Aj_Scope2

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_Scope2 unit.

This unit is designed as a 'Do-It-Yourself' (DIY) 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 500 ksps extending to 20 Msps using equivalent time sampling (ETS). Common DSO features such as XY-mode, spectrum analysis, waveform capture and data saving are provided. The input range is ± 12.5V with additional gain settings of X2 and X5. Trigger and sweep options are also provided.

2. Warning & Disclaimer:

All content provided in this document is for informational purposes only. The owner of this document makes no representations as to the accuracy or completeness of any information. The owner will not be liable for any errors or omissions in this information. The owner will not be liable for any losses, injuries, or damages from the display or use of this information including software.

3. Specifications

Input		
No of Channels	Two	
Analog bandwidth (Large Signal)	0.30/0.30/0.70 MHz	For Gain 1/2/5
Analog bandwidth (Small Signal)	12/6/7 MHz	For Gain 1/2/5
Input impedance	1 Meg Ohm	
Input connection	3 mm Audio Jack	
Vertical Scale	**Offset**	
+12.5V to -12.5V	+7.50V to -12.50V	Gain 1
+6.25V to - 6.25V	-6.25V to +13.75V	Gain 2
+2.50V to -2.50V	-2.50V to +17.50V	Gain 5

Sampling Rate		
1 Mbps to 20 Mbps	1 uses/sample to 0.05usec/sample	ETS Mode (repetitive signals)
10bps to 500 kbps	100ms/sample to 2uses/sample	Normal Mode
Trigger	Ch1 / Ch2 / Auto	
Trigger Polarity	Rising / Falling edge	
Trigger Range	+12.5V to -12.5V	Gain 1
	+6.25V to - 6.25V	Gain 2
	+2.50V to -2.50V	Gain 5
Display Modes	Ch1 + Ch2 vs. time	200 Samples each
	Ch1 vs. time	200 Samples
	Ch2 vs. time	200 Samples
	XY Ch1 + Ch2 vs. time	200 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 / Python 2.6/2.7	Virtual Com Port 115200 bps
Power Supply	USB +5V , 150 mA	

4. Block Schematic and Function Description

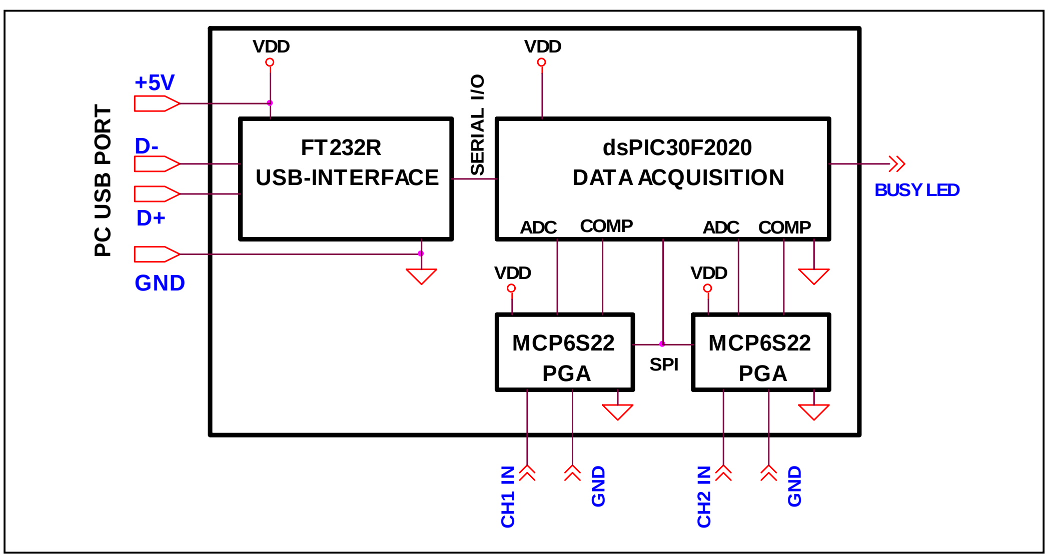

Figure 1, Aj_Scope2 simplified block schematic

Figure 1 shows the simplified block schematic of the system. For ease of portability the unit is powered and controlled from the USB port of a PC.

The configuration is optimized so that only four integrated circuits all operating on a single +5V supply are required to provide the full functionality of this Digital Storage Oscilloscope.

The **FT232R** from FDTI is a USB to serial UART interface with advanced features providing:

- A single chip USB to asynchronous serial data transfer interface.
- With the entire USB protocol handled on the chip.
- A fully integrated 1024 bit EEPROM storing device descriptors and CBUS I/O configuration.
- With fully integrated USB termination resistors.
- A fully integrated clock generation with no external crystal required
- Output selection enabling glue-less interface to external MCU or FPGA.
- And data transfer rates from 300 baud to 3 Mega baud

This chip provides a minimum component count USB-Serial interface and is used to communicate with the host PC for enumeration as a USB to UART device setting up the Aj_Scope2 as a 200mA device and acts as the USB communication interface.

The **MCP6S22** devices are digitally controlled Programmable Gain Amplifiers (PGA) with high bandwidth and high input impedance controlled through a Serial-Peripheral-Interface (SPI). These devices provide the input interface between the dsPIC18F14K50 and dsPIC30F2020 and the external analog signals being monitored.
The first PIC microcontroller implements the following functions:

The **dsPIC30F2020** 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.
- A Busy signal is also generated

The dsPIC30F2020 microcontroller is ideally suited to this task as it permits simultaneous 2-channel A/D conversion at rates up to 1Msps, has internal comparators which can handle the trigger functionality, provide PWM outputs which are used to set the input offset voltages and a SPI interface for controlling the PGAs.

5. Software on the PC Host:

Both Microsoft Windows and Linux based GUI software have been developed to interface with the Aj_Scope2 via the USB port of a PC.

Visual Basic .Net Microsoft Windows Application Code

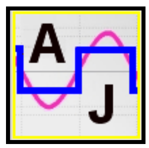

Figure 2, Aj_Scope2 Icon MS Windows

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 FTDI USB driver files has been tested for compatibility with Windows XP and Windows 7 with .Net 2.0.

* The FDTI VCP drivers can be downloaded from www.ftdichip.com/

Open Source Python Cross-Platform Application Code

Alternatively a Python based GUI program can be used to control the functions of the Aj_Scope2. An Aj_Scope.pyc python executable bit code provides a cross-platform application which has been tested using Python 2.7 on Windows XP and Windows 7 and on Debian 6.0 (“squeeze”) and Debian 7.0 (“wheezy”) using Python 2.6 and Python 2.7 respectively.

With the following packages:
Tkinter, ttk, serial, glob, math, time, csv, numpy and matplotlib

*On Linux systems appropriate ‘chmod’ commands need to be executed as root for giving users permission to access the VCP port which is typically /dev/ttyUSB0

GUI VB.Net 2.0:

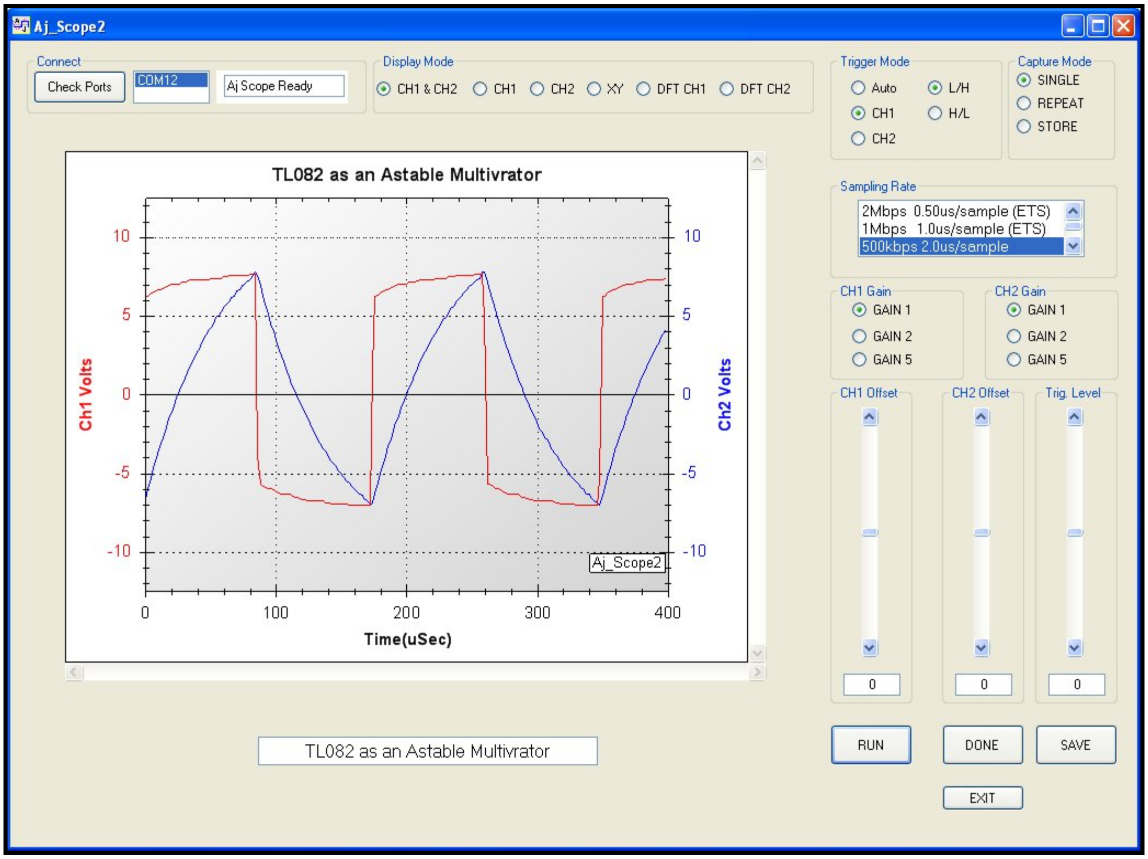

Figure 3, GUI

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.

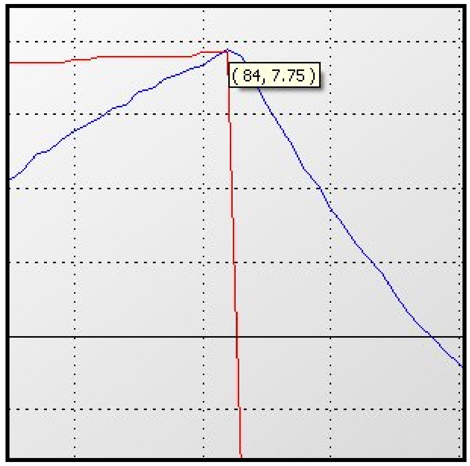

Figure 4, Mouse cursor data display

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

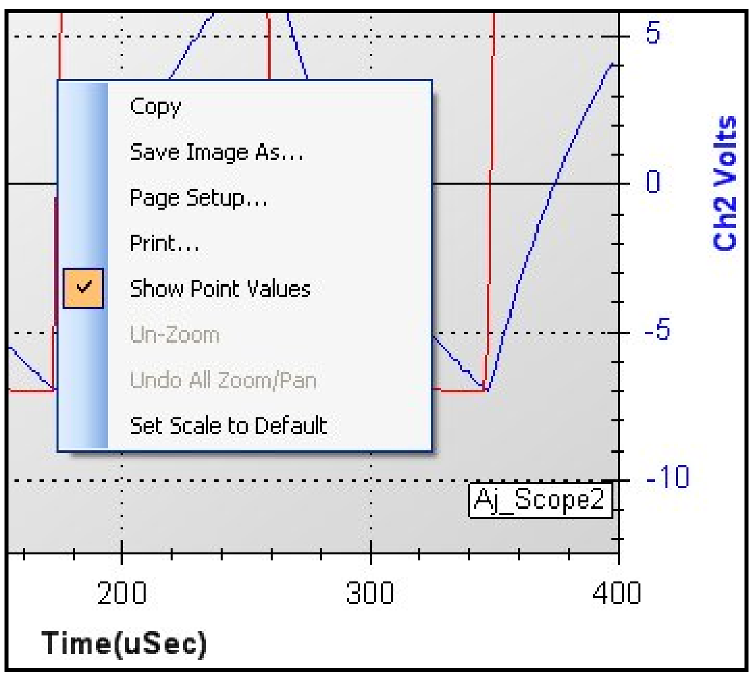

Figure 5, Image zoom, copy, print and save modes

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

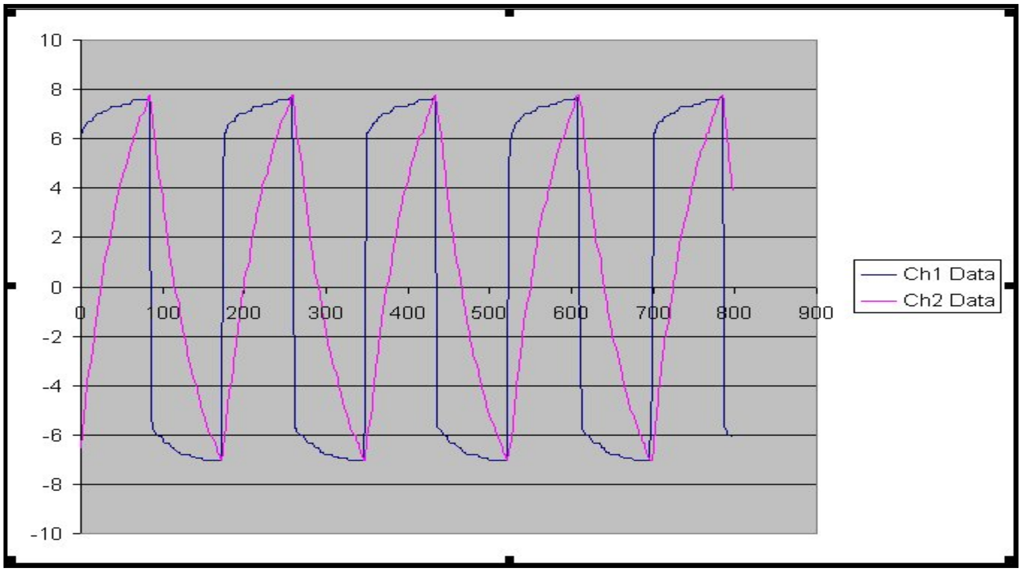

Figure 6, Plot in EXCEL based on saved data

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

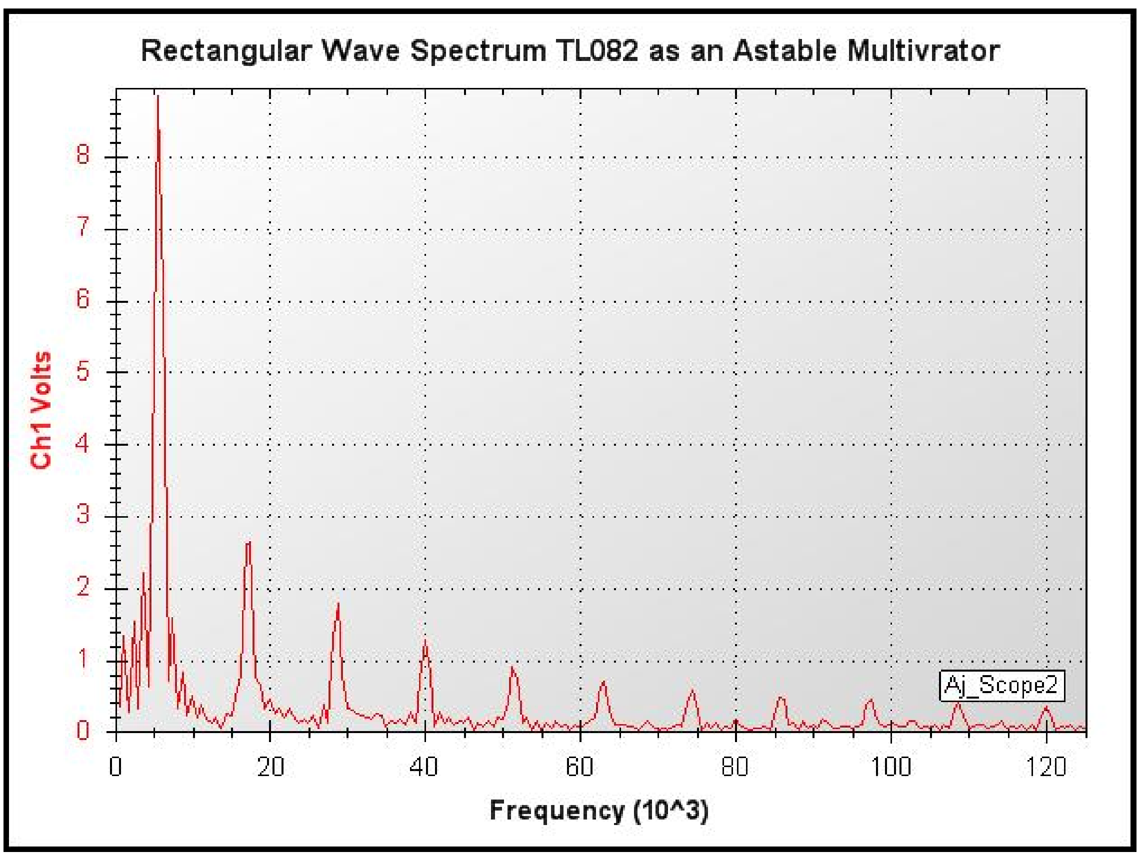

Figure 7, Spectrum Display

GUI PYTHON on DEBIAN 'Lenny':

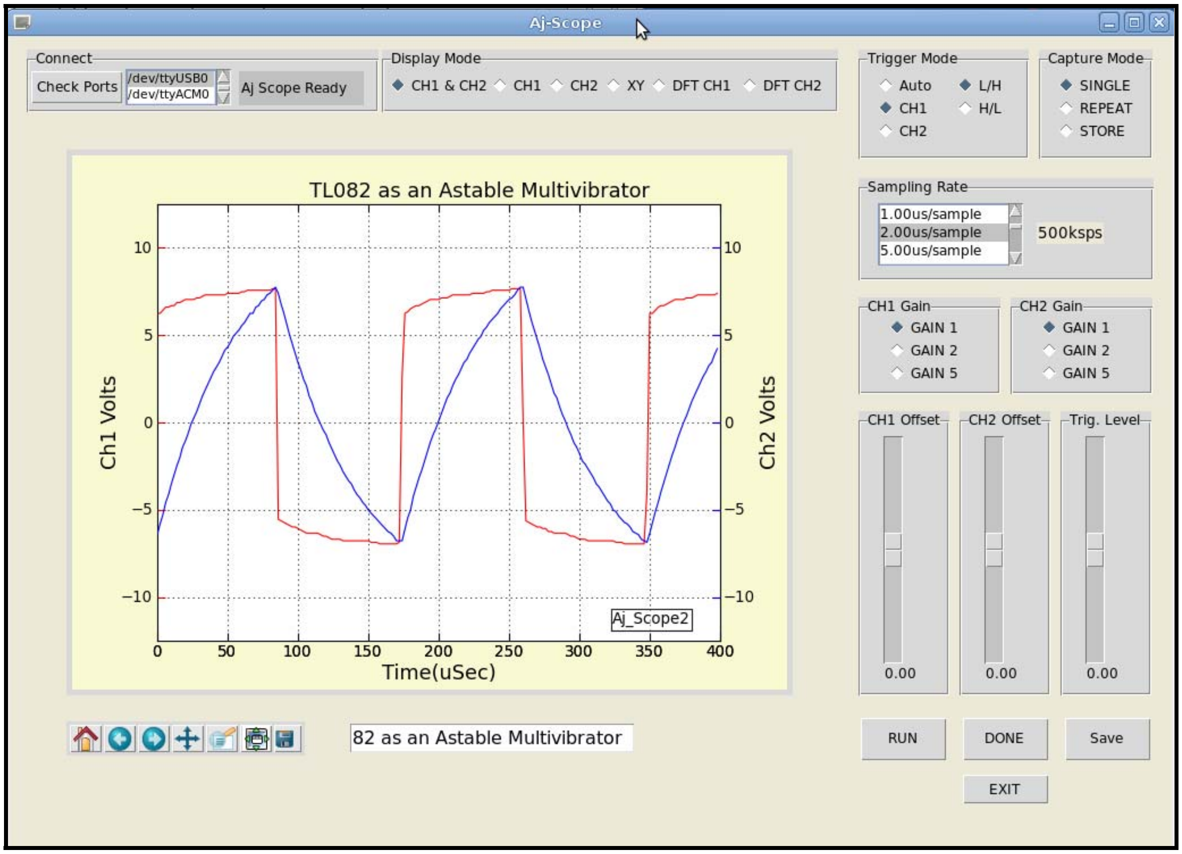

Figure 8, GUI Python

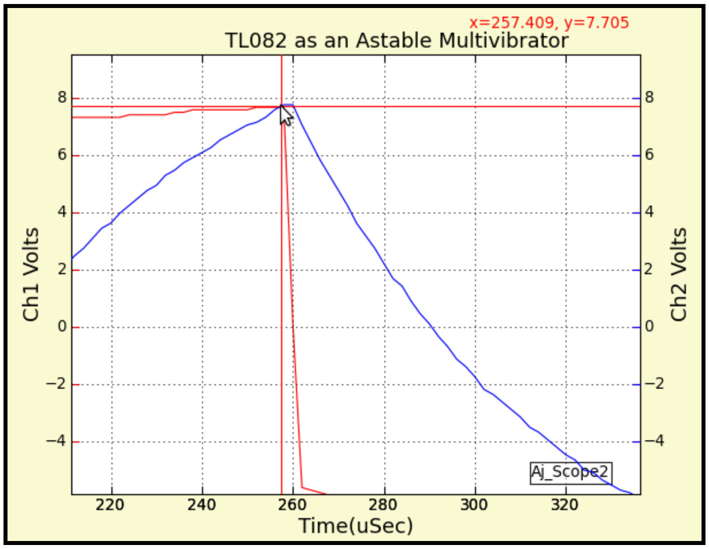

Figure 9, Curser Display

The cursor is toggled on/off with the right mouse button and the cursor choice toggled red/blue using the mouse left button. The parameter values are displayed on the top right-hand corner of the display.

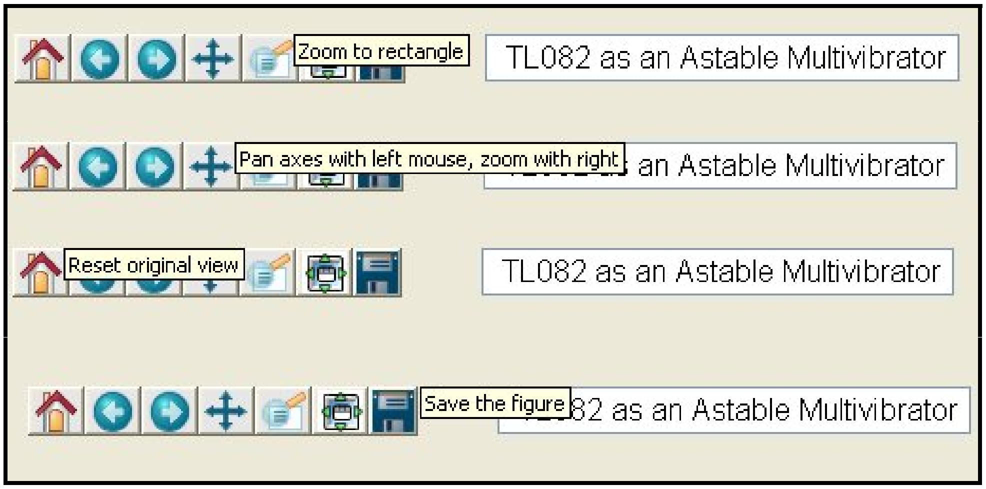

Figure 10 Image zoom, pan and save modes

Image zoom, pan and save mode are provided by the Python Tkinter Toolbar.

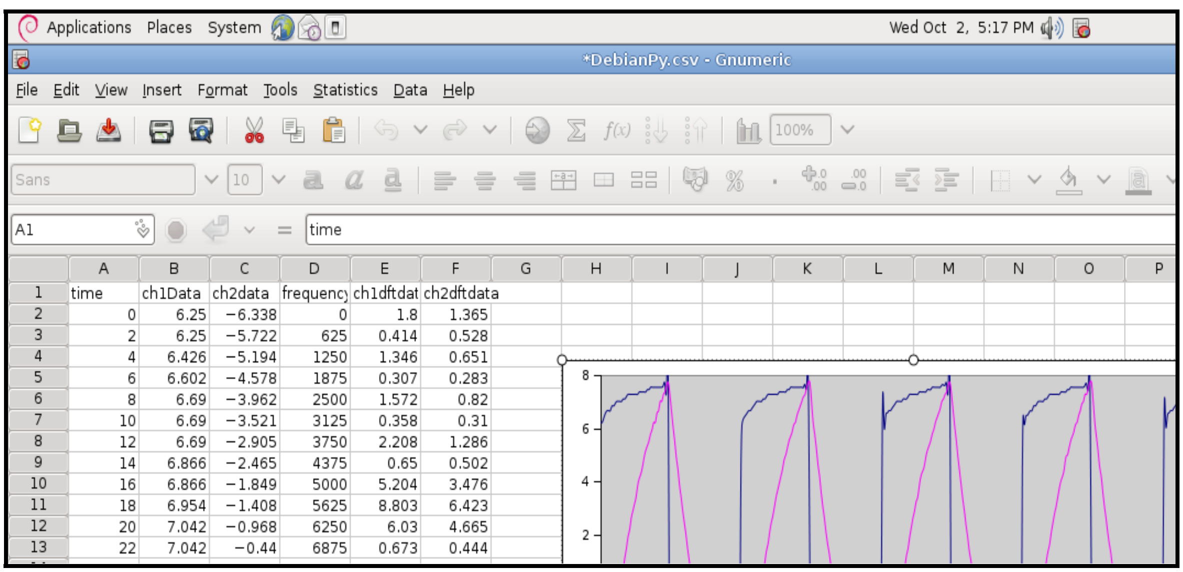

Figure 11, Plot in Debian Gnumeric based on saved .csv data

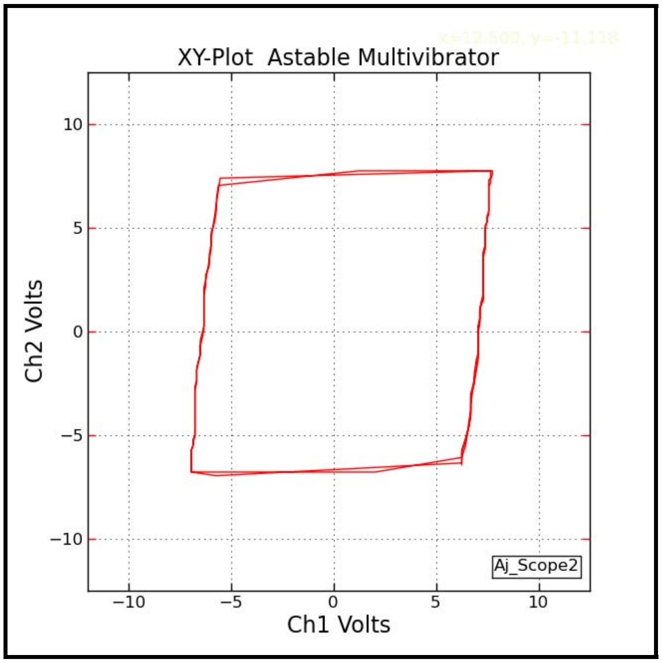

Figure 12, XY Plot

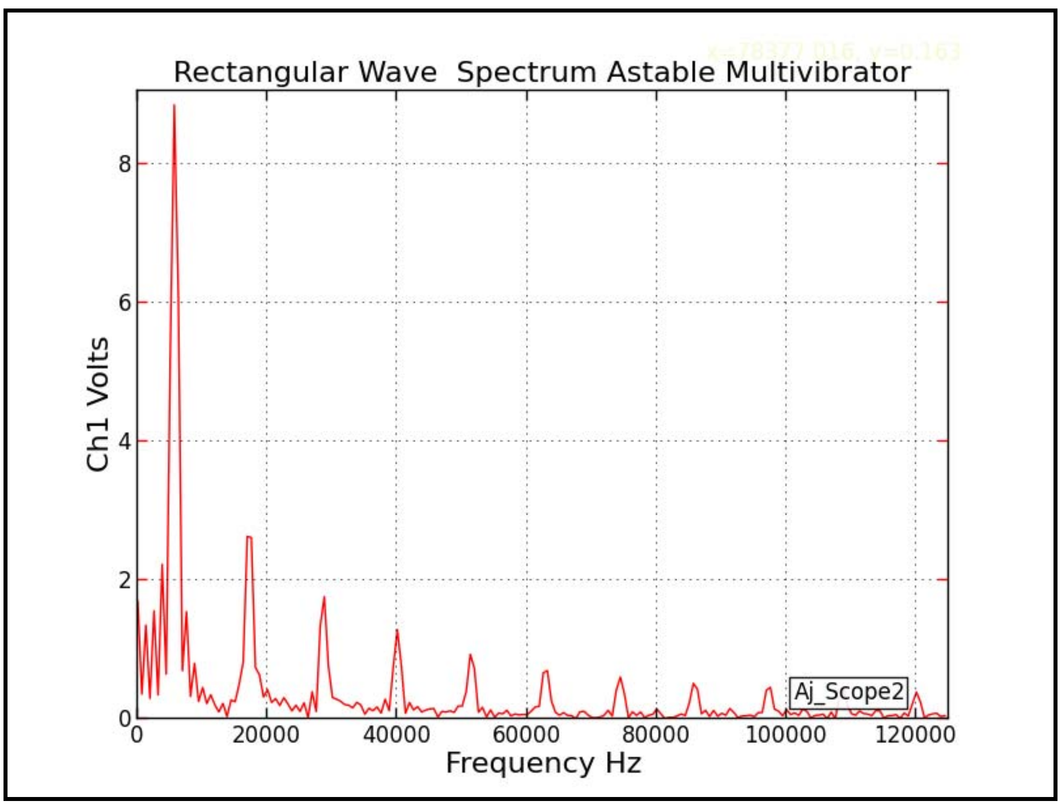

Figure 13, DFT Spectrum Plot

6. Aj_Scope2 Unit:

Figure 14, Showing Aj_Scope2 Unit

In order to economize on the cost of an enclosure while still providing an aesthetic unit the Aj_Scope2 is enclosed in a large size cardboard matchbox enclosure.

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

A ‘Busy’ LED is provided on one corner at the top and a ‘Reset’ switch is provided diagonally opposite.

The ‘Reset’ switch provides a restart of 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_Scope2 is operated correctly this switch is seldom used.

7. Circuit Diagrams:

The circuit of the Aj_Scope2 has been optimized for the minimum components meeting the overall system requirements. The details of each circuit are as follows:

7.1 USB Interface

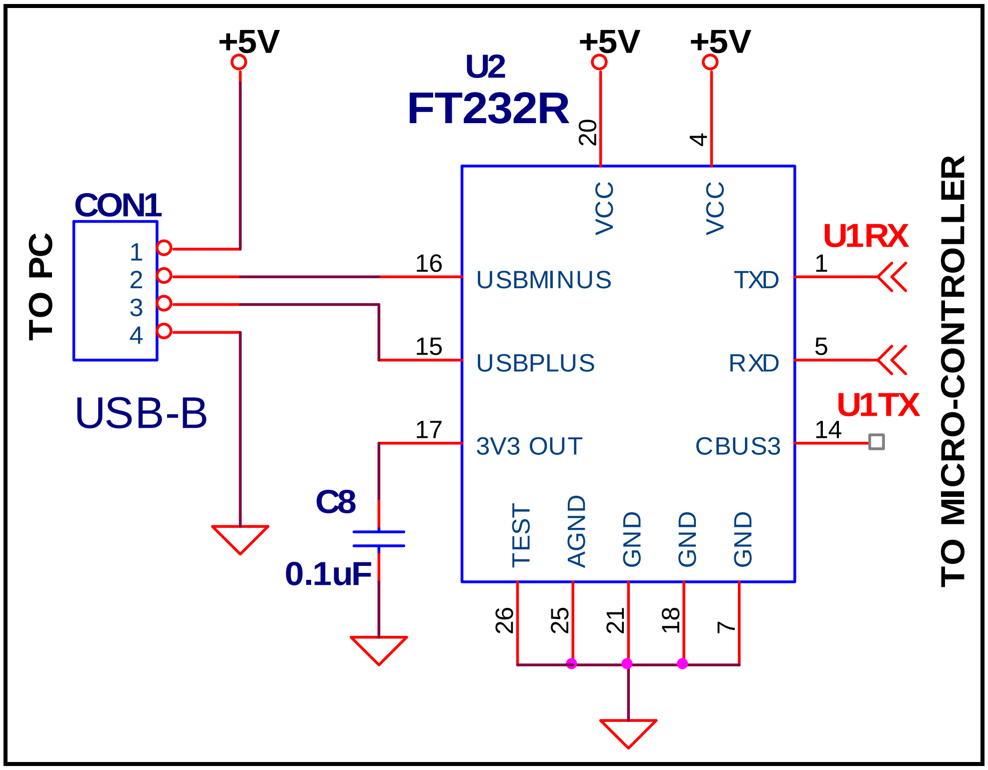

Figure 15, Showing USB Interface

The FDTI FT232R forms a single chip minimum component count interface between the PC USB port and the micro-controller serial-link Rx-Data and Tx-Data pins. As all the circuitry in self contained only one capacitor C8 needs to be added for the 3.3V generation.

Power to the rest of the circuitry is fed from the USB connector.

On connection to the PC USB port , the device is enumerated as a Virtual Com Port (VCP) and the corresponding drivers are loaded by the OS. As the Aj_Scope2 draws approximately 150mA the device has been programmed to indicate a 200mA device.

7.2 Input Analog Interface

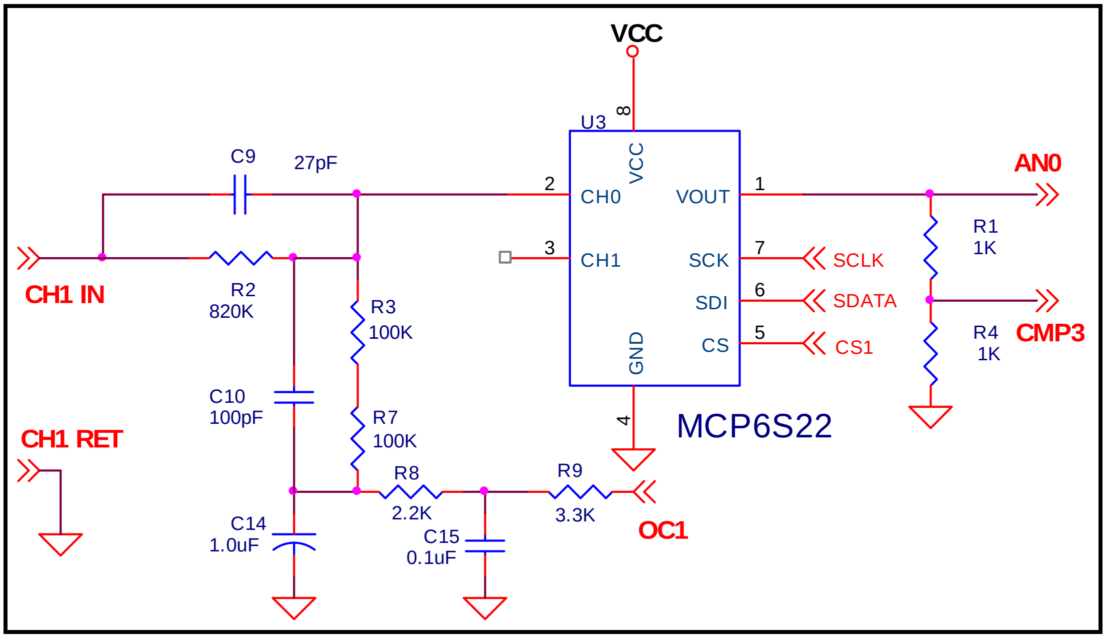

Figure 16, Showing the Analog Input Interface for Ch1 (duplicated for Ch2)

An input potential divider with a ratio 4:1 is formed by resistors R2: (R3+R7+R8+R9), 820k: 205k. The input impedance of this divider is therefore 1.025 Meg Ohm. Capacitors C9 and C10 are added so as to compensate for any input capacitance of the MCP6S22.

OC1 a PWM output of the micro-controller is filtered in tow stages by R9/C15 and R8/C14 and produces a DC offset voltage at the junction of R7/R8 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 MCP6S22 which is then changed by the Ch1 offset voltage slider around this value. The PWM voltage is suitably adjusted for different gain settings.

The MCP6S22 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 MCP6S22 is fed as an analog input to the microcontroller within a working range 0-VDD. This output is potential divided by 2 using R1/R4 and fed as an input to the internal comparator CMP3 of the microcontroller. This voltage is used for the trigger function.

7.3 Processor Circuit

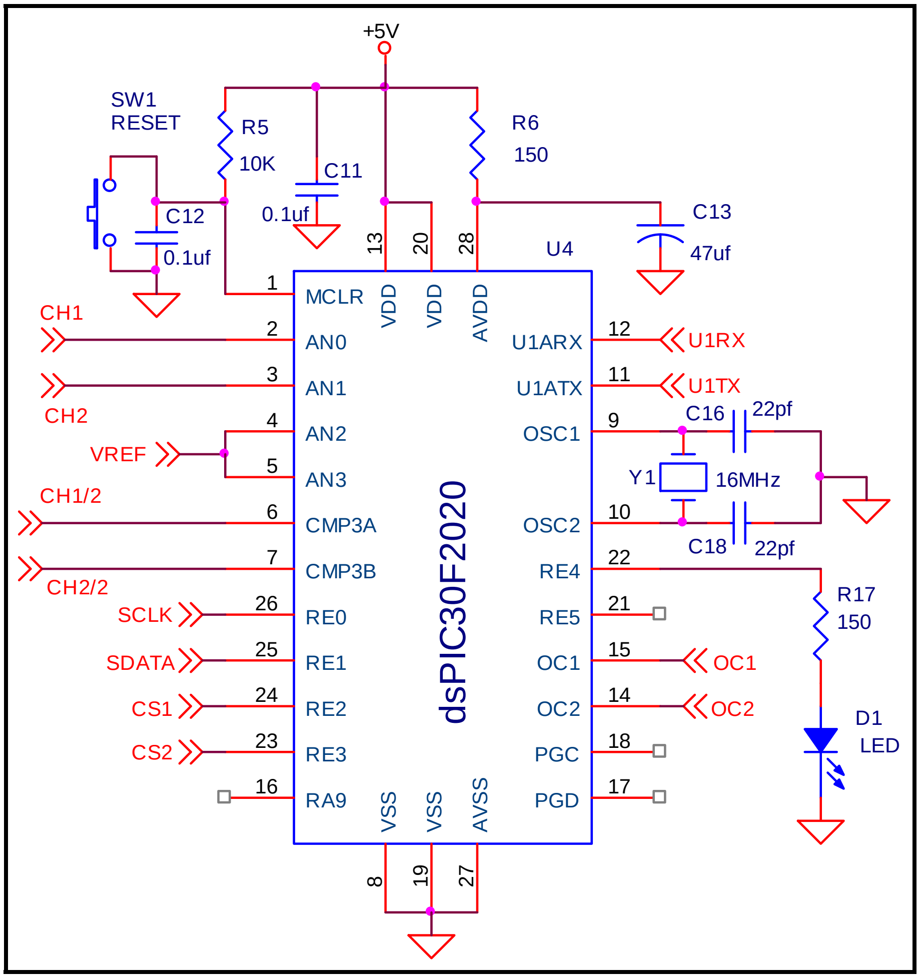

Figure 16a, Showing the Processor Circuit

The dsPic30F2020 is powered from the USB bus. A reset switch is provided at the MCLR pin.

A 16MHz crystal is connected across OSC1/OSC2 and sets up the processor clock.

RE0 to RE3 form the SPI interface to the two PGAs.

OC1 and OC2 for the PWM signals setting the offset voltages for Ch1 and Ch2. U1ARX and U1ATX are connected to the USB to Serial converter FT232R.

A Vref of 3V is connected to the analog inputs AN2/AN3 and is used to compensate for ADC scale-factor change with variation in VDD.

Finally the PGA outputs are connected to AN0/AN1 and CMP3A/CMP3B.

Under software control the microcontroller A/D converts the Ch1/Ch2 inputs at fixed intervals and stores them in internal memory before transferring them to the host PC.

When not in auto mode the start of the conversion sequence is determined by comparing an internally generated trigger reference voltage with the voltages at CMP3A/CMP3B.

LED D1 flashes during the initialization and acquisition process indicating that the processor is busy. No commands are initiated during this phase.

7.4 Overall Circuit

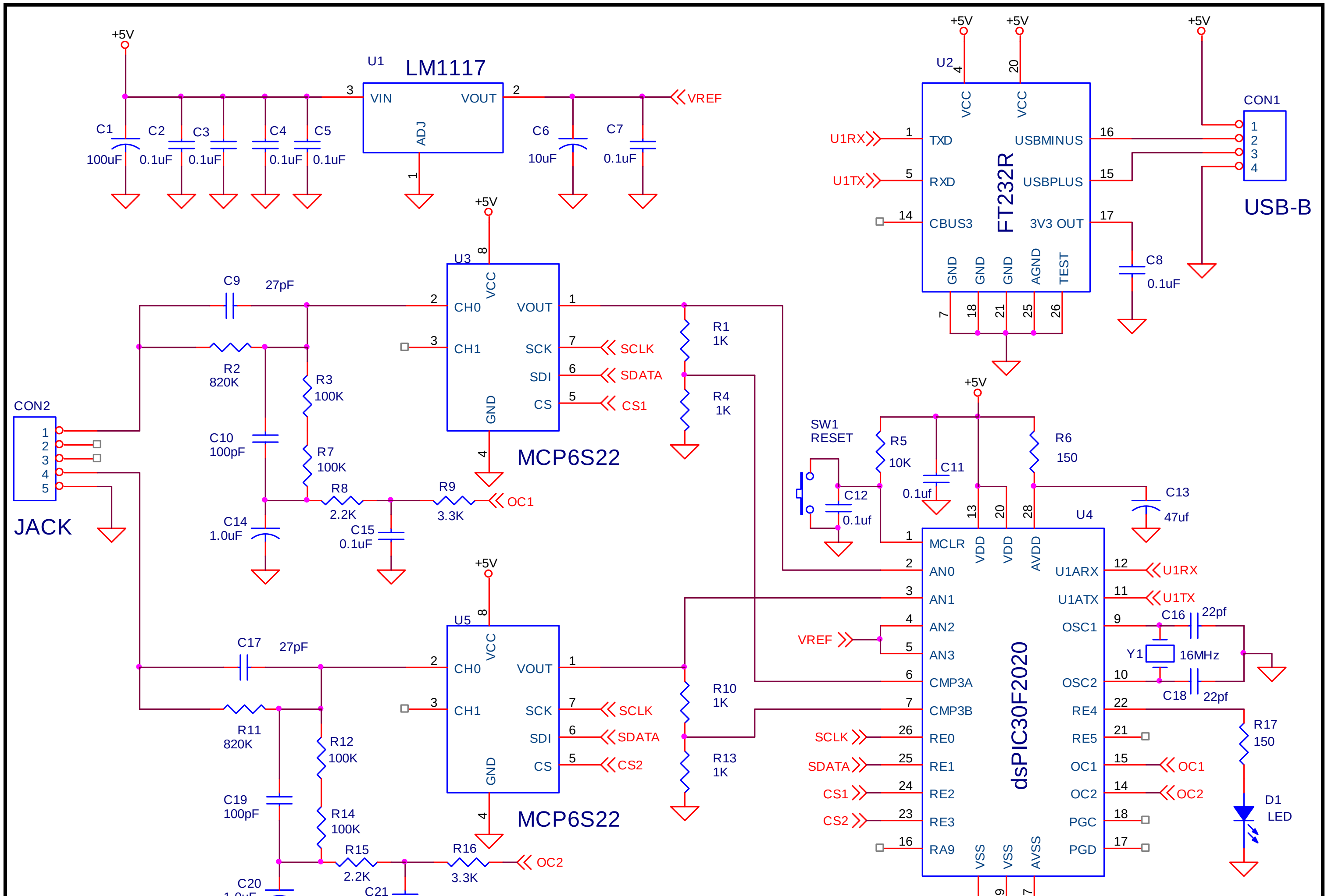

Fig 17 SCOPE2 SCHEMATIC
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8. Bill of materials

BILL OF MATERIALS					
Sl.No.	Value	Part. Reference	Qty.	Unit Cost	Cost (INR)
1	USB-B	CON1	1.0	10.0	10.0
2	PHONE JACK	CON2	1.0	20.0	20.0
3	100uF	C1	1.0	2.0	2.0
4	0.1uf	C2,C3,C4,C5,C7,C8,C11,	10.0	1.0	10.0
		C12,C15,C21			0.0
5	10uF	C6	1.0	2.0	2.0
6	27pF	C9,C17	2.0	1.0	2.0
7	100pF	C10,C19	2.0	1.0	2.0
8	47uf	C13	1.0	2.0	2.0
9	1.0uF	C14,C20	2.0	2.0	4.0
10	22pf	C16,C18	2.0	1.0	2.0
11	LED	D1	1.0	0.5	0.5
12	1K	R1,R4,R10,R13	4.0	0.2	0.8
13	820K	R2,R11	2.0	0.2	0.4
14	100K	R3,R7,R12,R14	4.0	0.2	0.8
15	10K	R5	1.0	0.2	0.2
16	150	R6,R17	2.0	0.2	0.4
17	2.2K	R8,R15	2.0	0.2	0.4
18	3.3K	R9,R16	2.0	0.2	0.4
19	RESET	SW1	1.0	3.0	3.0
20	LM1117	U1	1.0	15.0	15.0
21	FT232R	U2	1.0	175.0	175.0
22	MCP6S22	U5,U3	2.0	98.0	196.0
23	dsPIC30F2020	U4	1.0	452.0	452.0
24	16MHz	Y1	1.0	6.0	6.0
25	PCB	DIY	1.0	25.0	25.0
			Total	**Rupees**	**931.9**
				USD	**15.0**

9. Printed Circuit Boards :

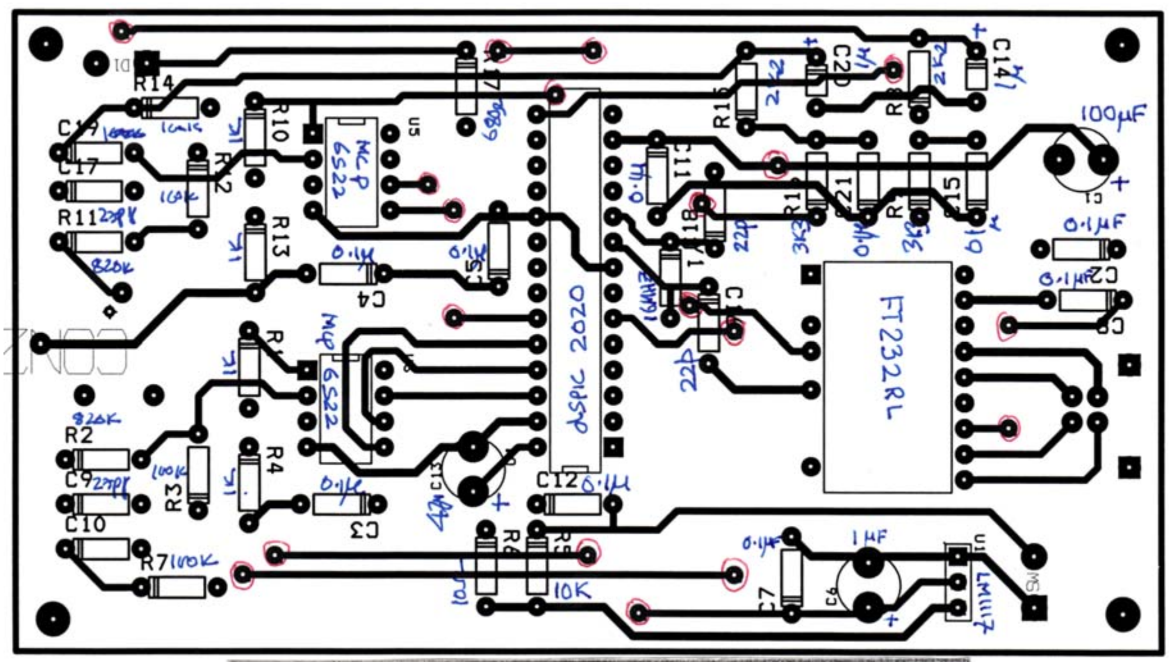


Figure 18, Component Layout

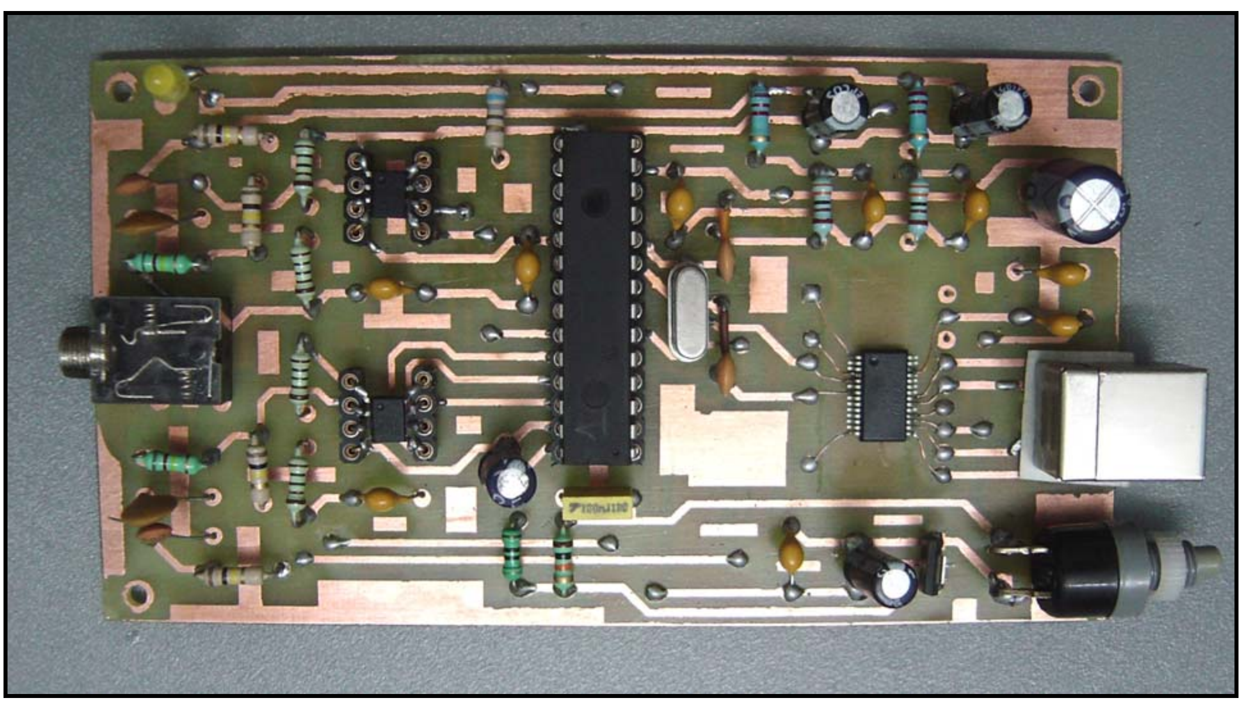
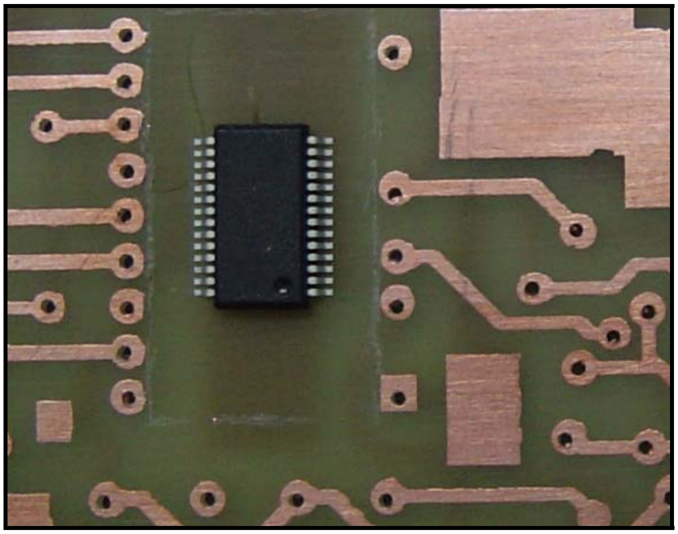
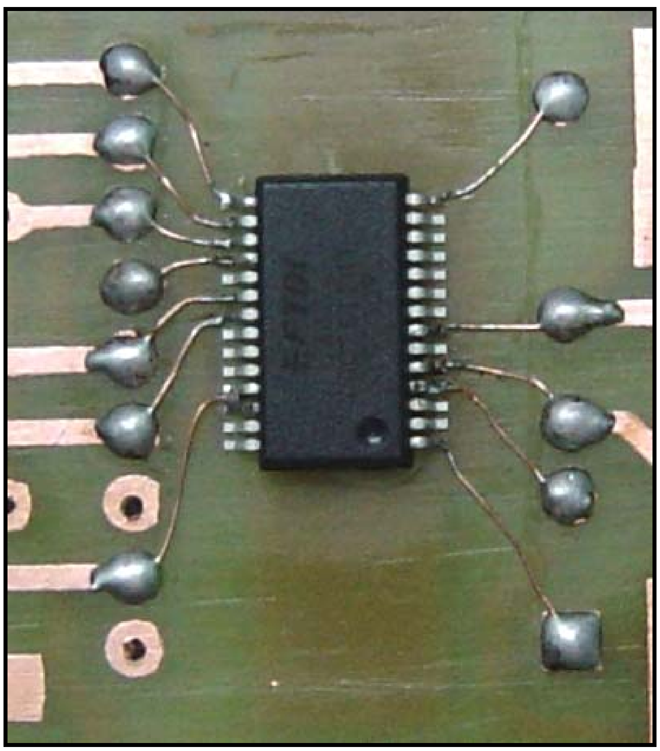


Figure 19, Wired PCB top view

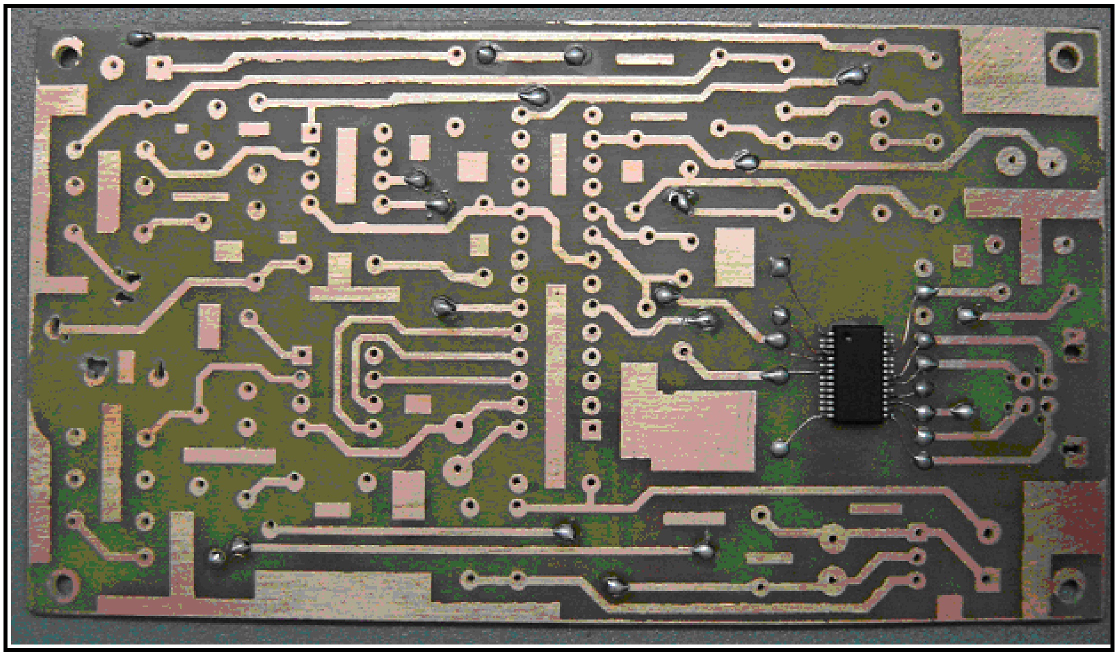
10. Construction Steps



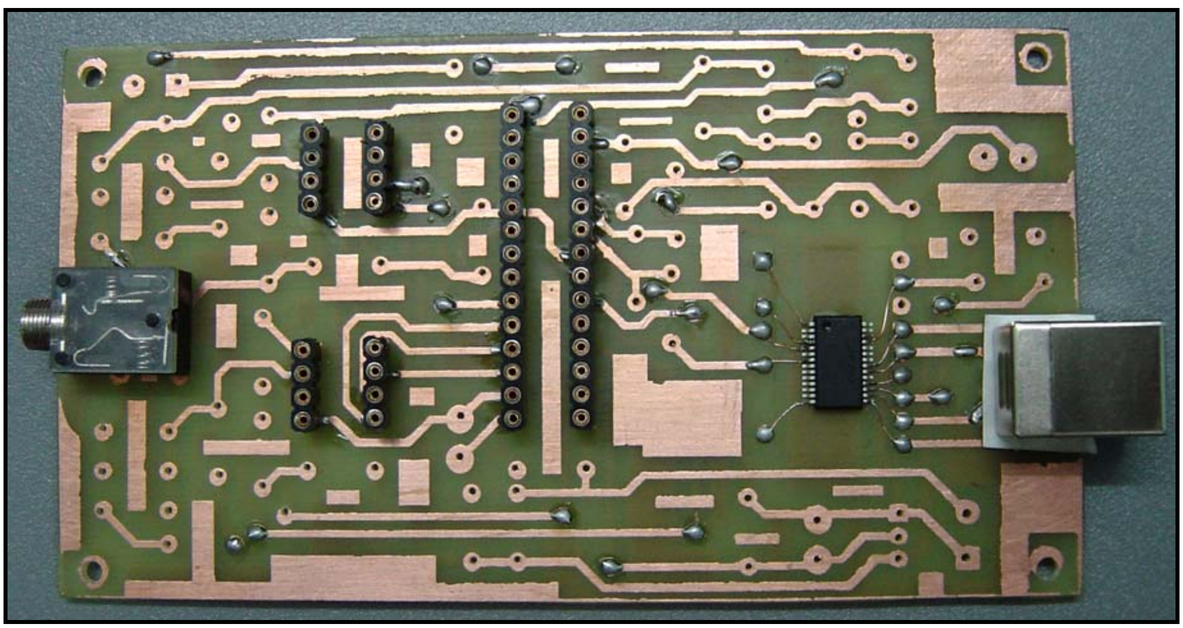
Step 1, Glue the FT232R in place



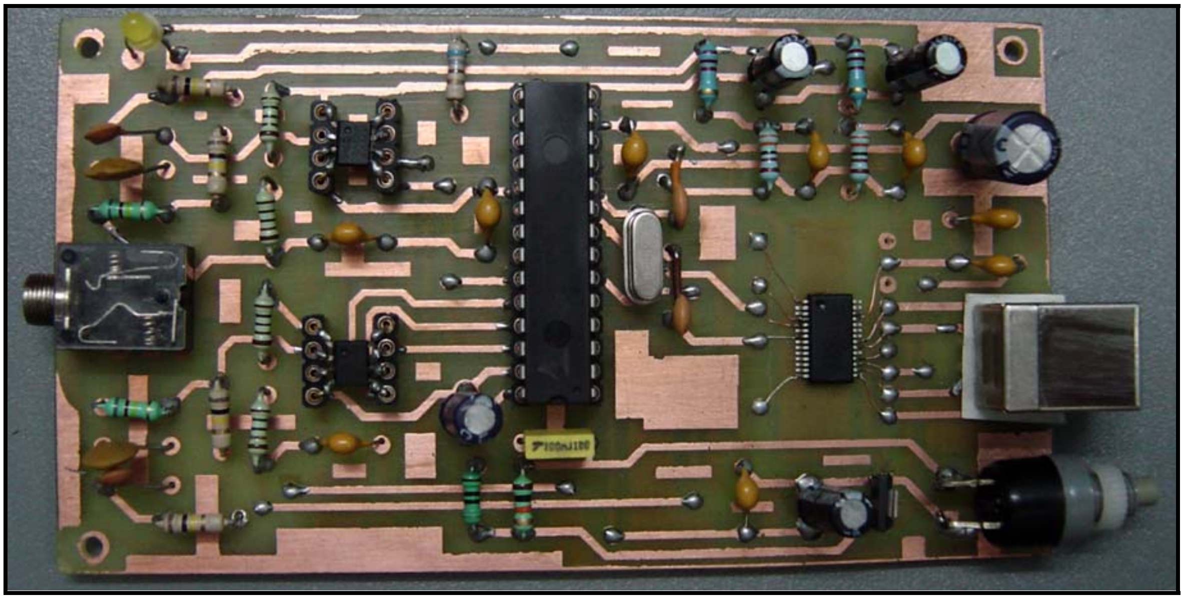
Step 2, Carefully solder only required pins of the FT232R



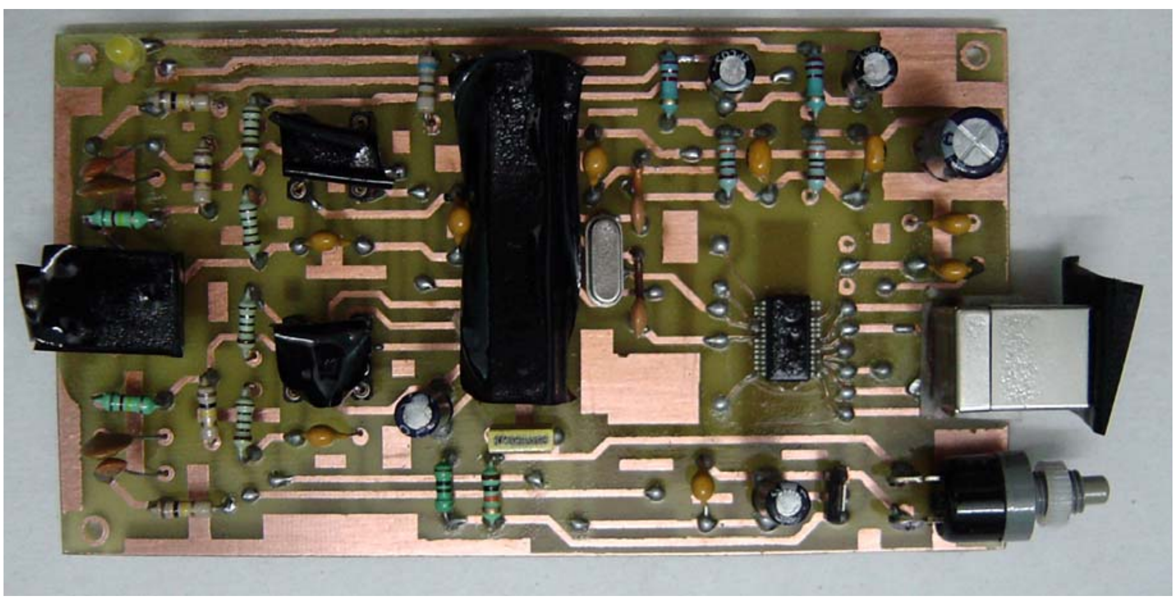
Step 3, Connect the thru-hole-vias by Solder a wire through both sided



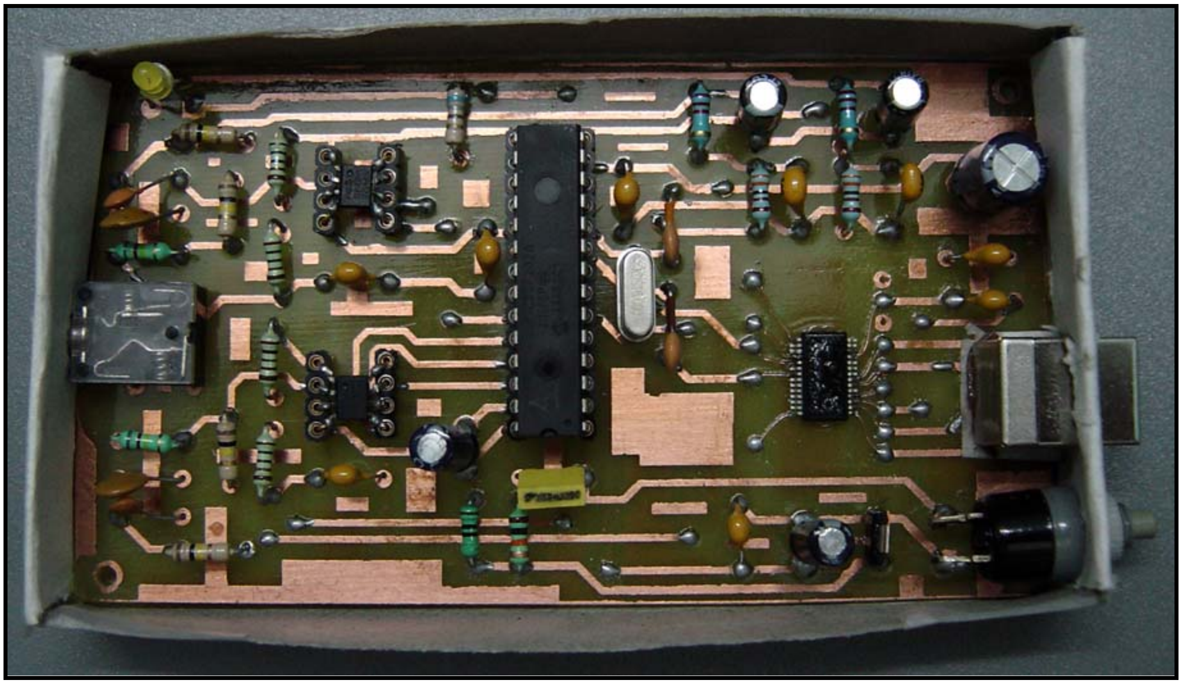
Step 4, Solder the connectors and IC bases



Step 5, Solder the passive components and insert the ICs

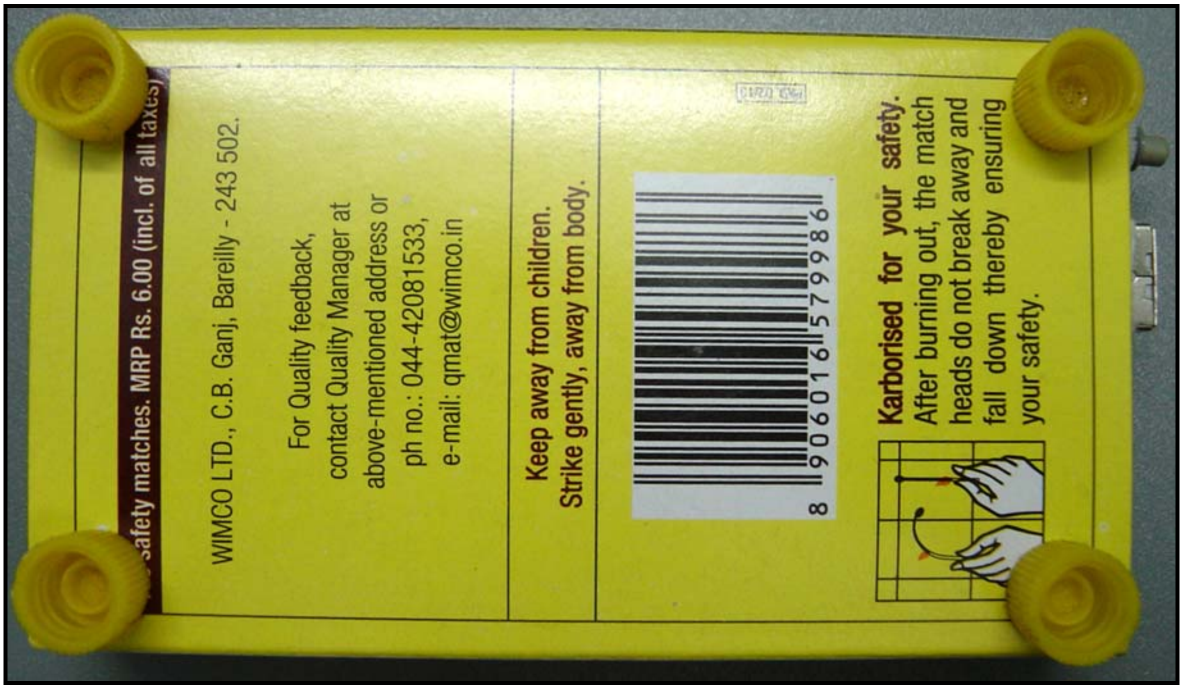


Step 6 Conformal Coating

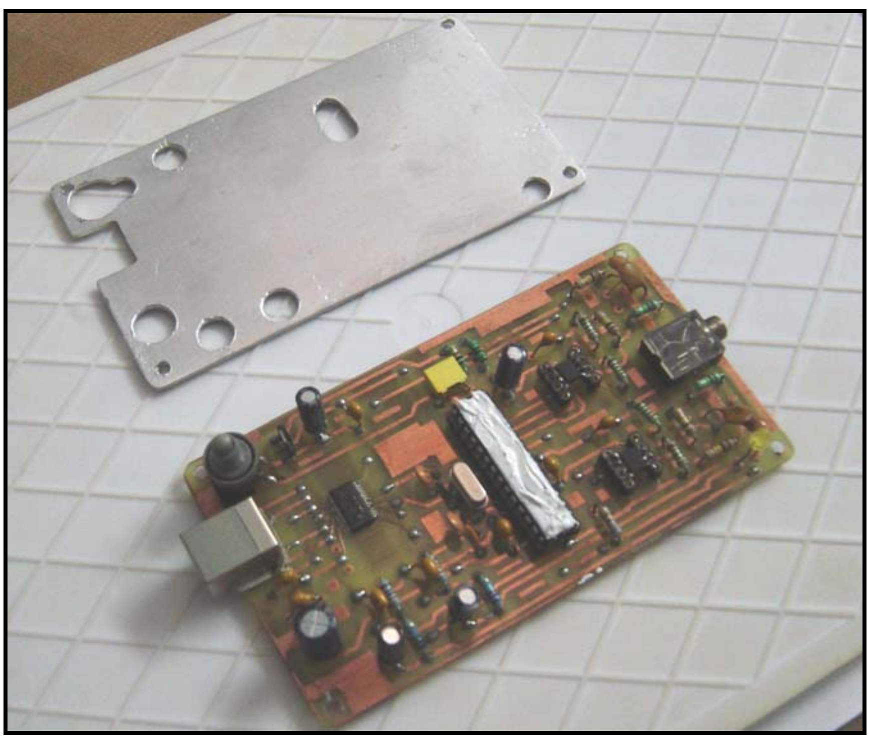


Step 7 Fit Inside Matchbox Sliding Inner Cardboard Container

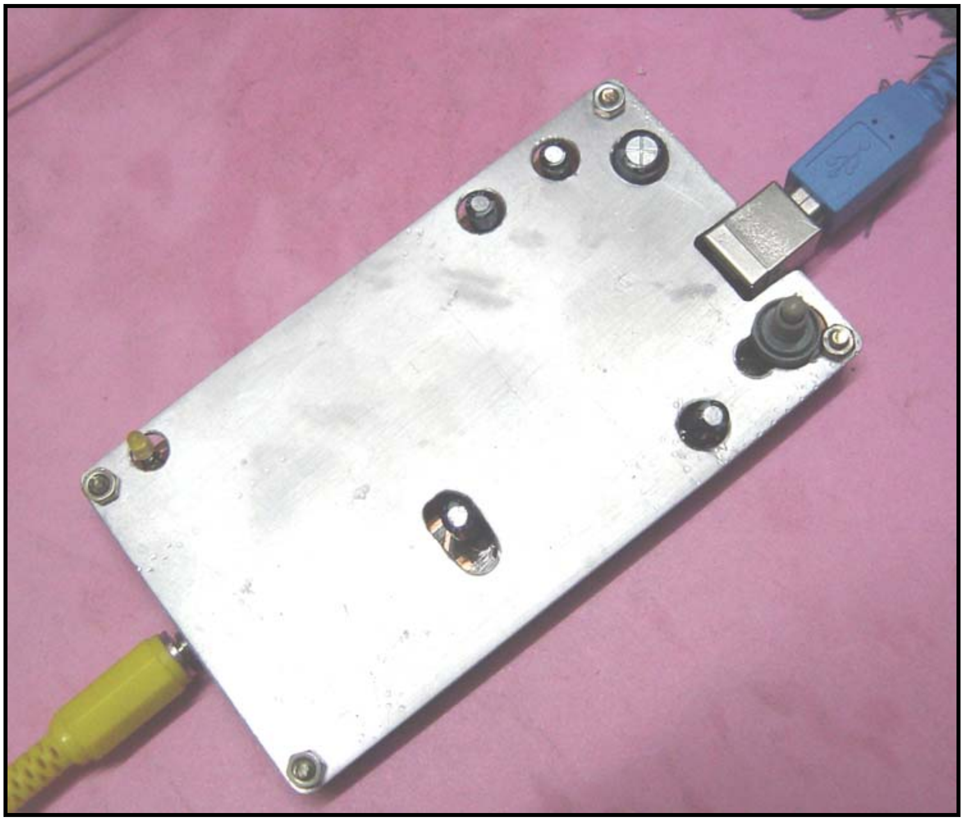
Step 8 Fit inside Matchbox Cover with hole for LED



Step 9 Fit the legs



Step 10 Modify Reset switch to vertical position and prepare heat sink plate. Add heat sink compound over the processor IC.



Step 11 Assemble the heat sink

Step 12 Final assembly into matchbox

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_Scope2 unit.

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

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

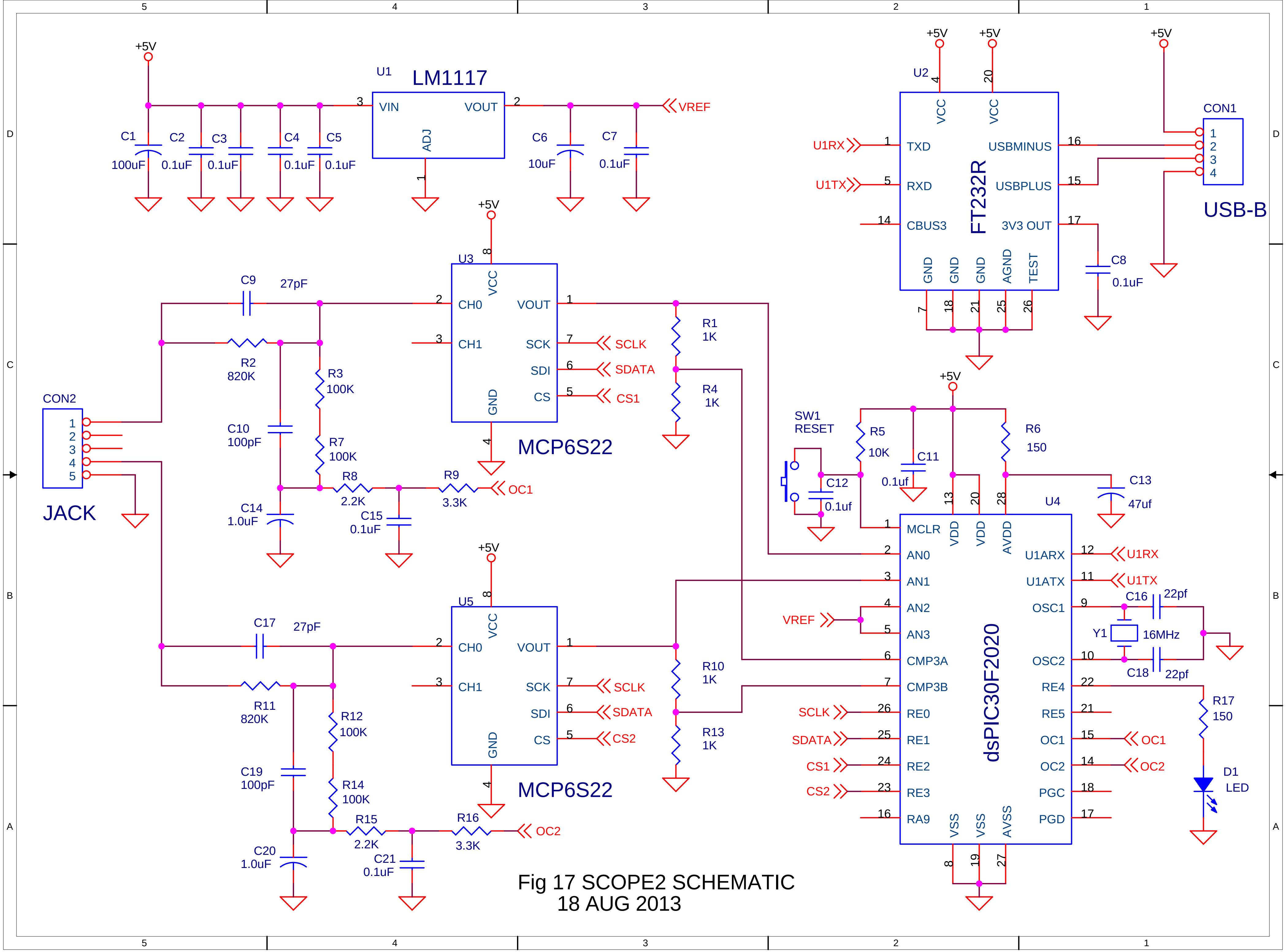


Fig 17 SCOPE2 SCHEMATIC
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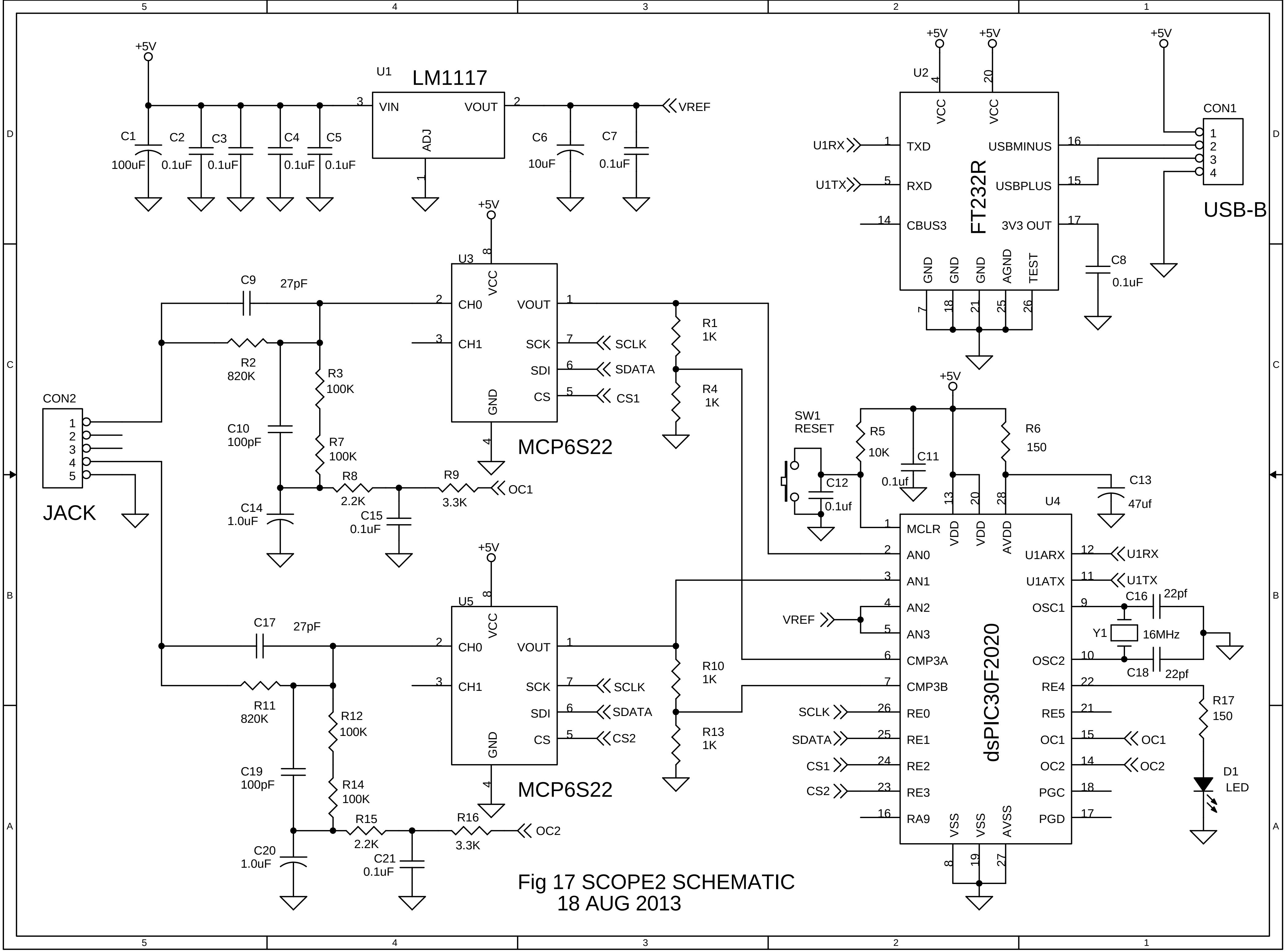

Fig 17 SCOPE2 SCHEMATIC
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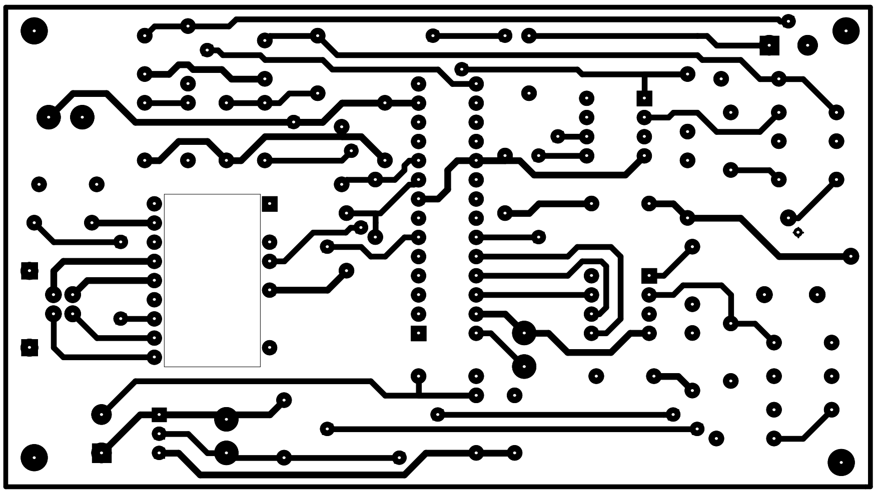
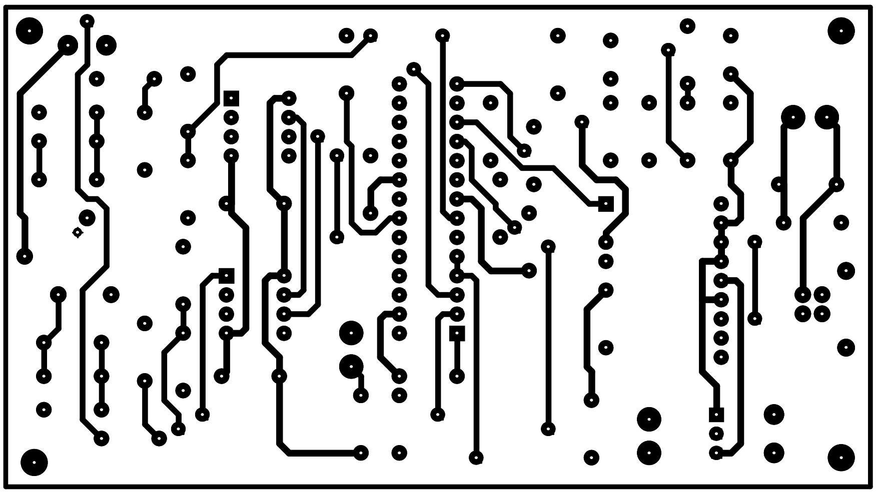
Scope2 PCB 1:1 Top-Mirrored



DRILL CHART				
SYM	DIAM	TOL	QTY	NOTE
+	0.020		1	
	0.028		20	
×	0.034		61	
◇	0.038		72	
⊠	0.056		8	
⊞	0.062		2	
○	0.080		4	
	0.100		6	
TOTAL			174	

Scope 2 PCB 1:1 Bottom



DRILL CHART				
SYM	DIAM	TOL	QTY	NOTE
+	0.020		1	
⊡	0.028		20	
×	0.034		61	
◇	0.038		72	
⊠	0.056		8	
⊞	0.062		2	
○	0.080		4	
⊡	0.100		6	
TOTAL			174	