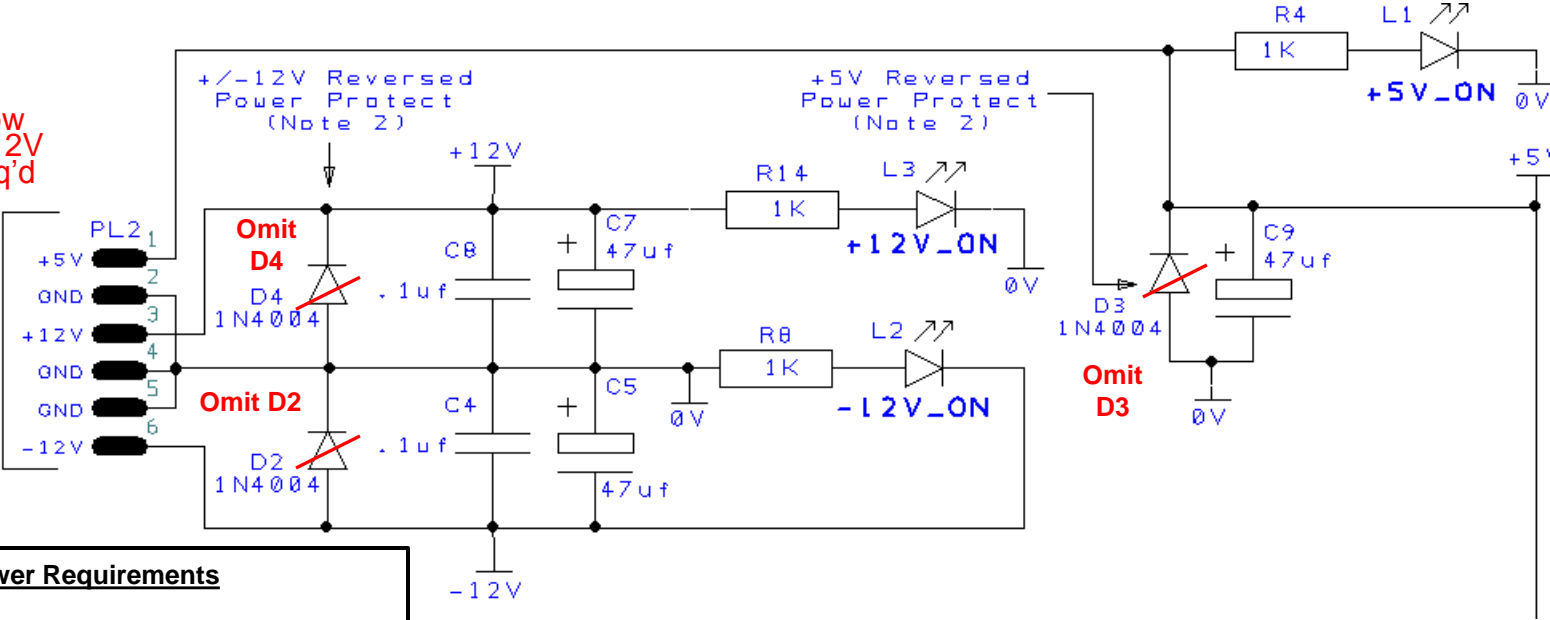
Schematic Details – PG 1

PAGE 1: POWER SUPPLY CIRCUITS

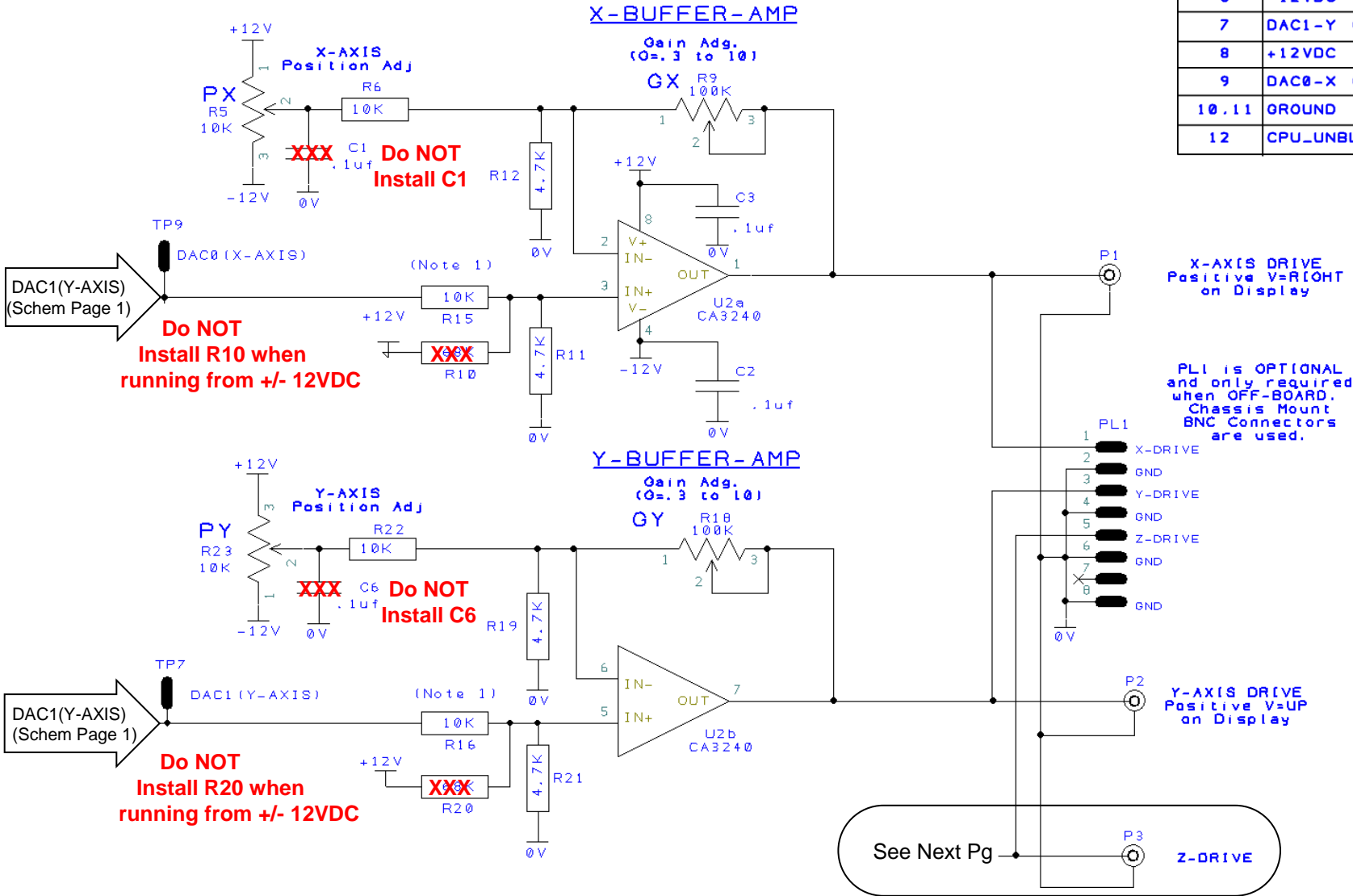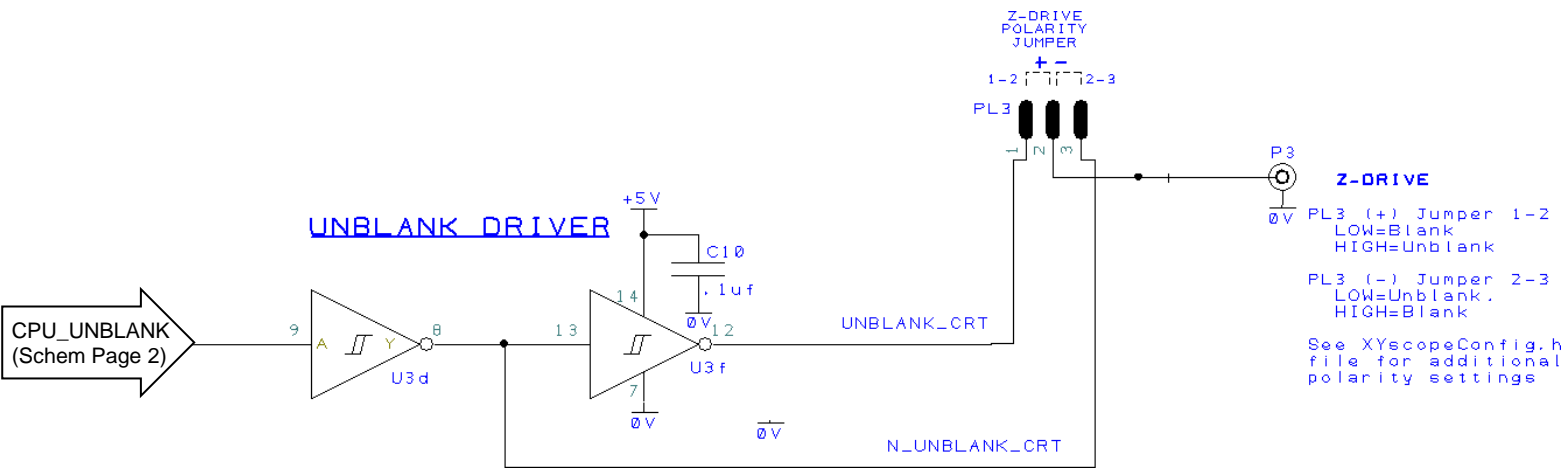| TEST POINT SUMMARY	
1.2	GROUND
3	+3.3VDC
4	A-REF
5	+5VDC
6	-12VDC
7	DAC1-Y (at CPU)
8	+12VDC
9	DAC0-X (at CPU)
10.11	GROUND
12	CPU_UNBLANK

Clean, Low noise +/- 12V Power Req'd

+/-12V Reversed Power Protect (Note 2)

+5V Reversed Power Protect (Note 2)

R4 1K L1 +5V_ON 0V

+5V

+12V

Omit D4 D4 1N4004 C8 .1uf C7 47uf R14 1K L3 +12V_ON 0V

DC POWER INPUT

PL2
1 +5V
2 GND
3 +12V
4 GND
5 GND
6 -12V

Omit D2 D2 1N4004 C4 .1uf C5 47uf R8 1K L2 -12V_ON 0V

D3 1N4004 Omit D3 C9 47uf 0V

-12V

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.

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PAGE 2: DATA CLOCK TIMING AND BLANKING SYNCHRONIZATION
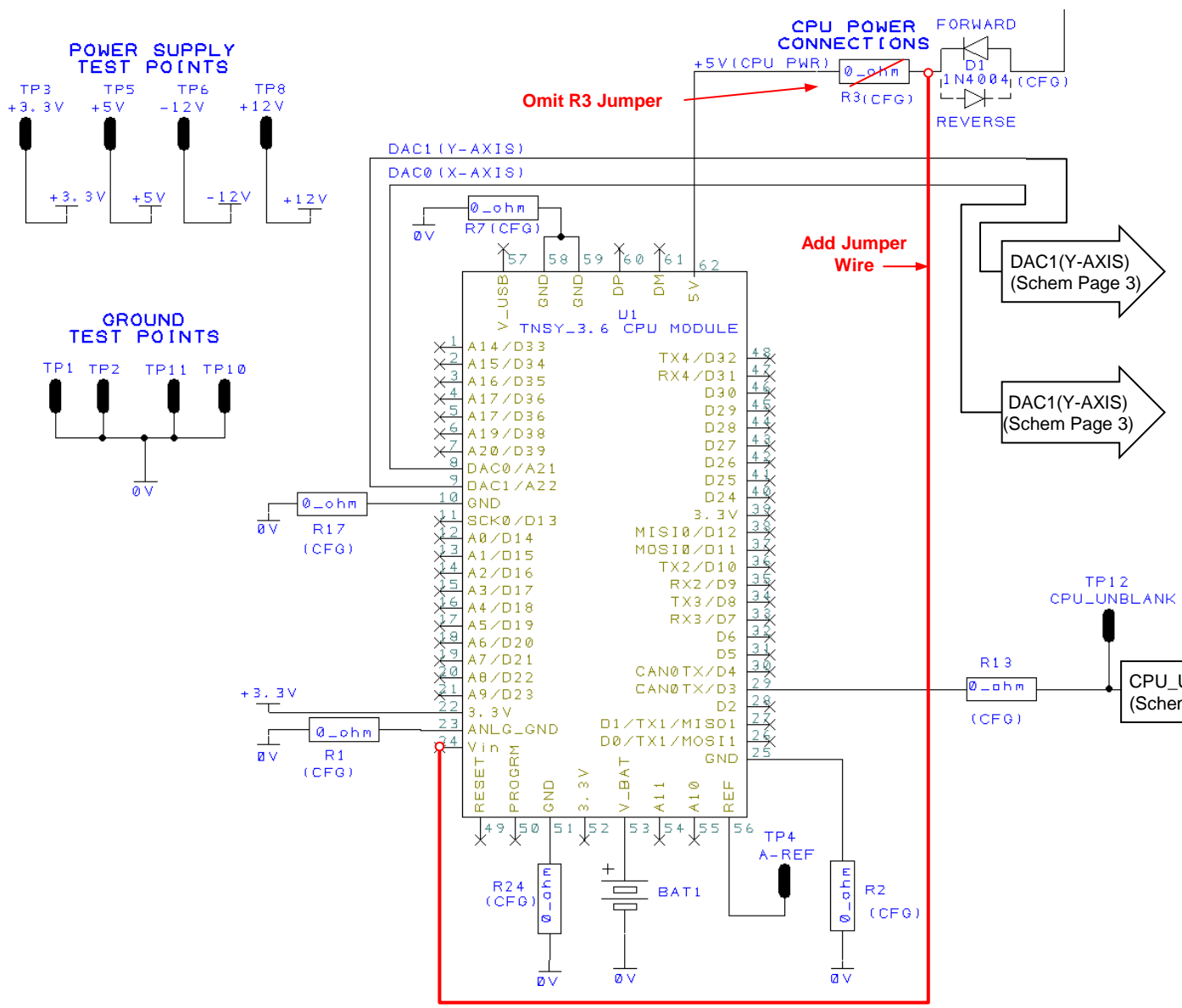
DIODE D1 INSTALLATION NOTES
- There are two installation options for D1 depending on how the TEENSY and TGI are to be powered.

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 silkscreen).

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

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Schematic Details – PG 3

PAGE 3: X-Y ANALOG BUFFER-AMPLIFIERS

X-BUFFER-AMP
Gain Adg.
(G=.3 to 10)

+12V

X-AXIS
Position Adj

PX
R5
10K

R6
10K

GX R9
100K

XXX C1 **Do NOT**
.1uf **Install C1**

-12V   0V

+12V

C3
.1uf

0V

R12
4.7K

TP9

DAC0(X-AXIS)

0V

2
V+
IN-

8

OUT   1

Do NOT
Install R10 when
running from +/- 12VDC

DAC1(Y-AXIS)
(Schem Page 1)

(Note 1)

10K
R15

3
IN+
V-

U2a
CA3240

+12V

4

-12V

C2
.1uf

0V

XXX
R10

4.7K R11

0V

P1

X-AXIS DRIVE
Positive V=RIGHT
on Display

PL1 is OPTIONAL
and only required
when OFF-BOARD.
Chassis Mount
BNC Connectors
are used.

PL1

1
2 X-DRIVE
3 GND
4 Y-DRIVE
5 GND
6 Z-DRIVE
7 GND
8
GND

0V

Y-BUFFER-AMP
Gain Adg.
(G=.3 to 10)

+12V

Y-AXIS
Position Adj

PY
R23
10K

R22
10K

GY R18
100K

XXX C6 **Do NOT**
.1uf **Install C6**

-12V   0V

R19
4.7K

0V

TP7

DAC1(Y-AXIS)

1

3

2

6
IN-

5
IN+

OUT   7

U2b
CA3240

Do NOT
Install R20 when
running from +/- 12VDC

DAC1(Y-AXIS)
(Schem Page 1)

(Note 1)

10K
R16

+12V

XXX
R20

4.7K R21

0V

P2

Y-AXIS DRIVE
Positive V=UP
on Display

See Next Pg

P3

Z-DRIVE

Schematic Details – PG 4

PAGE 4: Z-AXIS DRIVER

Z-DRIVE
POLARITY
JUMPER

+ –

1-2 2-3

PL3

P3

Z-DRIVE

UNBLANK DRIVER

+5V

C10
.1uf

0V

CPU_UNBLANK
(Schem Page 2)

9

A   Y

8

U3d

13

14

12

0V

7

0V

U3f

UNBLANK_CRT

N_UNBLANK_CRT

0V

PL3 (+) Jumper 1-2
    LOW=Blank
    HIGH=Unblank

PL3 (-) Jumper 2-3
    LOW=Unblank.
    HIGH=Blank

See XYscopeConfig.h
file for additional
polarity settings

TGI Assembly Overview & Connectors

PL3 BLANKING POLARITY

NEG   POS

PX X-Position

GX X-Gain

PY Y-Position

GY Y-Gain

CR2032 Battery

PL2 6 X 1 PIN SIP POWER SUPPLY CONNECTOR

1   6

-12VDC
GND
GND
+12VDC
GND
+5VDC
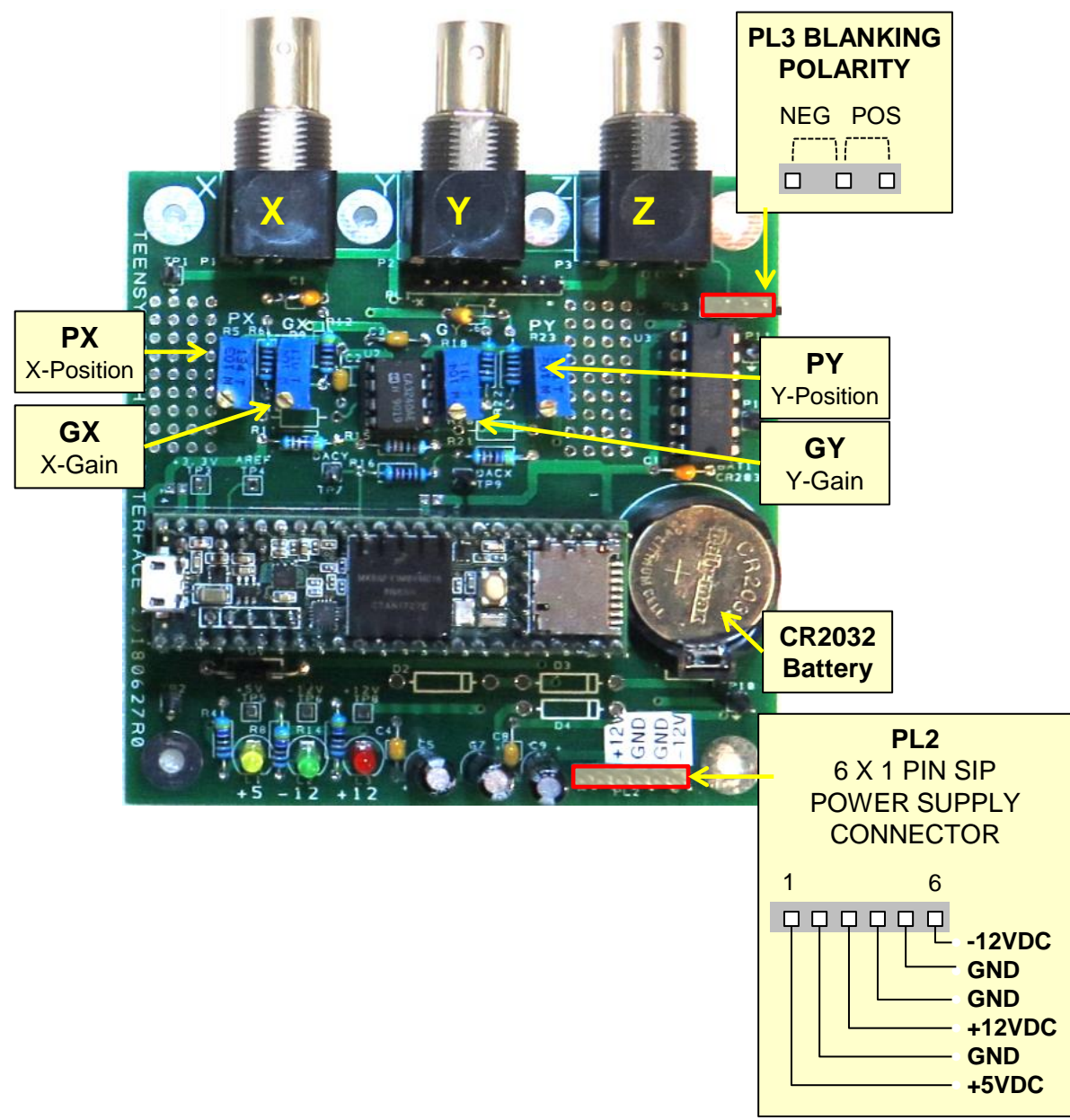
Load Parts: .1uf Capacitors, 1N4004 Diode

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
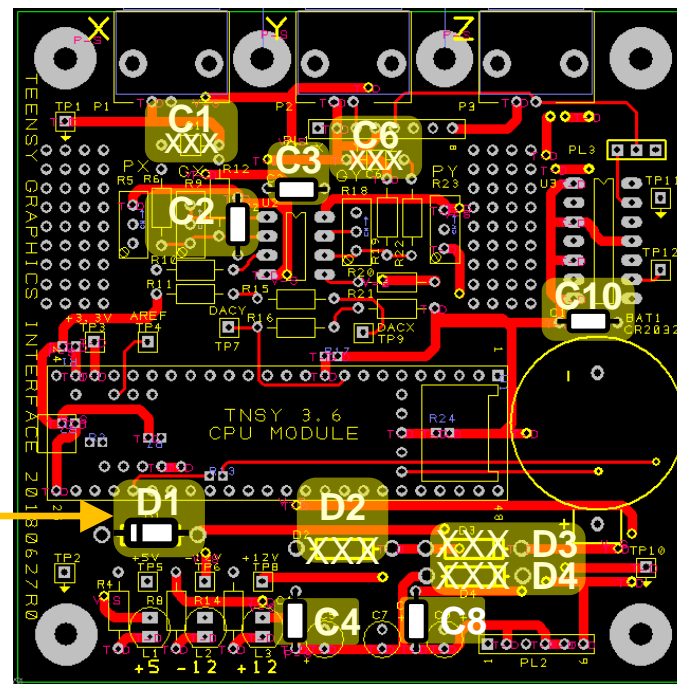
5 ← **D2,3,4 NOT REQ'D**

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.

THIS DOCUMENT CONTAINS PROJECT SPECIFIC DOCUMENTATION	First Made For	Filename	Revision	2	Page
Made by: E. Andrews Date: 7-16-2018	Arduino Teensy Graphics Interface	20180627R0 BUILD DOC (Rev 2 TEENSY).pptx	Printed 10/19/2018 16:27		

AMC
Brookfield, WI USA

Load Parts: Resistors, Test Points

INSTALL FIXED RESISTORS

Ref Name	Qty	Value	
R10	~~1~~	~~68K~~	← **XXX** - *DO NOT INSTALL!*
R15	1	10K	
R16	1	10K	②
R20	~~1~~	~~68K~~	← **XXX** - *DO NOT INSTALL!*
R22	1	10K	
R6	1	10K	②
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
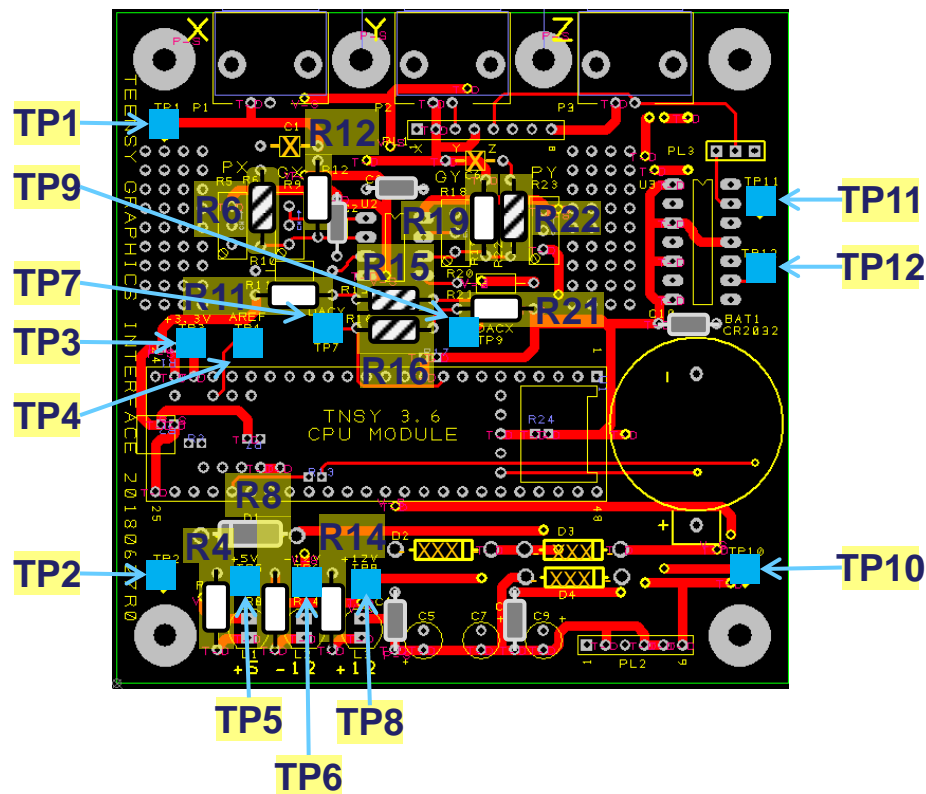
INSTALL BAT. HOLDER, ELECTROLYTIC CAPS, LEDs

Ref Name	Qty	Value	
BAT1	1	BATTERY HOLDER	←Note Orientation
C5	1		
C7	1	10uf/50V ③	←Observe Polarity!
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
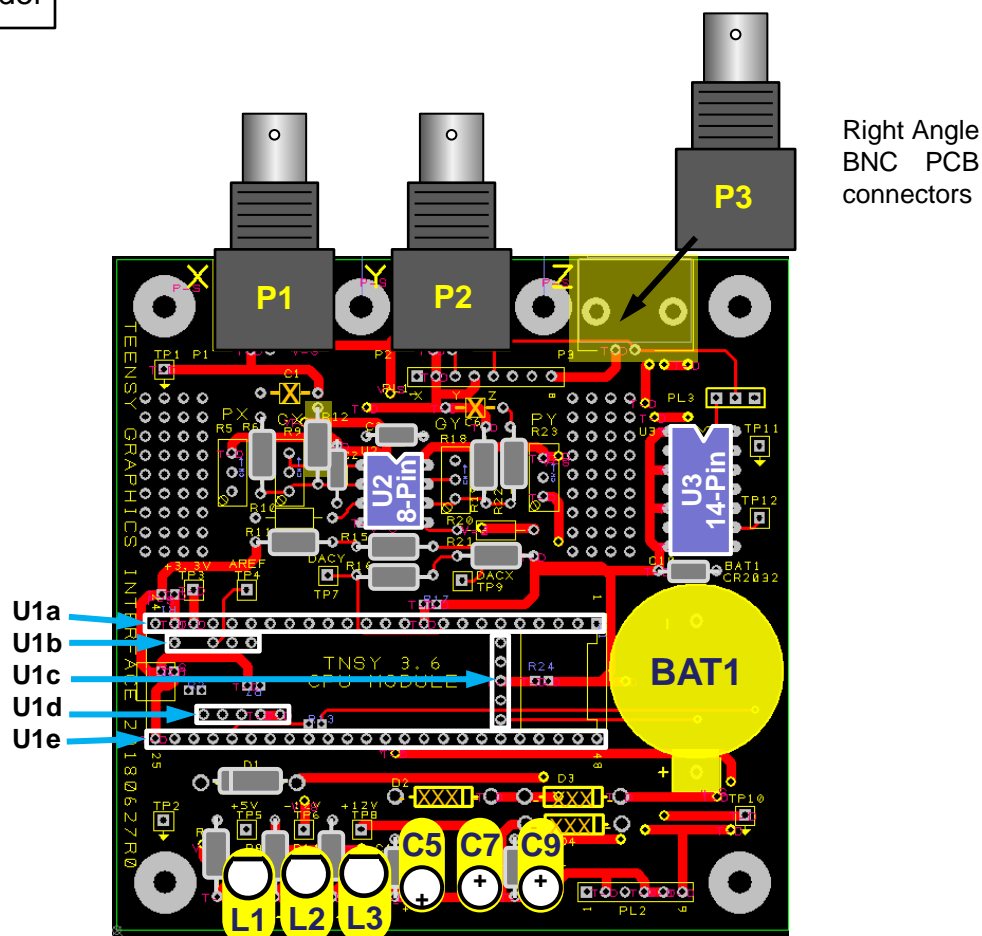
LED NOTES:
1. *Any color (Builders Choice) 3mm x .1" Lead Space LEDs may be used.*
2. *LED L1, L2, L3 silk screen pattern on Rev 0 PCB is <u>incorrect</u>. – Install with orientation shown in this diagram!*

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.

	First Made For	Filename	Revision	2	Page
THIS DOCUMENT CONTAINS PROJECT SPECIFIC DOCUMENTATION	Arduino Teensy Graphics Interface	20180627R0 BUILD DOC (Rev 2 TEENSY).pptx	Printed 10/19/20 16:27	7	19
Made by: E. Andrews Date: 7-16-2018					

AMC
Brookfield, WI USA
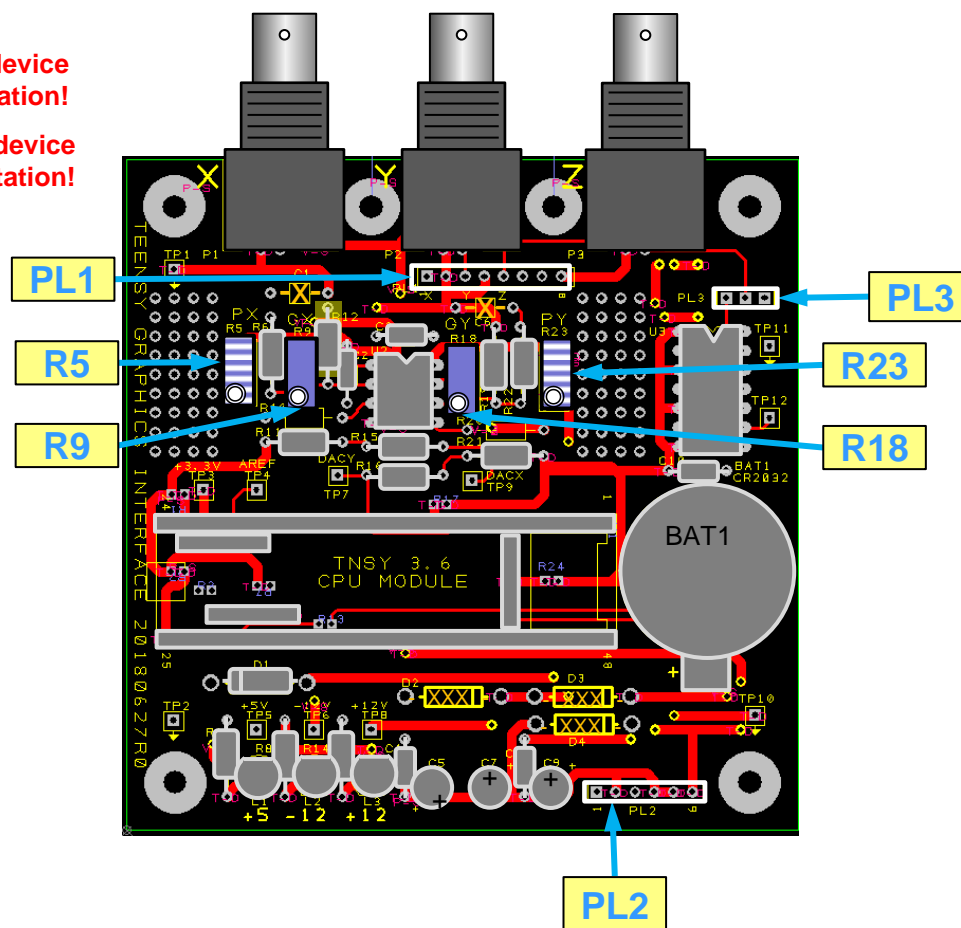
Install Jumper Wires

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

Place '0_OHM' solder blob across back side resistor-pads where directed
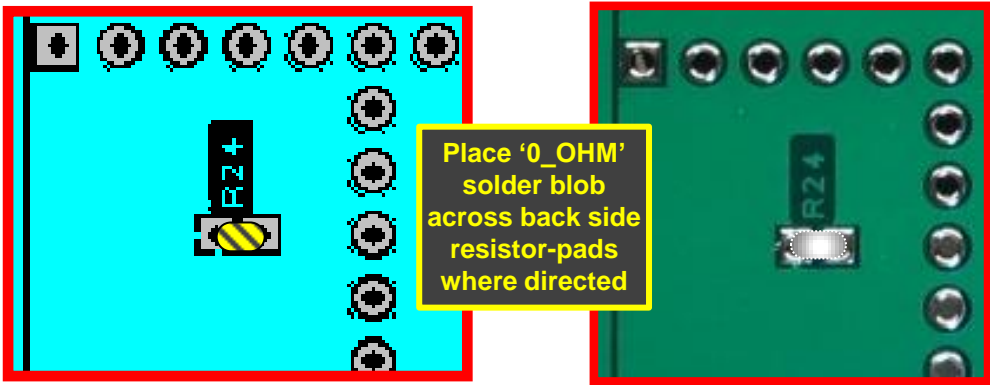
REAR VIEW
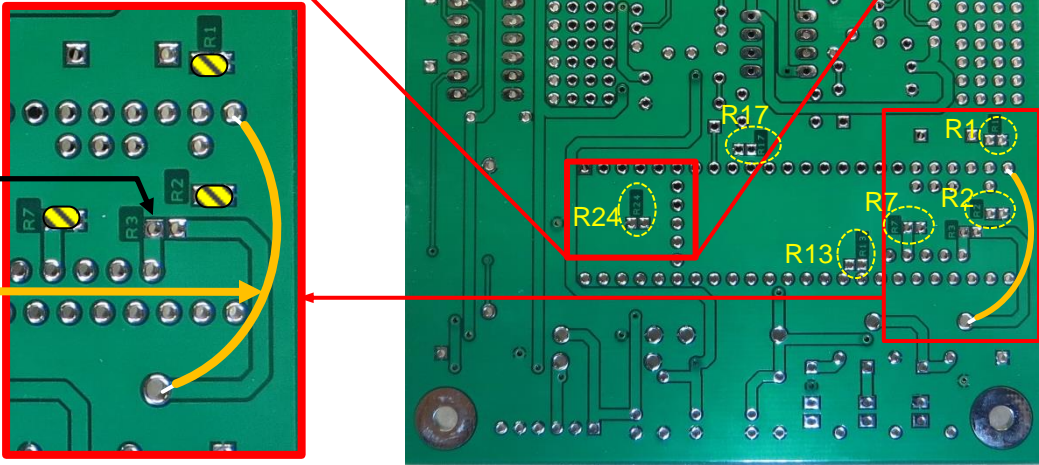
Prepare Teensy 3.6 CPU for Installation

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".

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

Short Pins   **Long Pins**

SIDE VIEW

Nominal Overall
Length: 11 mm

Nominal Overall
Length: 20 mm

Teensy 3.6 with "Long" pin style installed

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 underlined top side of the TEENSY.

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 1 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 25 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, +12, -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!

PL2
6 X 1 PIN SIP
POWER SUPPLY
CONNECTOR

1   6

- -12VDC
- GND
- GND
- +12VDC
- GND
- +5VDC
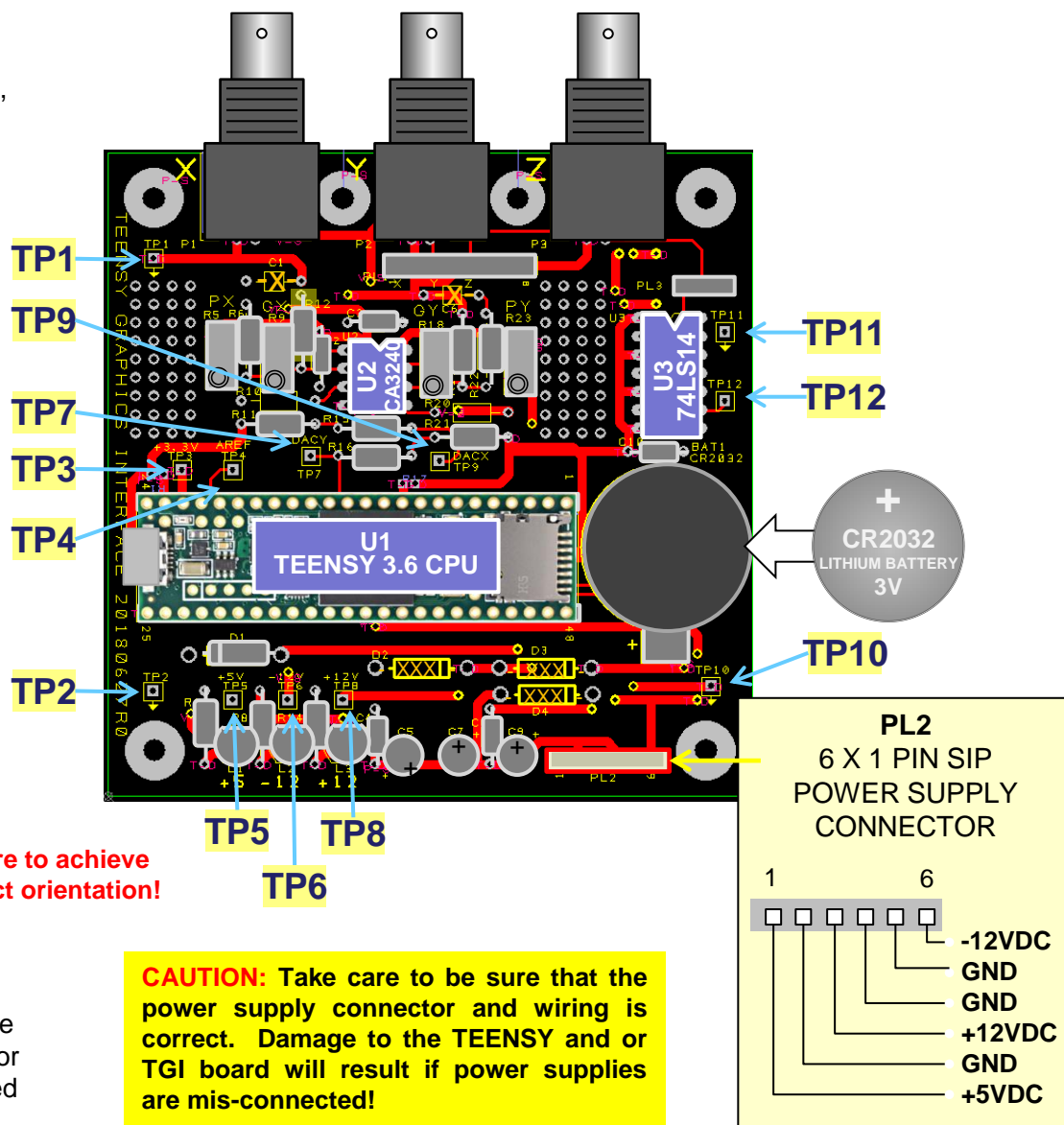
Power, Blanking Select & O'scope Wiring

Z-Input
(Typically on Back Panel)

X-Input *(Typically CH 1)*

Y-Input *(Typically CH 2)*
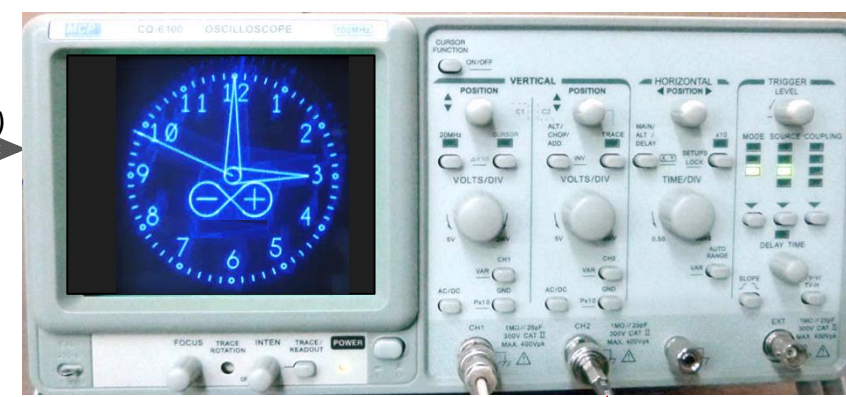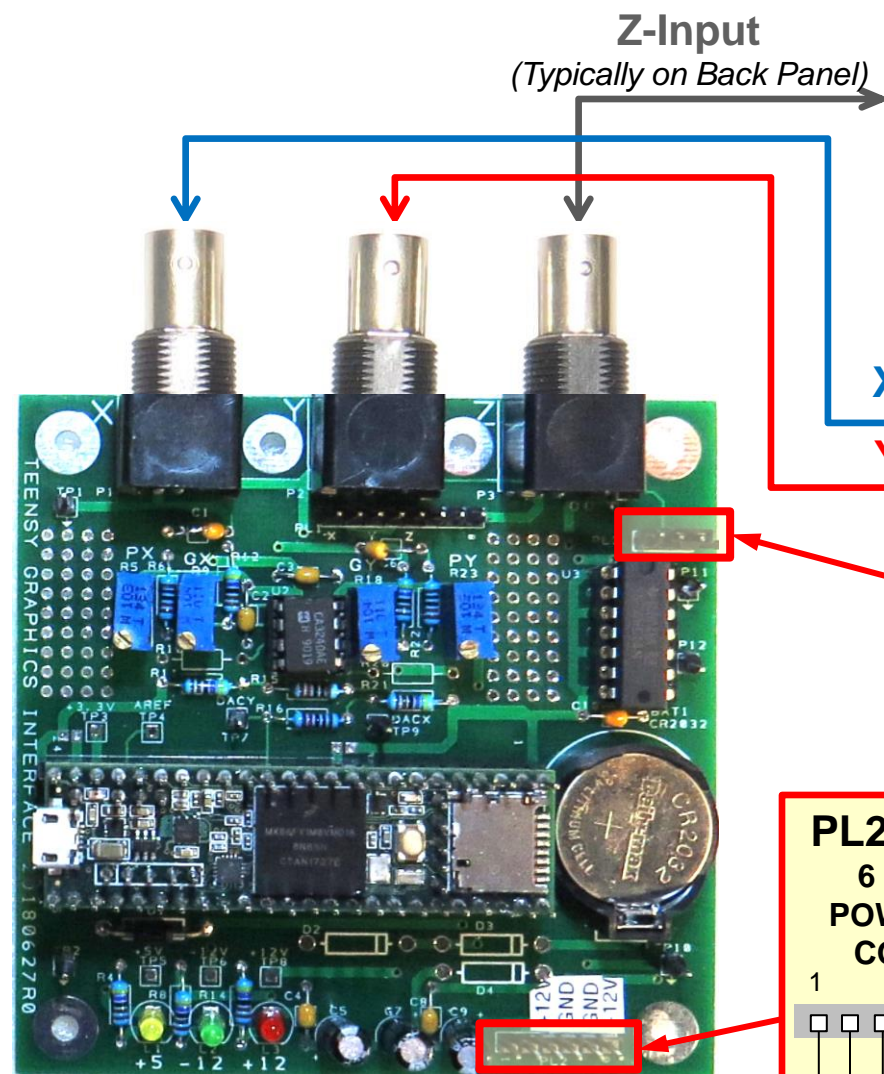
PL3 Blanking Select

3 2 1

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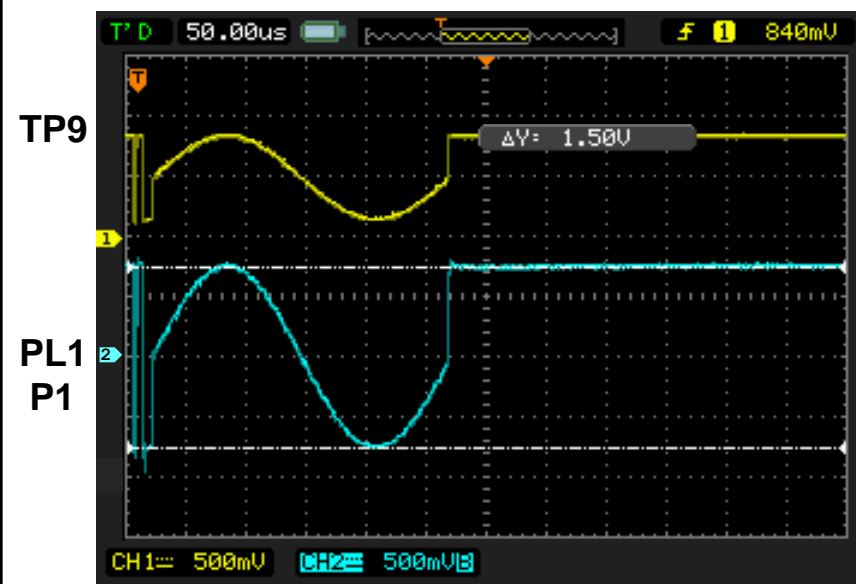Jumper position **1-2** for
Logic 1= UNBLANK

NEGATIVE Z-AXIS LOGIC
Jumper position **2-3** for
Logic 0 = UNBLANK
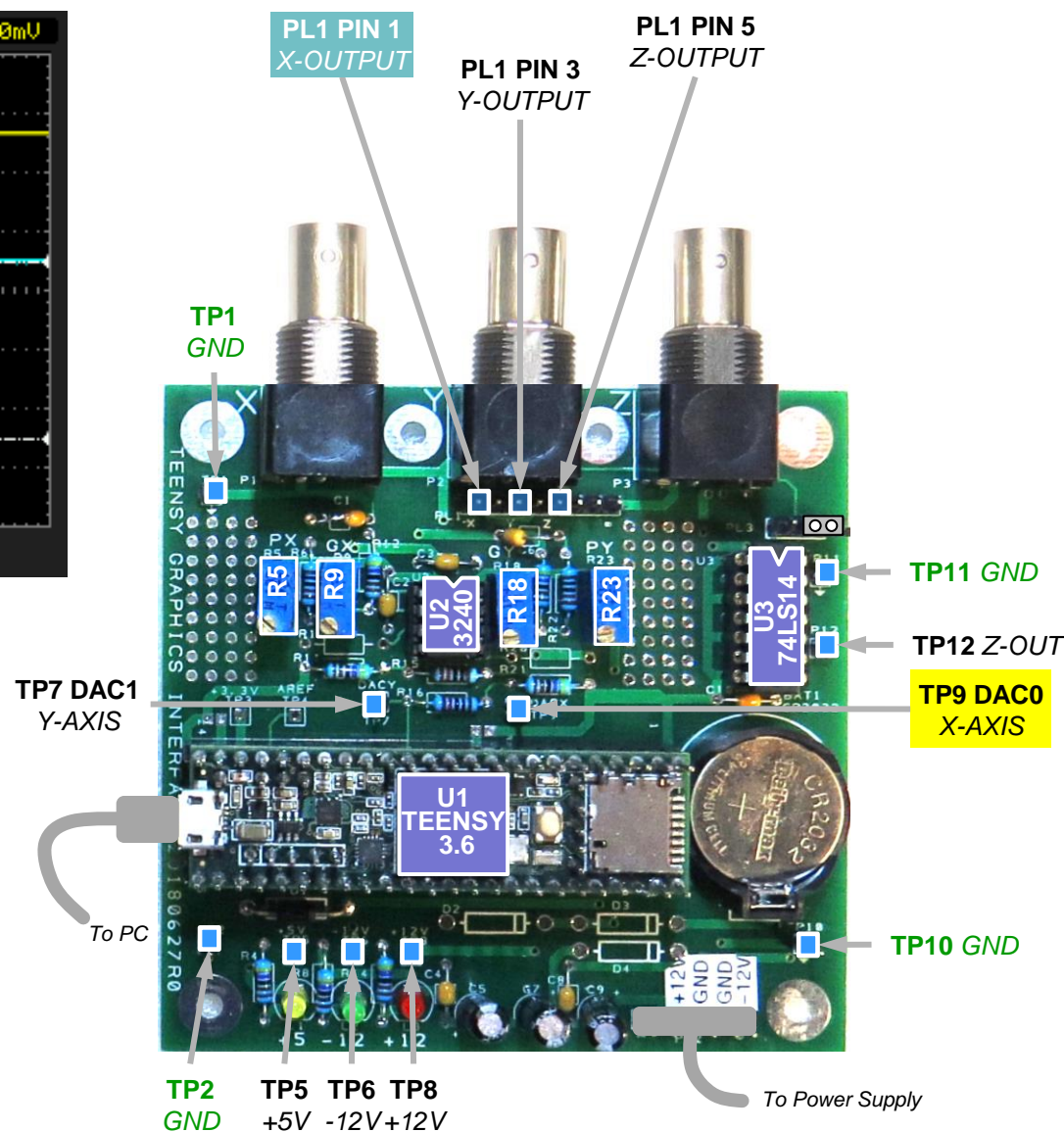
PL2 DC Power
**6 X 1 PIN SIP
POWER SUPPLY
CONNECTOR**

1   6

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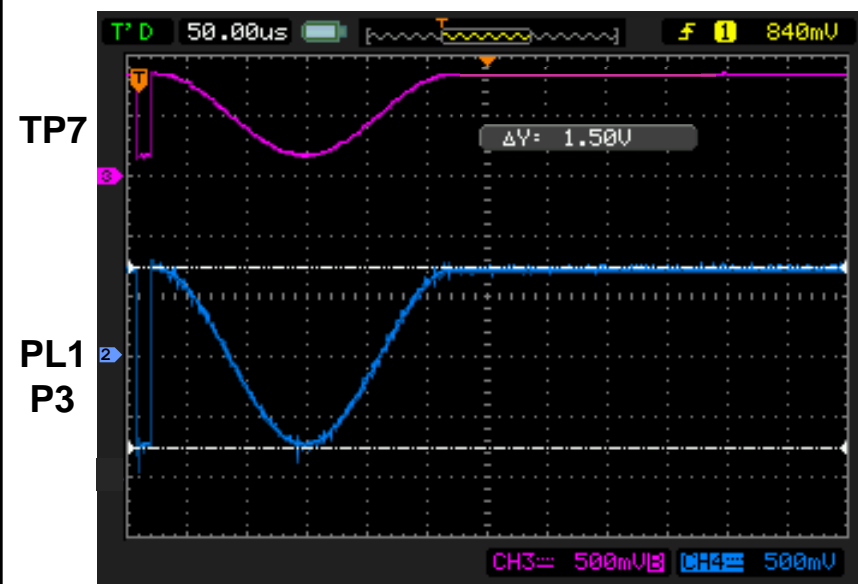GND
GND
+12VDC
GND
+5VDC

X-Axis Gain and Position Adjust

PL1 PIN 1 *X-OUTPUT*
PL1 PIN 3 *Y-OUTPUT*
PL1 PIN 5 *Z-OUTPUT*

TP1 *GND*

TP11 *GND*

TP12 *Z-OUT*

TP7 DAC1 *Y-AXIS*

TP9 DAC0 *X-AXIS*

TP10 *GND*

**TP2** *GND*
TP5 *+5V*
TP6 *-12V*
TP8 *+12V*

To PC

To Power Supply

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

TP7

PL1 P3

CH3⎓ 500mV🅑 CH4⎓ 500mV

PL1 PIN 1 *X-OUTPUT*
PL1 PIN 3 *Y-OUTPUT*
PL1 PIN 5 *Z-OUTPUT*

TP1 *GND*
TP11 *GND*
TP12 *Z-OUT*
TP7 DAC1 *Y-AXIS*
TP9 DAC0 *X-AXIS*

U1 TEENSY 3.6
U2 3240
U3 74LS14
R5 R9 R18 R23

To PC

TP10 *GND*
TP2 *GND*
TP5 *+5V*
TP6 *-12V*
TP8 *+12V*

To Power Supply

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
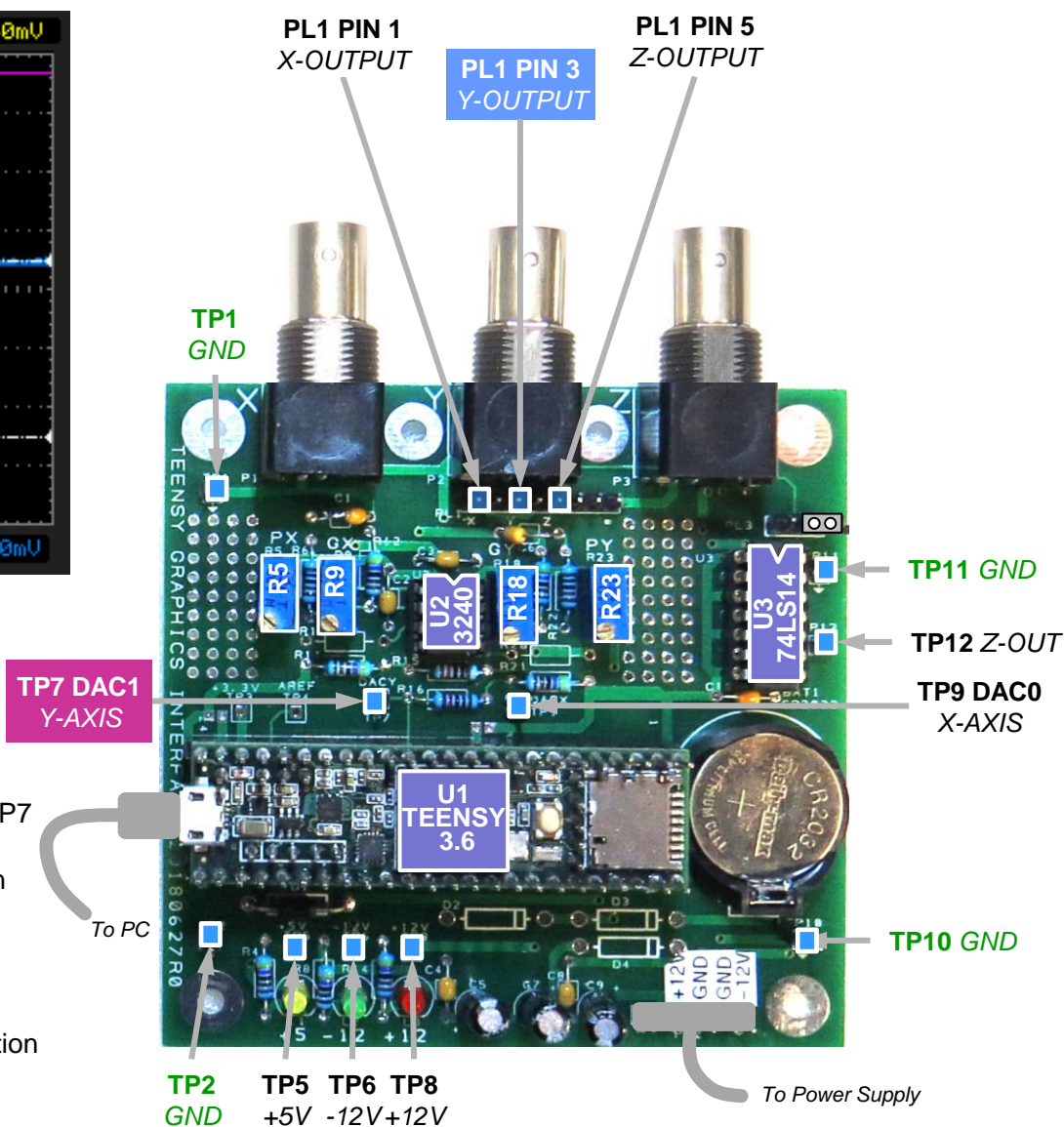
Display this HELP screen

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

```
========= 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)
===========================================
```

*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
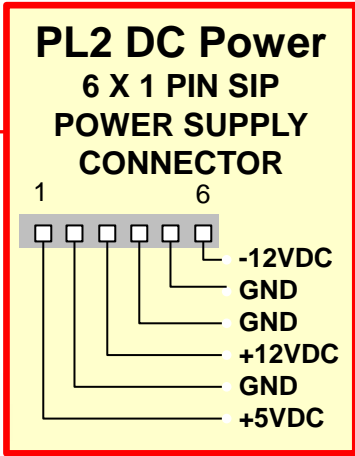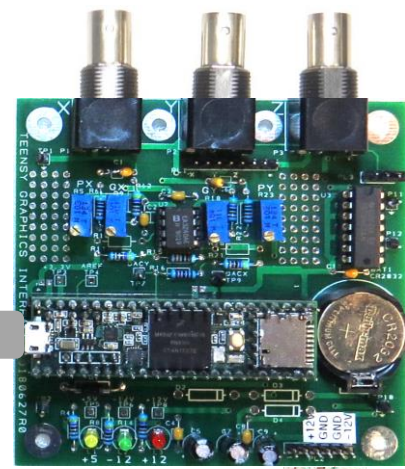
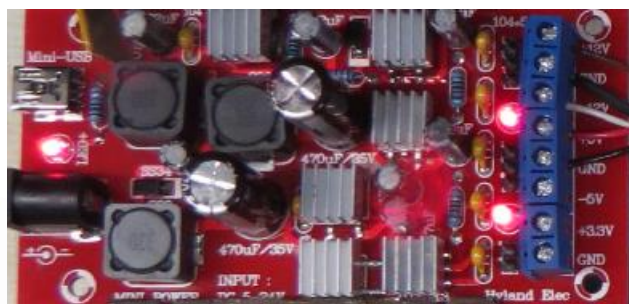| Ref Num	Issue Description	Severity	Status	Evaluation/Solution/Work-Around/Other Actions Taken
1	**TGI LED SILK SCREEN PATTERN ERROR** The top side silk screen patter for LEDs L1, L2, L3 are incorrect.	LOW	OPEN DATE: 20180618	**EVALUATION:** Pattern wrong in PCB library. **RECOMMENDATION:** Build per 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

+5VDC IN

Multi Output Supply
With Linear Output Regulators

See Next Page for Power Supply Kit Sourcing Suggestion

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

Arduino 5 VDC @ 1.5A
Power Supply

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!

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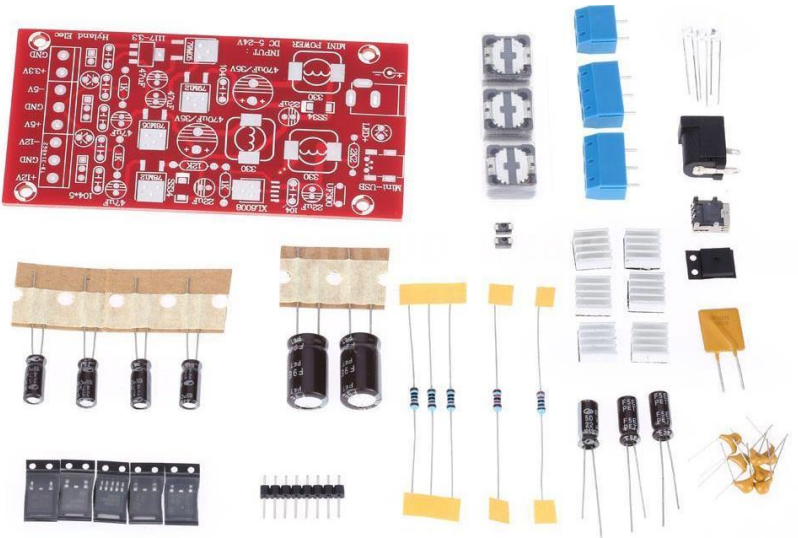
Specifications:
Input Voltage: 5-24V DC
Output Voltage: + 12V, -12V, + 5V, -5V , +3.3V.
Output Current: 300mA (per channel)
PCB Board Size: 98 * 50mm
Package Size: Approx. 11 * 8.5 * 1cm
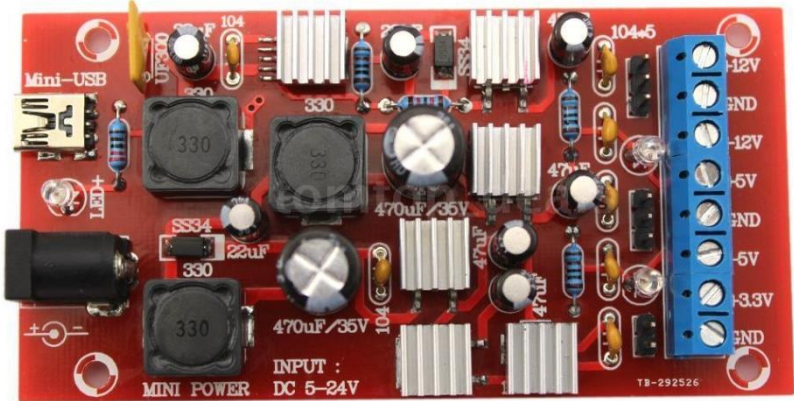Package Weight: 55g / 1.96oz

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

Price: $6.99 + $1.29 Shipping (from China)
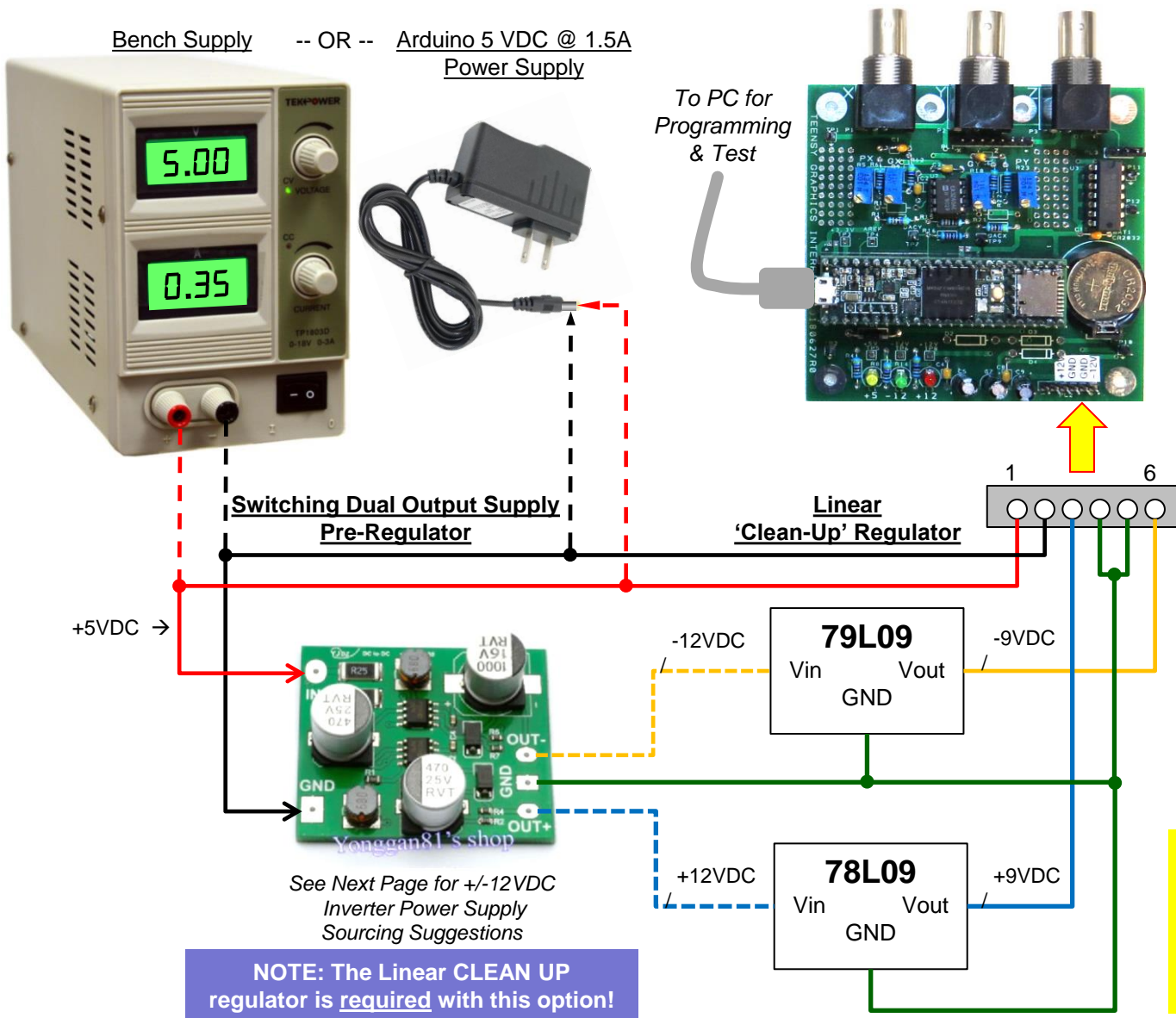
Comes as a Kit of Parts

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 underlined linear regulated voltage from +/- 9 VDC to +/- 12VDC

5.00

0.35

+5VDC →

Switching Dual Output Supply Pre-Regulator

Linear 'Clean-Up' Regulator

1   6

PL2 DC Power
6 X 1 PIN SIP POWER SUPPLY CONNECTOR

1   6

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

-12VDC

79L09

Vin   Vout

GND

-9VDC

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

+12VDC

78L09

Vin   Vout

GND

+9VDC

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!

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

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Made by: E. Andrews Date: 7-16-2018						

Appendix 3: Linear Regulators for Option 2

(TO-92)
Plastic Package (Z)

OUTPUT   INPUT

GND

DS007744-3

Bottom View

3 — INPUT
— GND
2

1

— OUTPUT

Fixed Output Regulator

INPUT ——— LM78LXX ——— OUTPUT

GND

C1*
0.33μF

C2**
0.01μF

DS007744-8
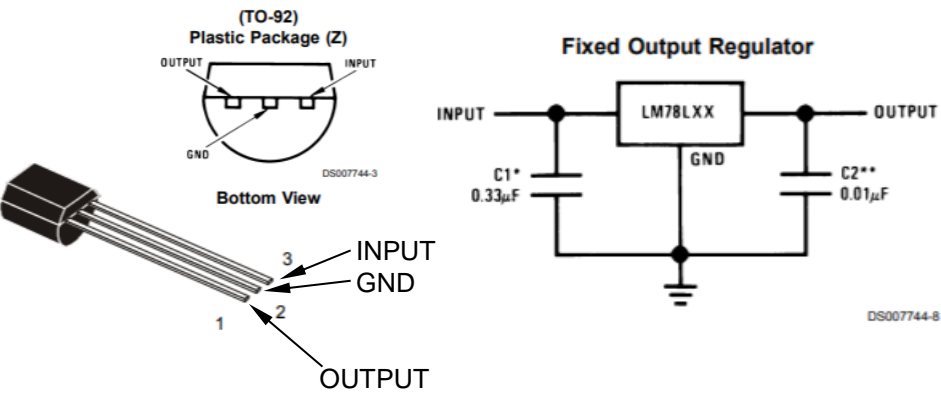
*Required if the regulator is located more than 3" from the power supply filter.
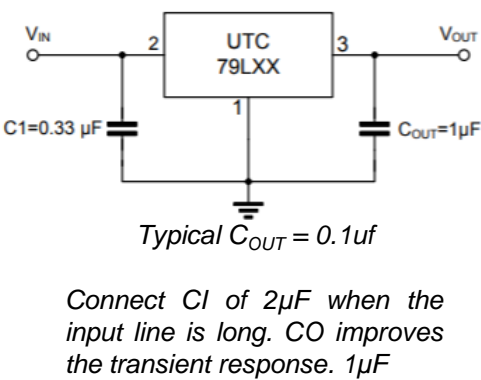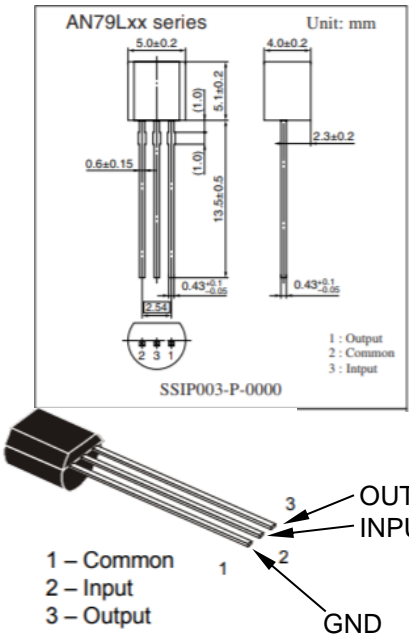***See (Note 4) in the electrical characteristics table.*

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	
		11.5V ≤ V_{IN} ≤ 24V 1 mA ≤ I_O ≤ 40 mA (Note 3)	8.55		9.45	V
		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	
ΔI_Q	Quiescent Current Change	11.5V ≤ V_{IN} ≤ 24V			1.5	mA
		1 mA ≤ I_O ≤ 40 mA			0.1	
V_n	Output Noise Voltage			70		μV
$\dfrac{\Delta V_{IN}}{\Delta V_{OUT}}$	Ripple Rejection	f = 120 Hz 15V ≤ V_{IN} ≤ 25V	38	44		dB
I_{PK}	Peak Output Current			140		mA
$\dfrac{\Delta V_O}{\Delta T}$	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

AN79Lxx series   Unit: mm

5.0±0.2   4.0±0.2

(1.0)   5.1±0.2   2.3±0.2

0.6±0.15

13.5±0.5 (1.0)

0.43 +0.1 −0.05   0.43 +0.1 −0.05

2.54

2 3 1

1 : Output
2 : Common
3 : Intput

SSIP003-P-0000

V_{IN} — 2 — UTC 79LXX — 3 — V_{OUT}

C1=0.33 μF   1 C_{OUT}=1μF

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

3 — OUTPUT
— INPUT
2

1

— GND

1 – Common
2 – Input
3 – Output

■ 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.

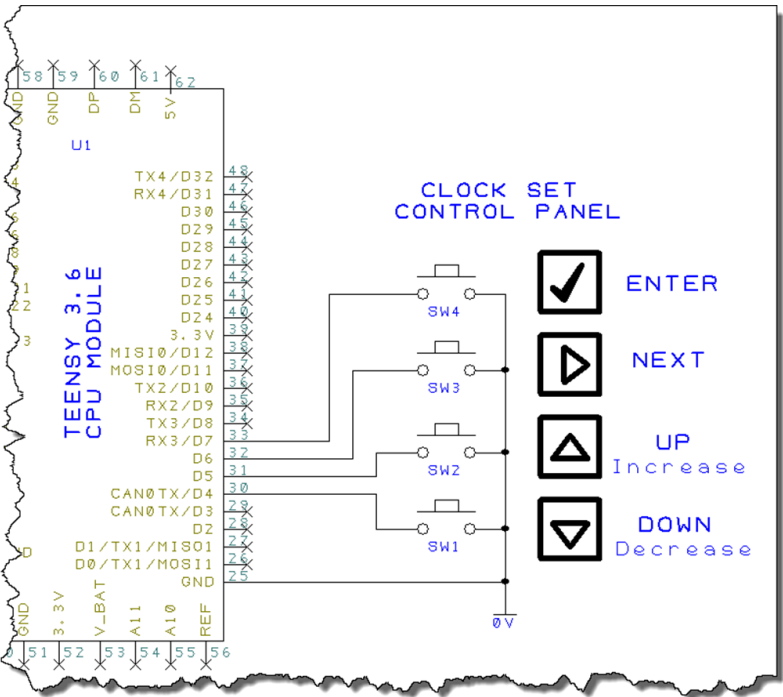Press and HOLD a UP/DOWN button to auto repeat (step) the value up or down.

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.

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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