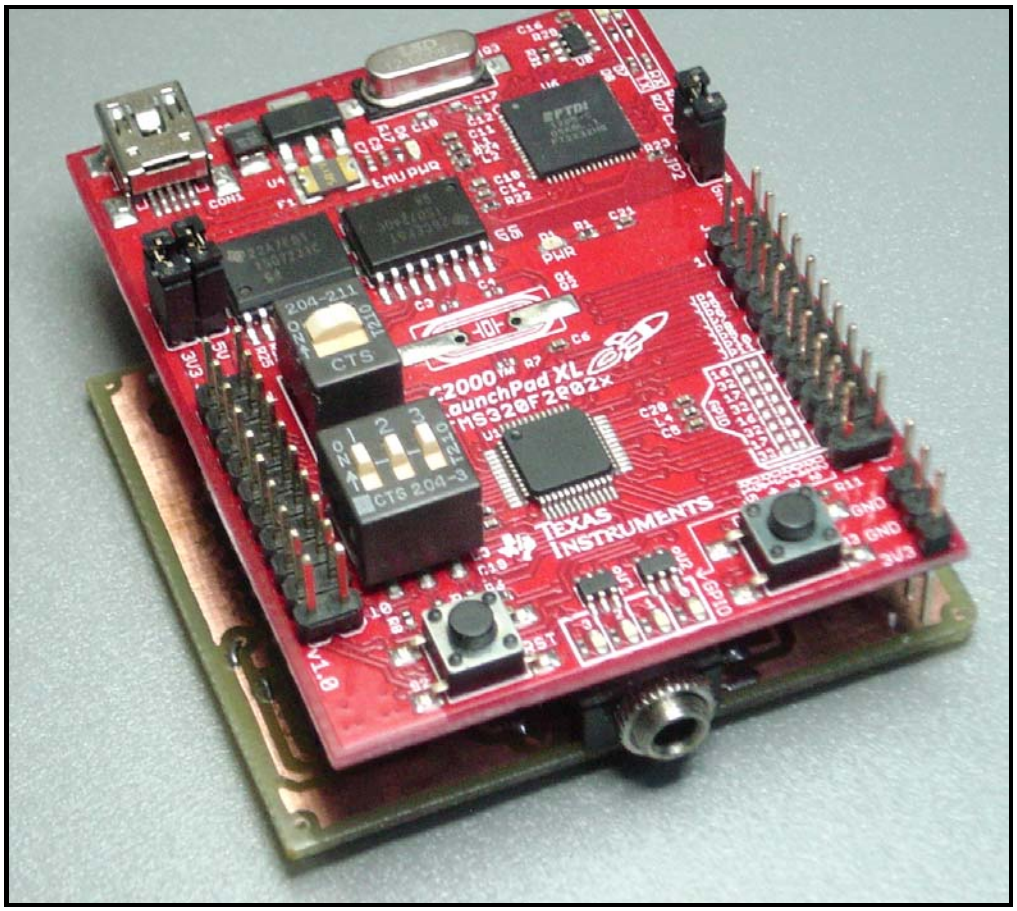
Oscilloscope Booster Pack for Texas Instruments C2000 Piccolo LaunchPad



Aj_Scope4

Technical Manual

www.ajoyraman.in

1. Introduction:

This is a brief manual containing relevant technical data required for understanding construction and use of the Aj_Scope4 Oscilloscope Booster pack for the Texas Instruments F28027 C2000 Piccolo LaunchPad Experimenter Kit.

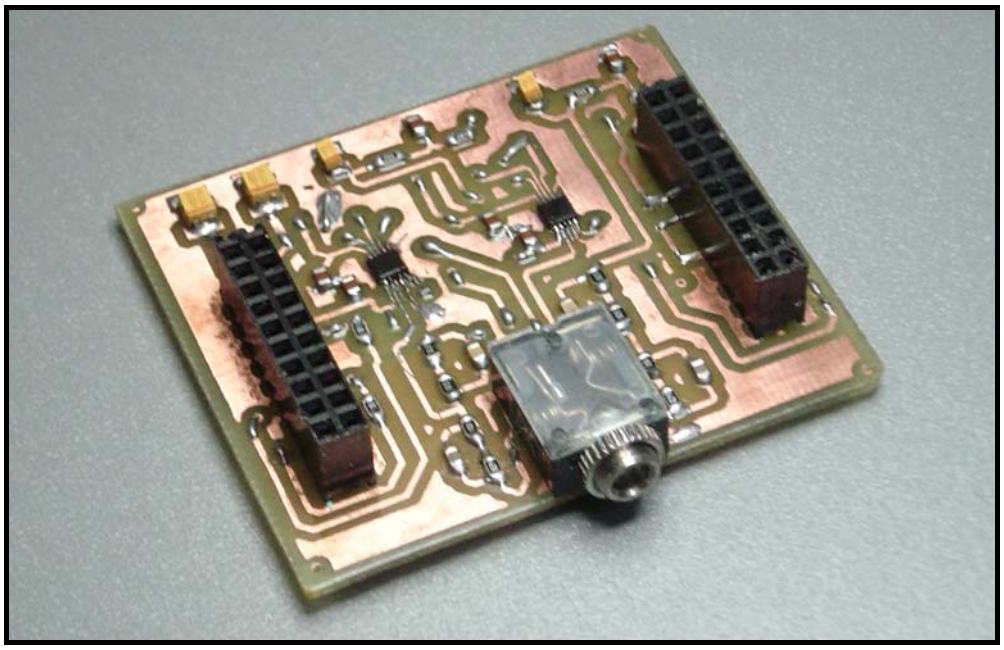


Figure 1 Oscilloscope Booster Pack for C2000 Launch Pad

This unit is designed as a teaching aid for budding engineers, electronic enthusiasts and hobbyists.

This USB connected unit implements a microcontroller based 2-Channel Oscilloscope providing continuous sampling rates up to 2.0 Msps. Common DSO features such as XY-mode, spectrum analysis, waveform capture and data saving are provided. The input range is ± 10.0V with additional gain settings of X2 and X5. Trigger and sweep options are also provided.

2. Warning & Disclaimer:

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3. Specifications

Input		
No of Channels	Two	
Analog bandwidth (Small Signal)	10/3.8/1.8 MHz	For Gain 1/2/5
Input impedance	1 Meg Ohm	
Input connection	3 mm Audio Jack	
Vertical Scale	**Gain**	
+10.0V to -10.0V	Gain 1	
+5.00V to – 5.00V	Gain 2	
+2.00V to -2.00V	Gain 5	
Sampling Rate		
10bps to 2.0Mbps	100ms/sample to 0.5uses/sample	Effective Maximum 4.0Mbps for 2 Channels
Trigger	Ch1 / Ch2 / Auto	
Trigger Polarity	Rising / Falling edge	
Trigger Range	+10.0V to -10.0V	Gain 1
	+5.00V to – 5.00V	Gain 2
	+2.00V to -2.00V	Gain 5
Display Modes	Ch1 + Ch2 vs. time	201 Samples each
	Ch1 vs. time	201 Samples
	Ch2 vs. time	201 Samples
	XY Ch1 + Ch2 vs. time	201 Samples each
	DFT Ch1	400 Samples
	DFT Ch2	400 Samples
Capture Modes	Single / Repeat / Store	
Save Modes	Data to CSV	Fig to multiple formats
PC Software	VB.Net 2.0 /	Virtual Com Port 115200 bps
Power Supply	USB +5V , 150 mA	

4. Block Schematic and Function Description

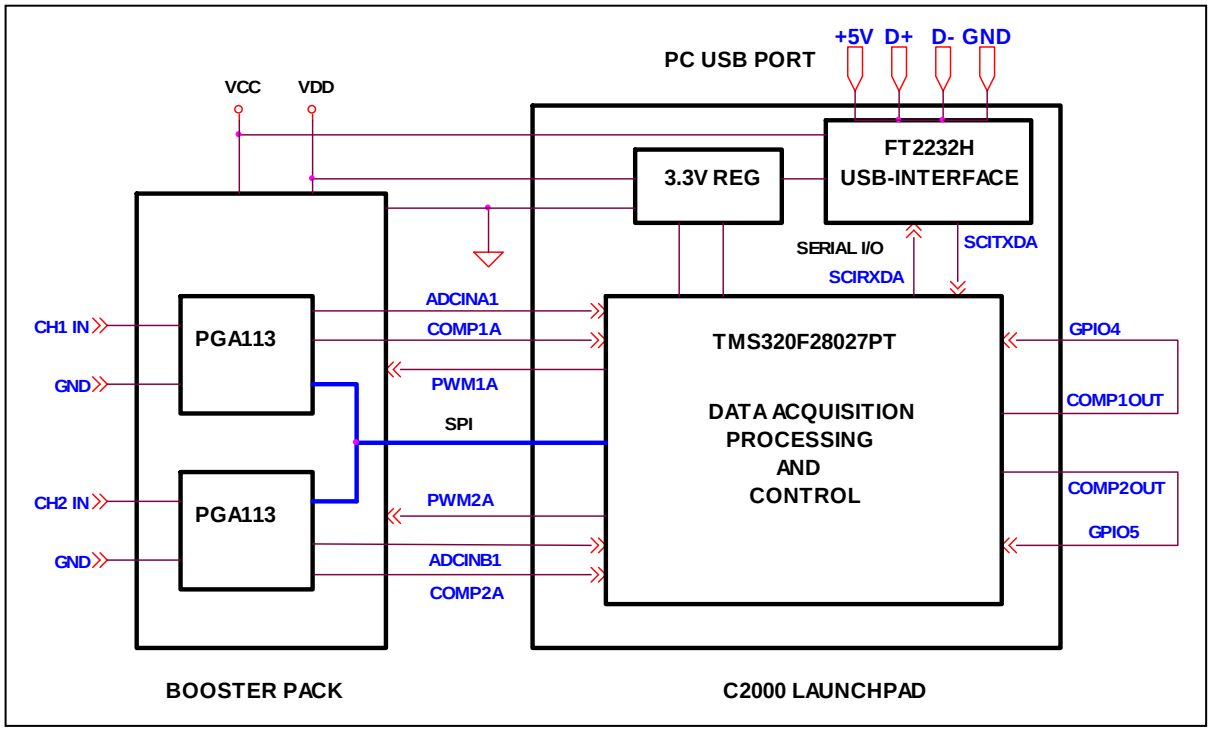


Figure 2, Aj_Scope4 simplified block schematic

Figure 2 shows the simplified block schematic of the system. The Booster Pack built around two Texas Programmable-Gain-Amplifiers and associated circuitry is connected to the C2000 Launch pad using the extension pins provided. The unit is powered and controlled from the USB port of a PC.

The configuration is optimized so that only two additional integrated circuits on the Booster Pack powered by the +5V and +3.3V supply from the C2000 are required to provide the full functionality of this Digital Storage Oscilloscope.

The Booster Pack and C2000 exercise all the functionalities provided by the TMSF28027 microcontroller:

- Analog inputs are connected to the two PGA's
- The PGA gains are set using the SPI interface
- Analog outputs from the PGA's are fed to the ADC inputs ADCINA1 and ADCINB1 which are simultaneously converted
- Analog outputs from the PGA's are also fed to the two comparators COMP1A and COMP2A whose outputs are looped back as interrupts to the processor.

- PWM1A and PWM2A outputs are averaged to provide the DC offsets for CH1 and CH2.
- Data is transferred using the serial interface to the FT2232H USB to serial converter
- The internal clock is used with temperature compensation

The TMSF28027 microcontroller implements the main Oscilloscope Functions.

- Analog to Digital conversion of the CH1 and CH2 signal conditioned inputs at the required sampling rates
- Trigger interrupt handling
- Responding to serial commands from PC and sending back the acquired data.

The TMSF28027 microcontroller is ideally suited to this task as it permits simultaneous 2-channel A/D conversion at rates up to 4Msps, has internal comparators which can handle the trigger functionality using interrupts, provide PWM outputs which are used to set the input offset voltages and a SPI interface for controlling the PGA's.

5. Software on the PC Host:

Microsoft Windows based GUI software has been developed to interface with the Aj_Scope4 via the USB port of a PC.

Visual Basic .Net Microsoft Windows Application Code

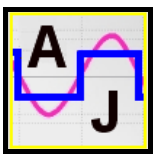


Figure 3, Aj_Scope4 icon MS Windows

A Visual Basic .Net 2.0 based GUI program is used to control the functions of the Aj_Scope2. An Aj_Scope.exe along with associated ZedGraph.dll and the XDS100v2 FTDI USB driver files has been tested for compatibility with Windows XP and Windows 7 with .Net 2.0.

* The XDS100v2 FDTI VCP drivers are provided by Texas Instruments

GUI VB.Net 2.0:

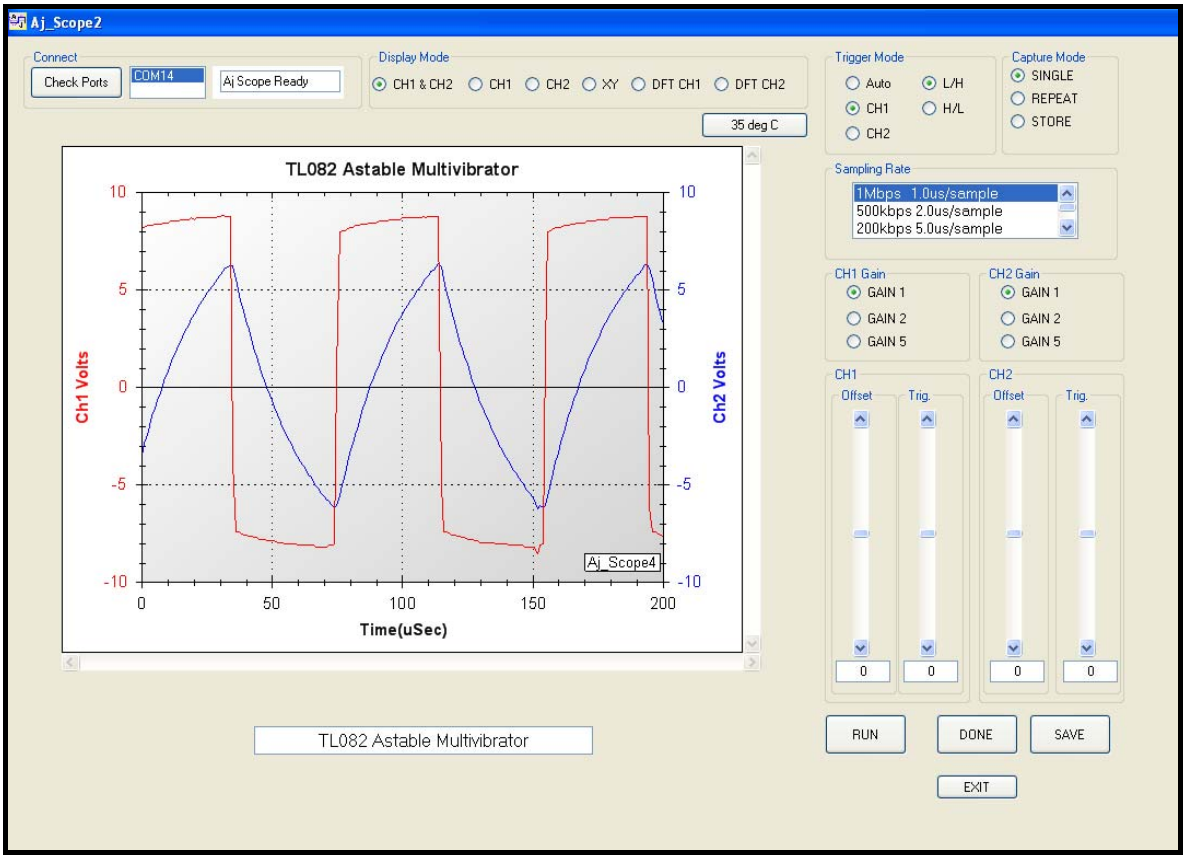


Figure 4, GUI

The GUI based Windows software on the Host PC permits checking for available COM ports and connecting to the port on which the hardware is connected. Once connected the hardware unit responds with a ready signal.

Display and trigger modes, sampling rate, channel gains, channel offset trigger offset and number of samples can be set using the simple controls.

The RUN button initiates the signal capture single, repetitive or over-plotted.

Initially signals can be acquired in auto / single mode after with suitable changes can be made in the gain and offsets and a trigger level set. Repeat mode can now be used for continuous display of the signals. Display of Ch1/Ch2 is possible with trigger by either Ch1 or Ch2.

Finally an EXIT button is provided to close the program and exit.

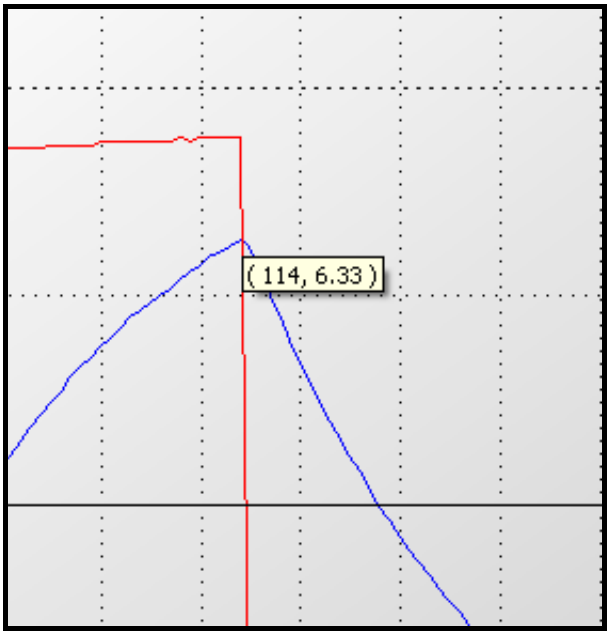


Figure 5, Mouse cursor data display

Values of data at the mouse cursor are automatically displayed.
The waveform caption can be entered and the figure stored as an image file.

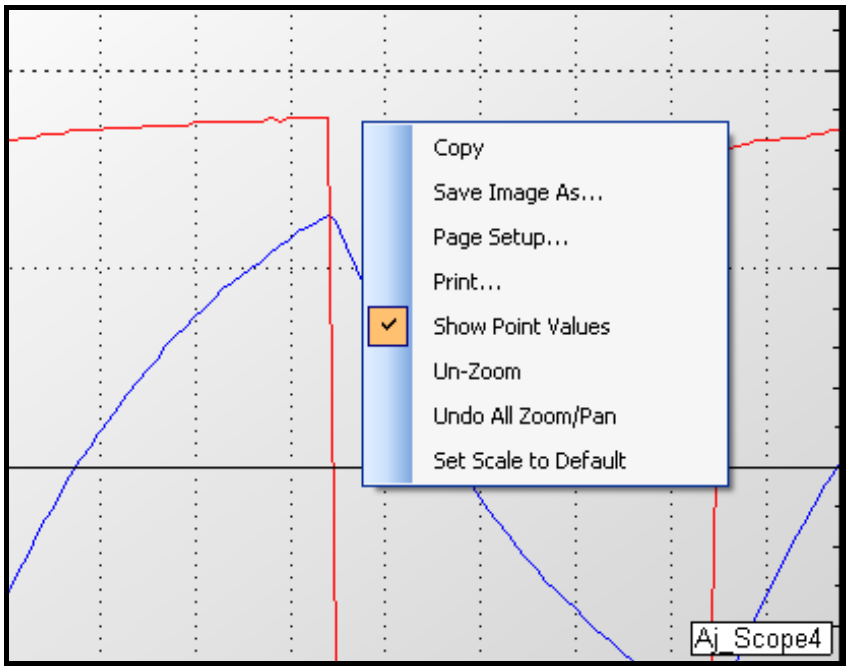
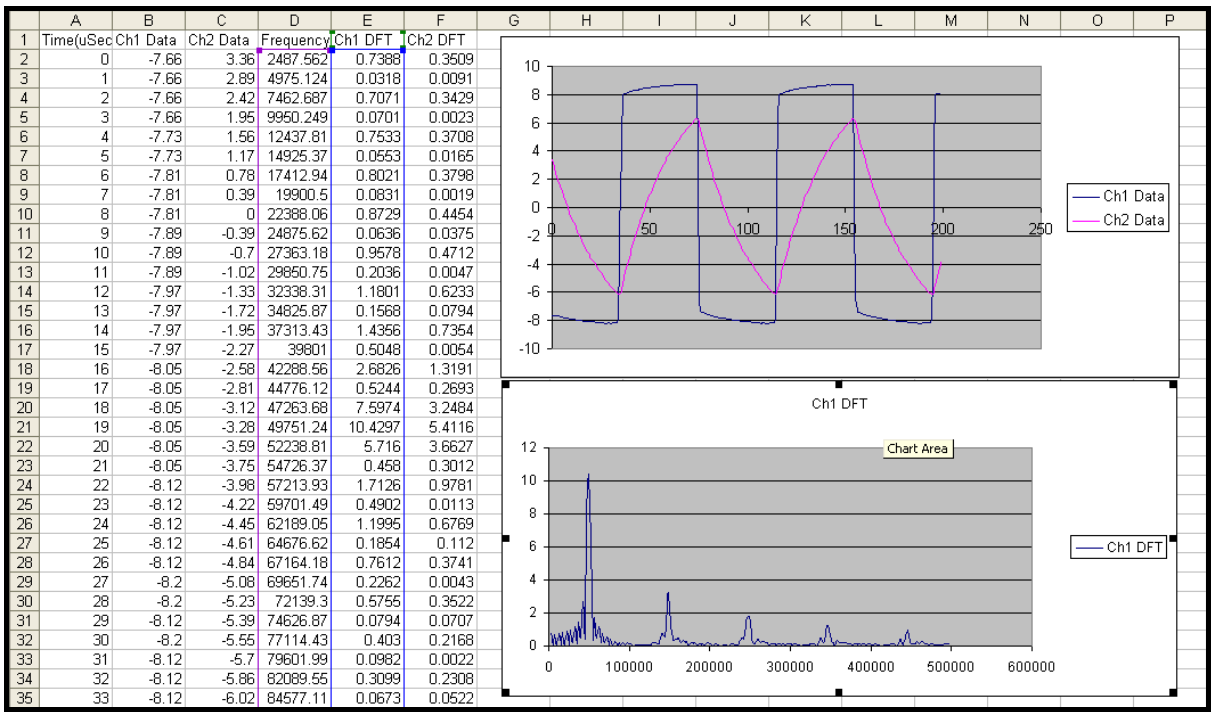


Figure 6, Image zoom, copy, print and save menu

Data can be stored in a .csv file using the SAVE option. Further processing can be carried out in MS EXCEL.



	A	B	C	D	E	F
1	Time(uSec	Ch1 Data	Ch2 Data	Frequency	Ch1 DFT	Ch2 DFT
2	0	-7.66	3.36	2487.562	0.7388	0.3509
3	1	-7.66	2.89	4975.124	0.0318	0.0091
4	2	-7.66	2.42	7462.687	0.7071	0.3429
5	3	-7.66	1.95	9950.249	0.0701	0.0023
6	4	-7.73	1.56	12437.81	0.7533	0.3708
7	5	-7.73	1.17	14925.37	0.0553	0.0165
8	6	-7.81	0.78	17412.94	0.8021	0.3798
9	7	-7.81	0.39	19900.5	0.0831	0.0019
10	8	-7.81	0	22388.06	0.8729	0.4454
11	9	-7.89	-0.39	24875.62	0.0636	0.0375
12	10	-7.89	-0.7	27363.18	0.9578	0.4712
13	11	-7.89	-1.02	29850.75	0.2036	0.0047
14	12	-7.97	-1.33	32338.31	1.1801	0.6233
15	13	-7.97	-1.72	34825.87	0.1568	0.0794
16	14	-7.97	-1.95	37313.43	1.4356	0.7354
17	15	-7.97	-2.27	39801	0.5048	0.0054
18	16	-8.05	-2.58	42288.56	2.6826	1.3191
19	17	-8.05	-2.81	44776.12	0.5244	0.2693
20	18	-8.05	-3.12	47263.68	7.5974	3.2484
21	19	-8.05	-3.28	49751.24	10.4297	5.4116
22	20	-8.05	-3.59	52238.81	5.716	3.6627
23	21	-8.05	-3.75	54726.37	0.458	0.3012
24	22	-8.12	-3.98	57213.93	1.7126	0.9781
25	23	-8.12	-4.22	59701.49	0.4902	0.0113
26	24	-8.12	-4.45	62189.05	1.1995	0.6769
27	25	-8.12	-4.61	64676.62	0.1854	0.112
28	26	-8.12	-4.84	67164.18	0.7612	0.3741
29	27	-8.2	-5.08	69651.74	0.2262	0.0043
30	28	-8.2	-5.23	72139.3	0.5755	0.3522
31	29	-8.12	-5.39	74626.87	0.0794	0.0707
32	30	-8.2	-5.55	77114.43	0.403	0.2168
33	31	-8.12	-5.7	79601.99	0.0982	0.0022
34	32	-8.12	-5.86	82089.55	0.3099	0.2308
35	33	-8.12	-6.02	84577.11	0.0673	0.0522

Figure 7, Plot in EXCEL based on saved data

A DFT (discrete furrier transform) can be carried out to show the frequency spectrum of captured waveforms.

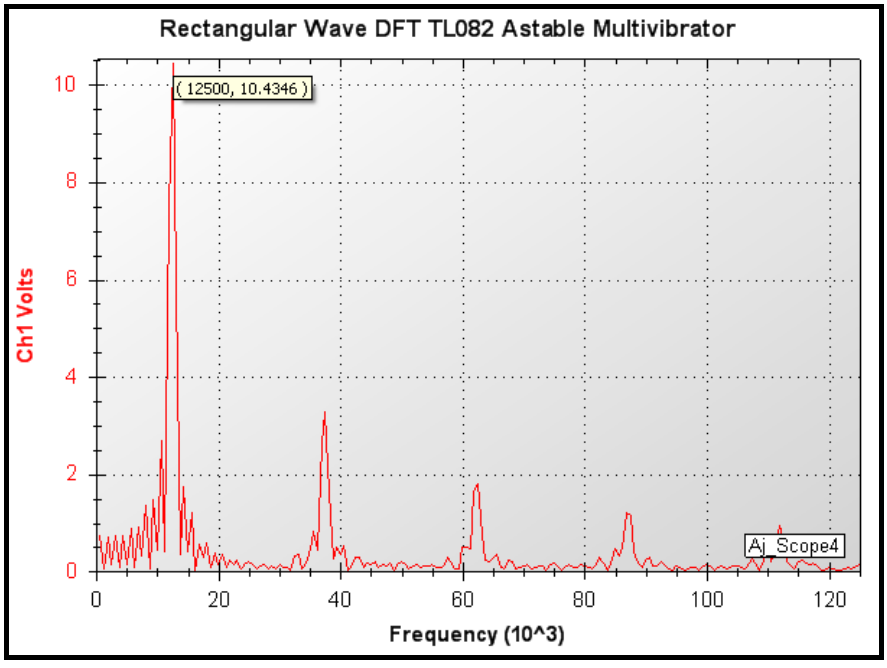


Figure 8, Spectrum Display

Data may also be presented in XY mode

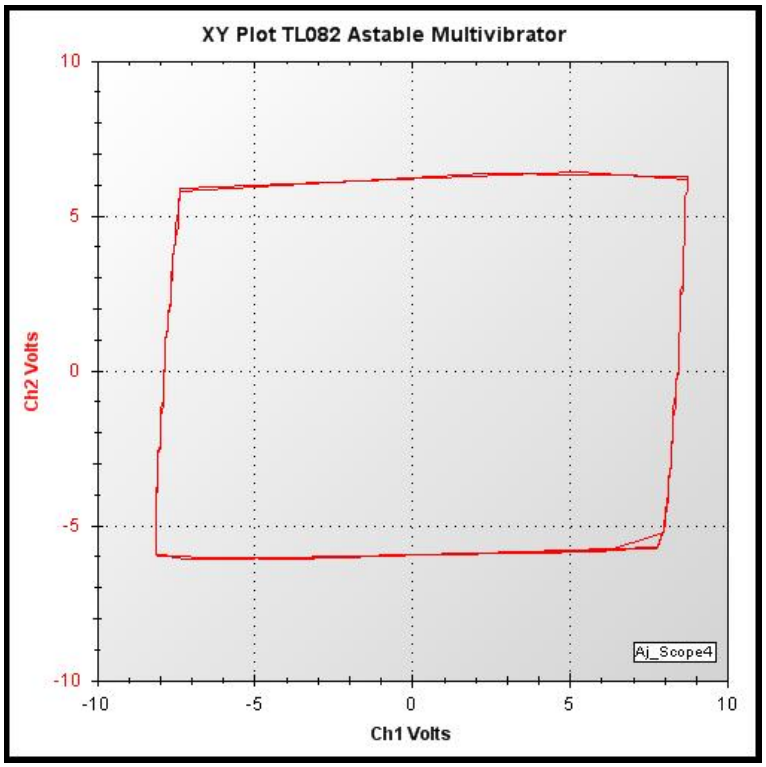


Figure 9, XY Plot

6. Aj_Scope4 Unit:

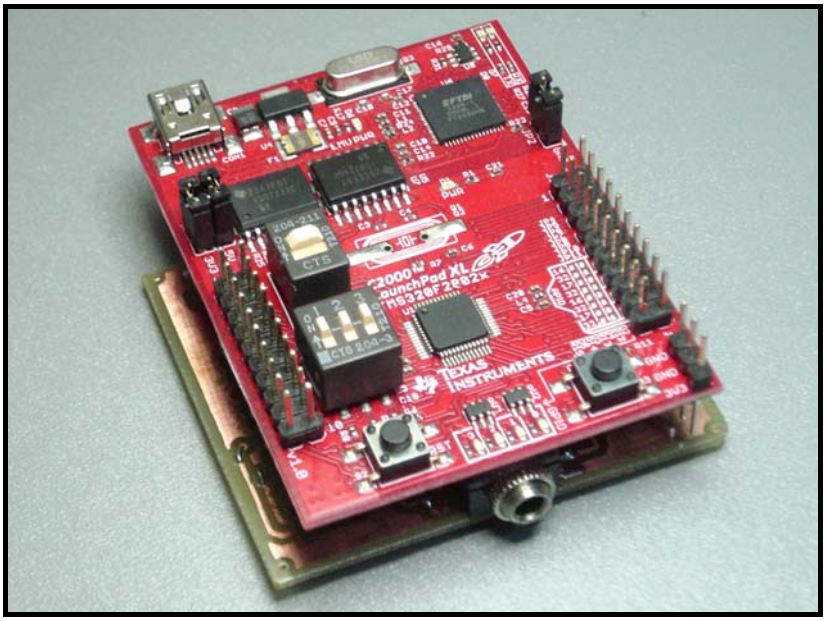


Figure 10, Showing Aj_Scope4 Unit

In order to economize on the cost of an enclosure the circuitry has been designed as a booster pack which mates with the existing pins on the C2000 Launch Pad.

The USB connection to the PC is on one end while the Audio-Jack for the signals to be monitored is on the other.

The 'Reset' switch provided on the C2000 restarts the micro-controller is the worst-case of hang-up. This typically occurs when the operator selects a trigger threshold which is out of limits with respect to the waveform being observed. If the Aj_Scope4 is operated correctly this switch is seldom used.

7. Functional Description:

The circuit of the Aj_Scope4 has been optimized for the minimum components meeting the overall system requirements. The details of each circuit are as follows:

Input Analog Interface

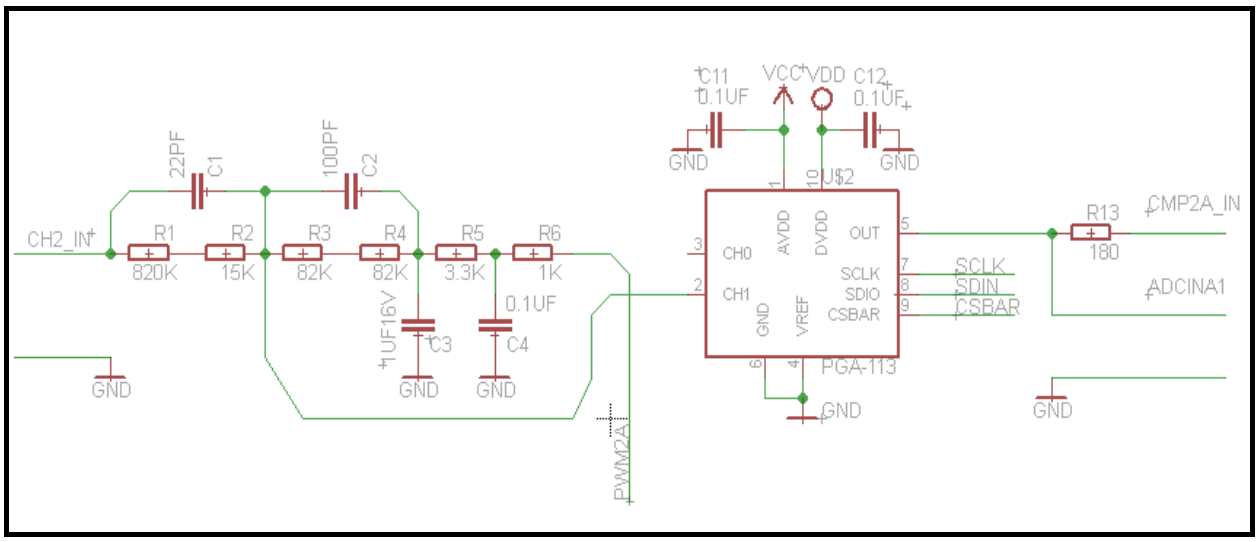


Figure 11, showing the Analog Input Interface for Ch2 (duplicated for Ch1)

An input potential divider with a ratio 5:1 and an input impedance of 1 Meg Ohm is formed by resistors (R1+R2) /(R3+R4+R5+R6) 835k:/168k. Capacitors C1 and C2 are added so as to compensate for any input capacitance of the PGA-113.

PWM2A a PWM output of the micro-controller is filtered in tow stages by R6/C4 and R5/C3 and produces a DC offset voltage at the junction of R4/R5 based on

the duty cycle of the PWM. This offset voltage is initialized to produce a fixed VDD/2 voltage at the output of the PGA-113 which is then changed by the Ch1 offset voltage slider around this value. The PWM duty-cycle is suitably adjusted for different gain settings.

The PGA-113 is connected to the micro-controller through an SPI interface in order to setup the gain values 1/2/5.

VOUT at Pin 1 of the PGA-113 is fed as an analog input to the microcontroller within a working range 0-VDD. This output is fed through a 180 ohm resistor R13 as an input to the internal comparator CMP2A of the microcontroller. This voltage is used for the trigger function.

Processor Functions

The TMSF28027 processor on the C2000 is powered from the USB bus. A reset switch is provided at the MCLR pin.

A processor is programmed to operate at 50MHz using the internal OSC1. This internal clock is used with temperature compensation

The PGA gains are set using the SPI interface

Analog outputs from the PGA's are fed to the ADC inputs ADCINA1 and ADCINB1 which are simultaneously converted

Analog outputs from the PGA's are also fed to the two comparators COMP1A and COMP2A whose outputs are looped back as interrupts to the processor.

PWM1A and PWM2A outputs are averaged to provide the DC offsets for CH1 and CH2.

Data is transferred using the serial interface to the FT2232H USB to serial converter

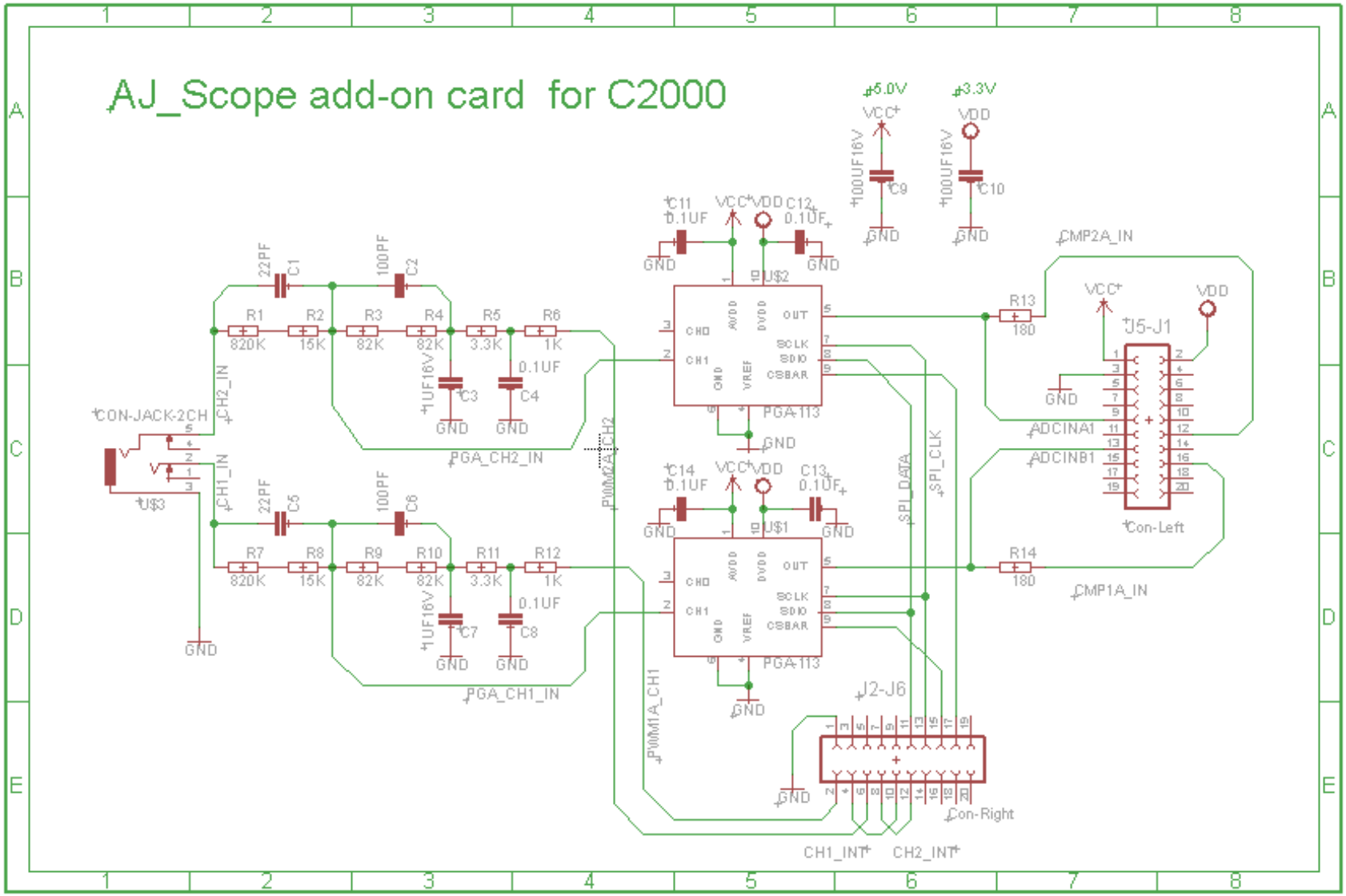
The inputs are sampled based on the sampling-rate set and data stored in two internal arrays corresponding to CH1/CH2.

Sampling can be asynchronous or based on interrupts which are generated by the comparators whose reference is set to the desired value based on commands.

Command Summary

"I" Identify	:	Returns "Aj_Scope4 Ready"
"A" Abort	:	Software Reset
"B" Read Busy	:	Checks if Busy
"R" Read Vref	:	Reads Vref
"D" Send Data	:	Sends Sampled Data
"S" Sample Rate	:	Sets Sample Rate
"N" Noise Filter	:	Not Implemented
"C" Capture Data	:	Captures Data
"c" Compensate OSC1	:	Compensates OSC1 based on Temperature
"L" Trig Level Ch1	:	Sets Trigger Level for CH1
"Small L" Trig Level Ch2	:	Sets Trigger Level for CH2
"T" Trig Source	:	Sets Trigger Source Auto/Ch1/Ch2
"P" Trig Polarity CH1	:	Sets Trigger Polarity CH1
"p" Trig Polarity CH2	:	Sets Trigger Polarity CH2
"G" Gains	:	Sets PGA Gains
"O" Offset Ch1	:	Sets CH1 Offset
"o" Offset Ch2	:	Sets CH2 Offset
"F" FFT mode	:	Selects CH1+CH2/CH1/CH2
"t" Test LED	:	Not Implemented

8. Overall Circuit



9. Bill of materials

No.	Part	Value	Package	Description
1.	C1	22PF	C0805	CAPACITOR,
2.	C2	100PF	C0805	CAPACITOR,
3.	C3	1UF16V	C1210	CAPACITOR, Tantalum
4.	C4	0.1UF	C0805	CAPACITOR,
5.	C5	22PF	C0805	CAPACITOR,
6.	C6	100PF	C0805	CAPACITOR,
7.	C7	1UF16V	C1210	CAPACITOR, Tantalum
8.	C8	0.1UF	C0805	CAPACITOR,
9.	C9	100UF16V	C1812K	CAPACITOR, Tantalum
10.	C10	100UF16V	C1812K	CAPACITOR, Tantalum
11.	C11	0.1UF	C0805	CAPACITOR,
12.	C12	0.1UF	C0805	CAPACITOR,
13.	C13	0.1UF	C0805	CAPACITOR,
14.	C14	0.1UF	C0805	CAPACITOR,
15.	J2-J6	Con-Right	FE10-2	FEMALE
16.	J5-J1	Con-Left	FE10-2	FEMALE
17.	R1	820K	R0805	RESISTOR,
18.	R2	15K	R0805	RESISTOR,
19.	R3	82K	R0805	RESISTOR,
20.	R4	82K	R0805	RESISTOR,
21.	R5	3.3K	R0805	RESISTOR,
22.	R6	1K	R0805	RESISTOR,
23.	R7	820K	R0805	RESISTOR,
24.	R8	15K	R0805	RESISTOR,
25.	R9	82K	R0805	RESISTOR,
26.	R10	82K	R0805	RESISTOR,
27.	R11	3.3K	R0805	RESISTOR,
28.	R12	1K	R0805	RESISTOR,
29.	R13	180	R0805	RESISTOR,
30.	R14	180	R0805	RESISTOR,
31.	U$1	PGA113AIDGSR	MSOP-10	PGA 2Ch Scope Gains
32.	U$2	PGA113AIDGSR	MSOP-10	PGA 2Ch Scope Gains
33.	U$3	CON-JACK-2CH	JACK_2CH	2Channel Audio jack

10. Printed Circuit Boards :

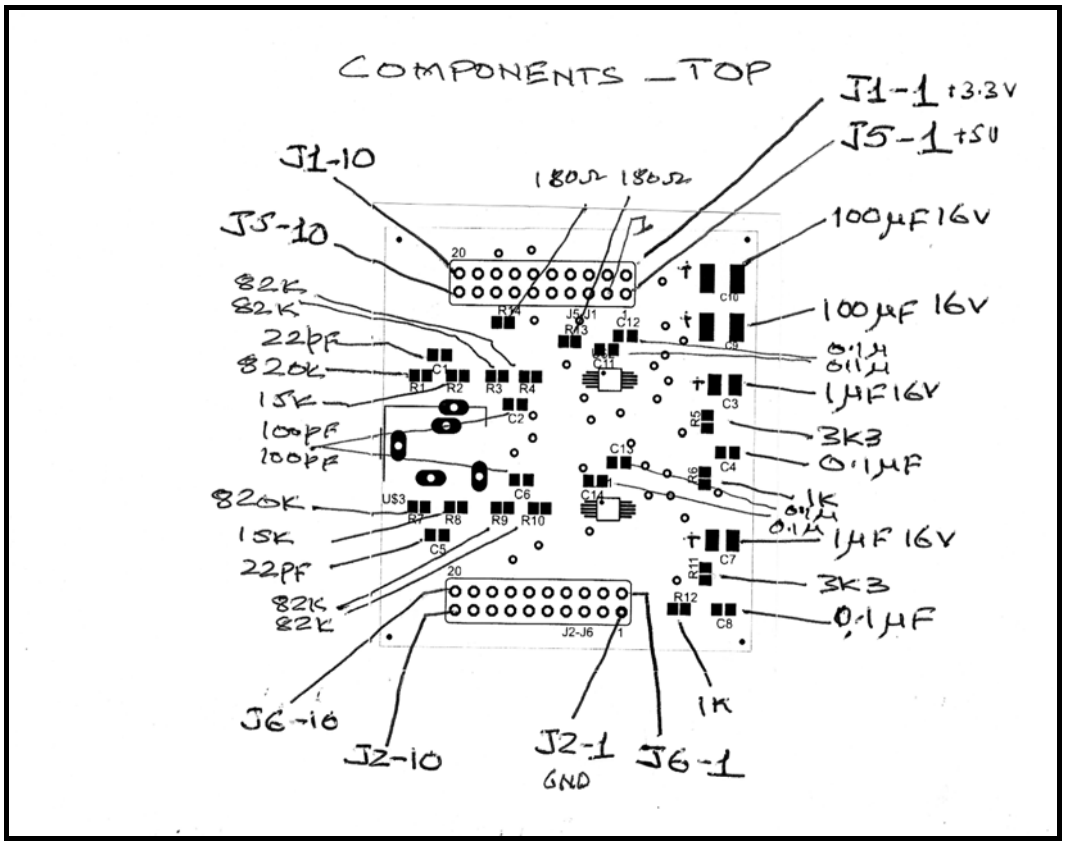


Figure 12, Component Layout

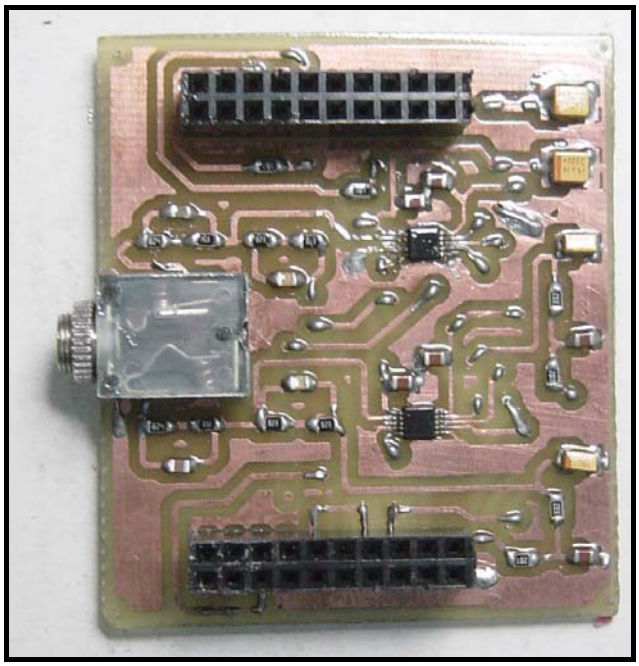


Figure 13, Wired PCB top view

11. Appendices

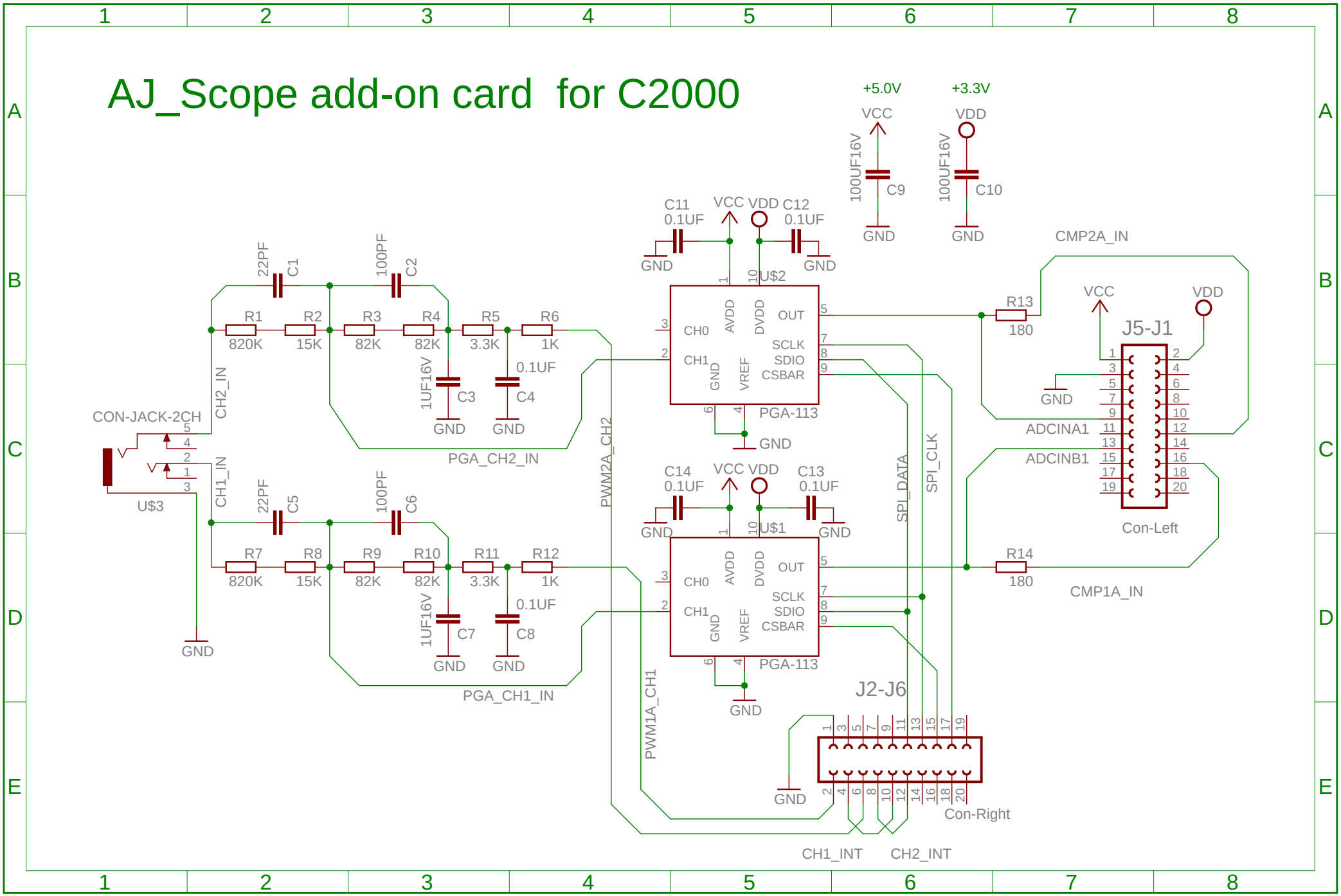
- Circuit Diagram Color
- Circuit Diagram B/W
- PCB 1:1 A4 Top mirrored
- PCB 1:1 A4 Bottom

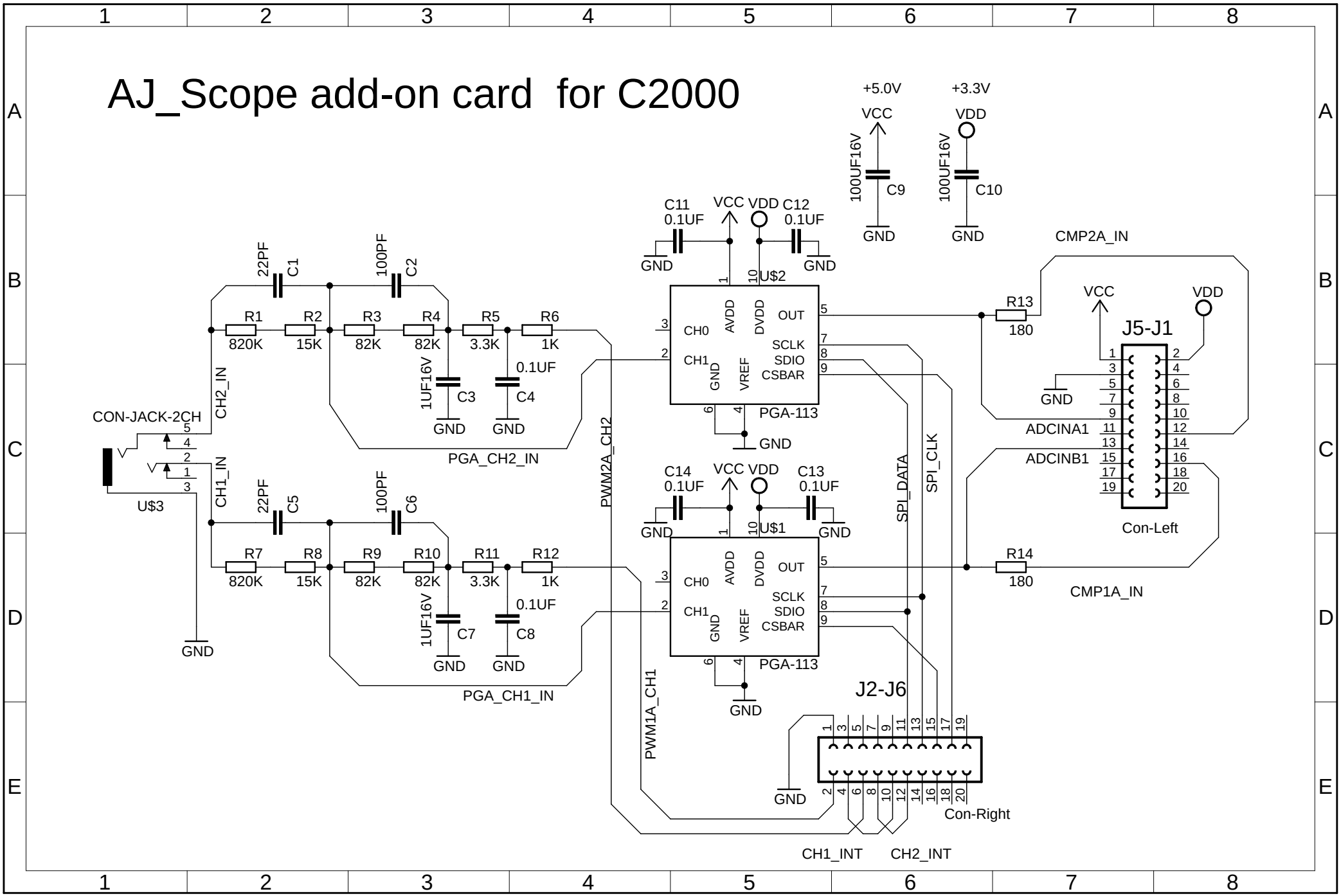
12. Summary

This document provides essential information for fabrication and operation of the Aj_Scope4 unit.

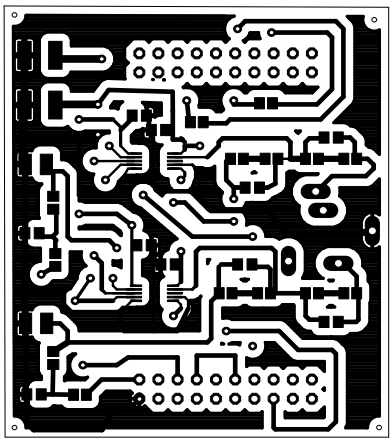
Software and Gerber Files can be downloaded from my website
http://www.ajoyraman.in

Address any doubts and clarifications to me at ajoyraman@gmail.com

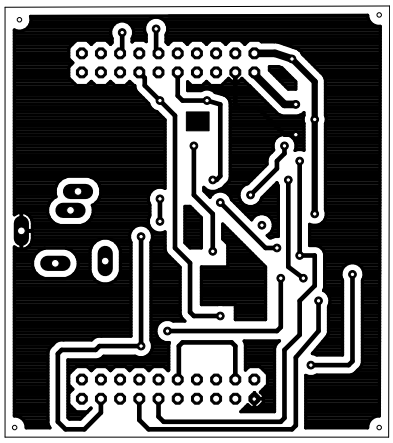

AJ_Scope add-on card for C2000
+5.0V
+3.3V
VCC
VDD
100UF16V
C9
C10
GND
C11 0.1UF
C12 0.1UF
U$2
PGA-113
CH0
CH1
AVDD
DVDD
OUT
SCLK
SDIO
CSBAR
VREF
CMP2A_IN
R13
180
J5-J1
ADCINA1
ADCINB1
Con-Left
22PF
C1
100PF
C2
R1
820K
R2
15K
R3
82K
R4
82K
R5
3.3K
R6
1K
1UF16V
C3
0.1UF
C4
CON-JACK-2CH
CH2_IN
CH1_IN
U$3
PGA_CH2_IN
PWM2A_CH2
C14 0.1UF
C13 0.1UF
U$1
C5
C6
R7
R8
R9
R10
R11
R12
C7
C8
PGA_CH1_IN
PWM1A_CH1
SPI_DATA
SPI_CLK
R14
CMP1A_IN
J2-J6
Con-Right
CH1_INT
CH2_INT

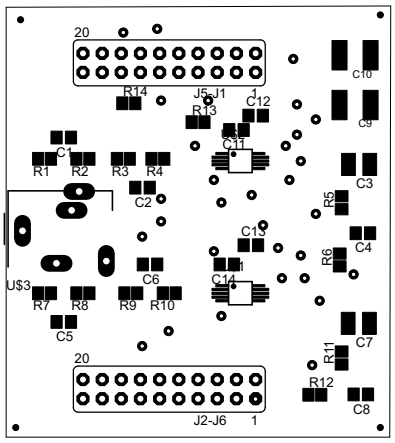

AJ_Scope add-on card for C2000
+5.0V
VCC
100UF16V
C9
GND
+3.3V
VDD
100UF16V
C10
GND
C11
0.1UF
C12
0.1UF
U$2
PGA-113
CH0
CH1
AVDD
DVDD
VREF
OUT
SCLK
SDIO
CSBAR
GND
R1
820K
R2
15K
R3
82K
R4
82K
R5
3.3K
R6
1K
22PF
C1
100PF
C2
1UF16V
C3
0.1UF
C4
PGA_CH2_IN
CH2_IN
CON-JACK-2CH
U$3
CH1_IN
R7
820K
R8
15K
R9
82K
R10
82K
R11
3.3K
R12
1K
22PF
C5
100PF
C6
1UF16V
C7
0.1UF
C8
PGA_CH1_IN
C14
0.1UF
C13
0.1UF
U$1
PWM2A_CH2
PWM1A_CH1
SPI_DATA
SPI_CLK
CMP2A_IN
R13
180
CMP1A_IN
R14
180
J5-J1
Con-Left
ADCINA1
ADCINB1
J2-J6
Con-Right
CH1_INT
CH2_INT

Appendix III Top Mirrored



Appendix IV Bottom




20
R14
J5-J1
1
C10
R13
C12
C9
C11
C1
R1
R2
R3
R4
C2
C3
R5
C13
C4
R6
C14
U$3
C6
R7
R8
R9
R10
C5
C7
R11
20
R12
C8
J2-J6
1