
INTERNSHIP REPORT

Project:

Color Mixer using four Single Slope
ADCs and four PWM outputs



Submitted by,

Naman Puri (2018UIC3011)
Department of Instrumentation and Control Engineering
NSUT
Dwarka, New Delhi

TABLE OF CONTENTS

- 1. Certificate**
- 2. Acknowledgement**
- 3. Introduction**
- 4. Description**
- 5. About FPGA**
- 6. Ecosystem for FPGA**
- 7. The Block Diagram**
- 8. Schematic and Board Layout**
- 9. Final PCB Picture**
- 10. References**

ACKNOWLEDGEMENT

I owe my deep gratitude to Prof. Dhananjay V. Gadre, Associate Professor, ECE Division at Netaji Subhas University of Technology, for providing me an opportunity to learn Embedded System Design under him and giving all the support and guidance to complete my project ‘FPGA Based Color Mixer using single slope ADC’ duly. Apart from the technical skills learnt and implemented, he provided an environment aimed at learning, exploring, innovating, making, and spreading knowledge.

I would also like to thank my family for their constant support.

INTRODUCTION:

As the FPGAs are inherently digital devices so we can't sense any analog input using it without any external ADC, so during the internship period I started to design single slope ADCs using external comparator to create analog to digital convertor inside the FPGA, whose basic concept is discussed as follows.

In a single slope ADC, an external comparator's output is connected to the FPGA. The negative input terminal of the comparator is connected to the analog voltage that we would like to measure, and the positive input terminal is connected to a capacitor which is being charged by a constant current source. The voltage of the capacitor increases linearly, $dV/dt = I/C$ and when it matches with the voltage connected at the negative terminal, the output of the comparator goes HIGH, this can be sensed by the FPGA and the ADC value can hence be obtained.

To present the output which is matched with the analog input I decided to use a 3W RGB LED, whose intensity would define the given input analog voltage.

So, at the input we would have four potentiometers to vary the analog voltage and at the output we would connect the RGB LED whose intensity will also be controlled, thus requiring four PWM outputs.

DESCRIPTION:

Facing the user, the board is having four linear rotary potentiometers, one for varying the intensity of red color, second for varying the intensity of green color, third for varying the intensity of blue color and fourth for varying the intensity of the resultant color. At the top of the PCB there is a 3W RGB LED which is used to output the red, green and blue colors. At the center lies the brain of the complete system which is Xilinx Spartan 3AN XC3S50AN FPGA soldered on a breakout board.

Below the FPGA is the circuitry for the clock of the complete system, which is made using Schmitt Trigger oscillator oscillating at 12Mhz.

The project also has a reset switch which can be pressed if the system enters in any faulty condition or state.

About FPGA:

Field Programmable Gate Arrays (FPGAs) are semiconductor devices that are based around a matrix of configurable logic blocks (CLBs) connected via programmable interconnects. FPGAs can be reprogrammed to desired application or functionality requirements after manufacturing. This feature distinguishes FPGAs from Application Specific Integrated Circuits (ASICs), which are custom manufactured for specific design tasks. Although one-time programmable (OTP) FPGAs are available, the dominant types are SRAM based which can be reprogrammed as the design evolves.

Some of the key features of the selected FPGA are:

- Xilinx Spartan FPGA - XC3S50AN
- In-system Flash memory of 1 Mb for storing non-volatile data
- 50k gates
- 176 CLBs
- 108 user IO pins
- Can be programmed through JTAG (Joint Test Action Group) protocol

Beginning with Roti, Kapda, Makaana and Internet of our system.

Just as today every human being requires four basic things for his/her survival, similar is the case with the FPGAs. They also require four basic things, which we generally refer to their ecosystem and toolchain.

The four basic requirements for the FPGAs are:

- Power Supply
- System Clock
- Reset, and
- Ability to download program

1. Power Supply

One of the most important sub-part of the embedded system is the power supply. The power supply for the selected IC is divided into four groups, the below table taken from the datasheet shows the required voltage levels.

Symbol	Description	Conditions	Min	Max	Units
V_{CCINT}	Internal supply voltage		-0.5	1.32	V
V_{CCAUX}	Auxiliary supply voltage		-0.5	3.75	V
V_{CCO}	Output driver supply voltage		-0.5	3.75	V
V_{REF}	Input reference voltage		-0.5	$V_{CCO}+0.5$	V

Figure 1: Power Supply Requirements

Making and testing of the power supply board:

The power supply was designed and soldered on a general purpose PCB for testing using two linear low dropout regulators -

- LM1117 - Fixed 3.3V output
- LM1117 adj - Adjustable output voltage, configured to output 1.25V

The figure below shows the images of the general purpose testing board for the power supply system.

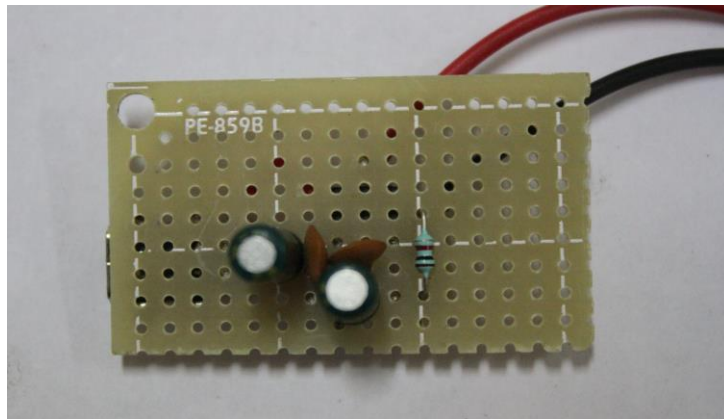


Figure 2 : Power Supply Test Board (Front)

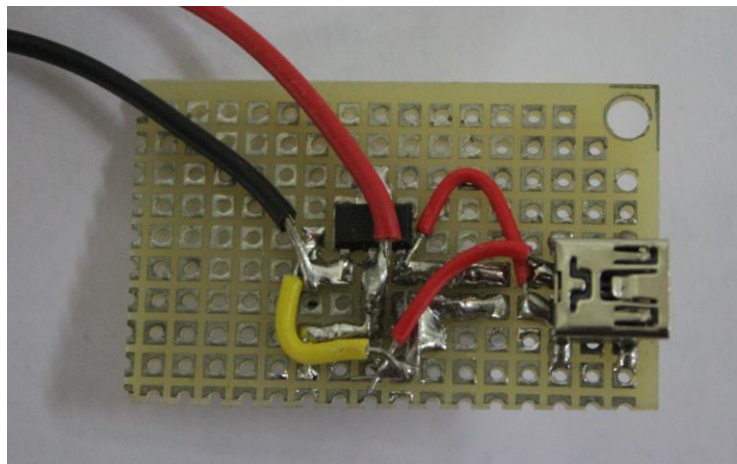


Figure 3: Power Supply Test Board (Bottom)

2. System Clock

The system clock of 12Mhz was designed using an oscillator and schmitt trigger IC 74HC14 and tested on a general purpose board.

The figures below shows the circuit diagram, and the soldered general purpose board for the testing.

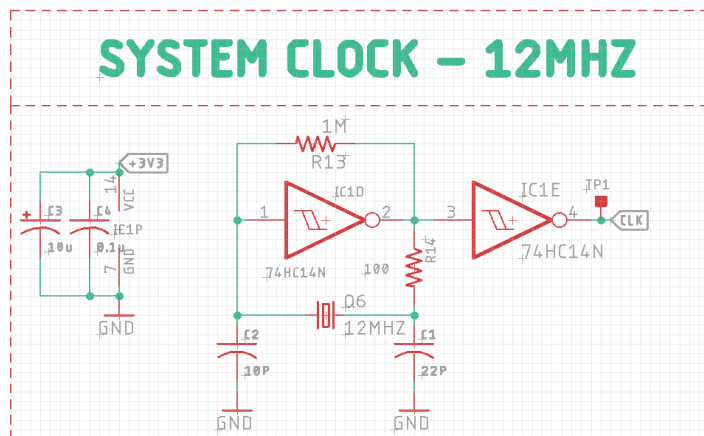


Figure 5 : Circuit Diagram of Clock System

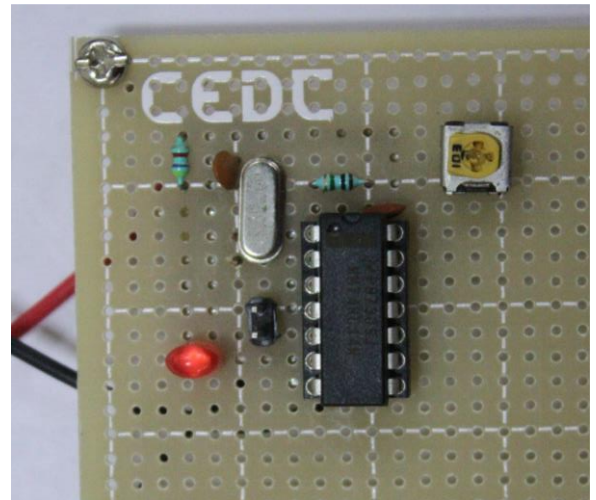


Figure 4: Clock System Test Board

3. Program download Capability

The flash memory of the device can be programmed by the JTAG programmers. A separate PCB was made to test the programming of the device.

The below image shows the JTAG programmer used for programming the FPGA.

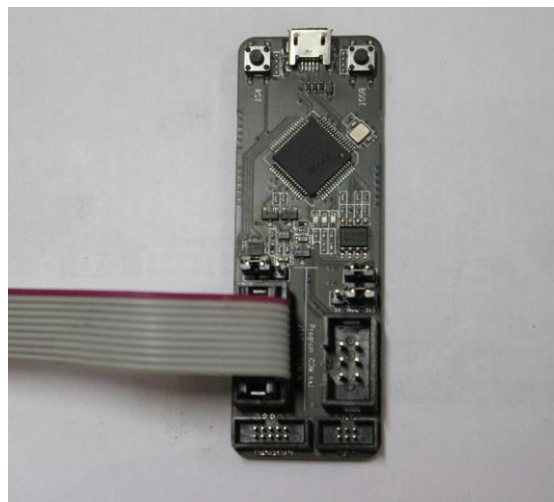


Figure 6: JTAG Programmer

4. Reset

Reset signal is given from a push-button on the final PCB and is incorporated in the state machine to reset the system.

The below image shows the circuit diagram for the reset push-button.

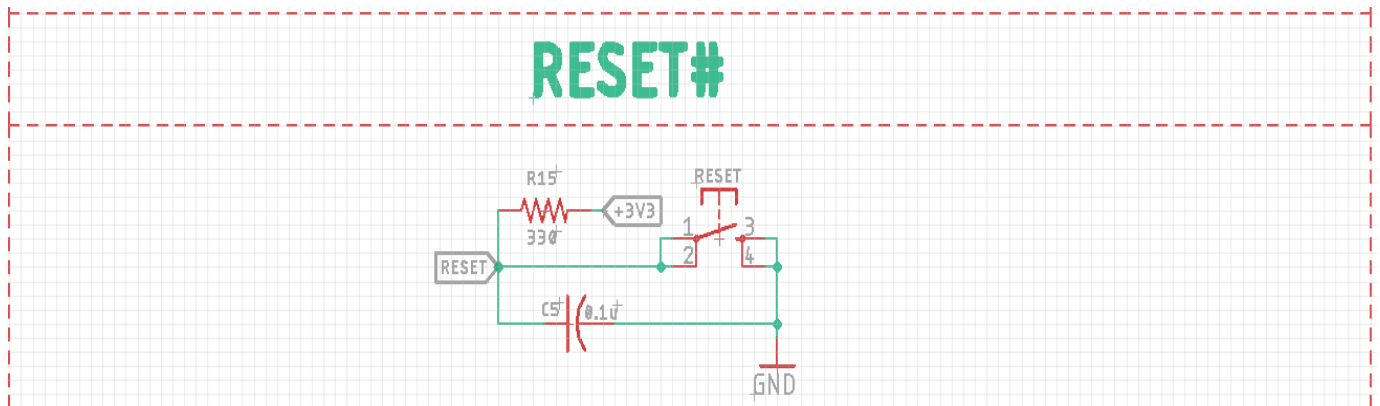


Figure 7: Circuit Diagram Reset Signal

BLOCK DIAGRAM

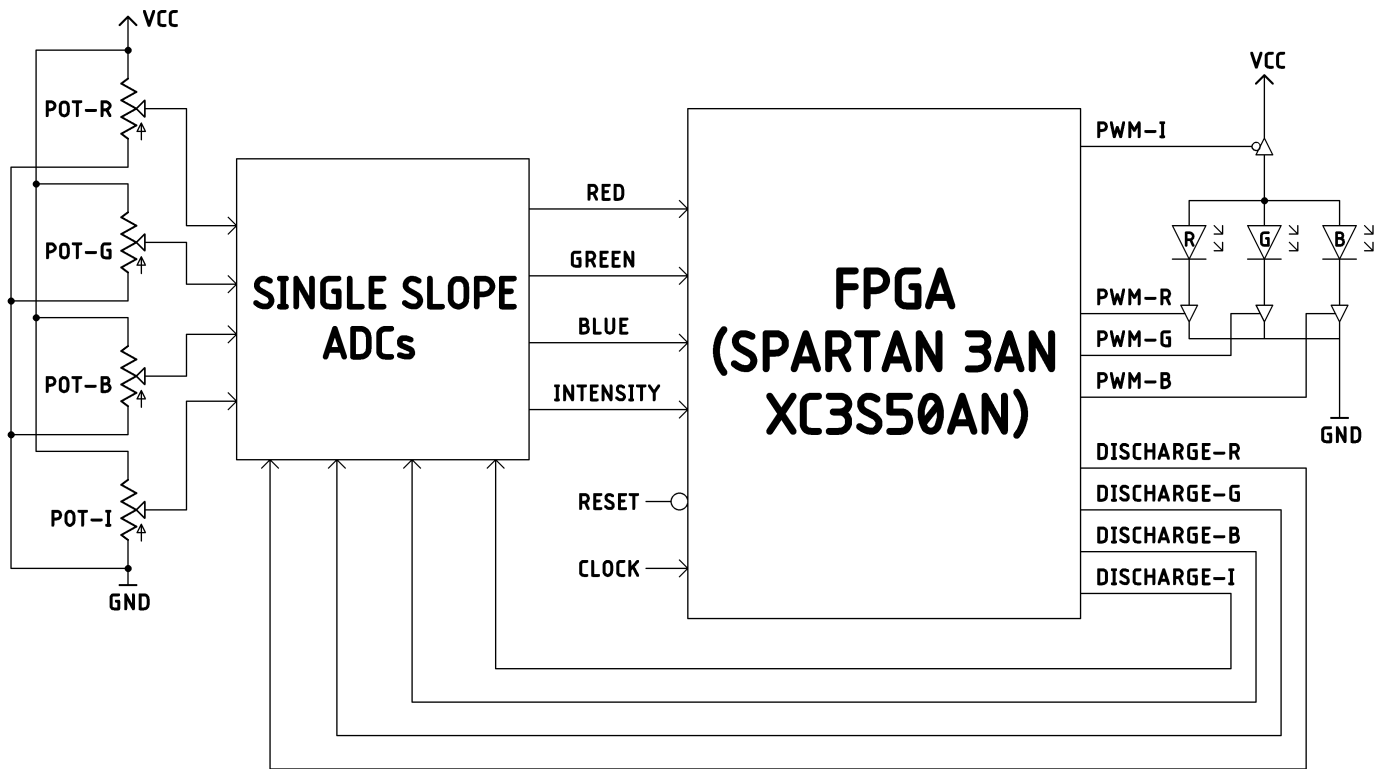


Figure 8: Block Diagram of Complete System

I/O BLOCKS:

- 1. Reset switch:** To Reset in any given condition.
- 2. 3W RGB LED:** To output Red, Green and Blue color.
- 3. Single slope ADCs:** Constructed using a comparator, they output signal based on comparison of two signals, one being the voltage of the linearly charged capacitor while other being the voltage from the potentiometer,
- 4. Linear Rotary Potentiometers:** To give analog input to the single slope ADCs.

CONTROL AND DATA PATH:

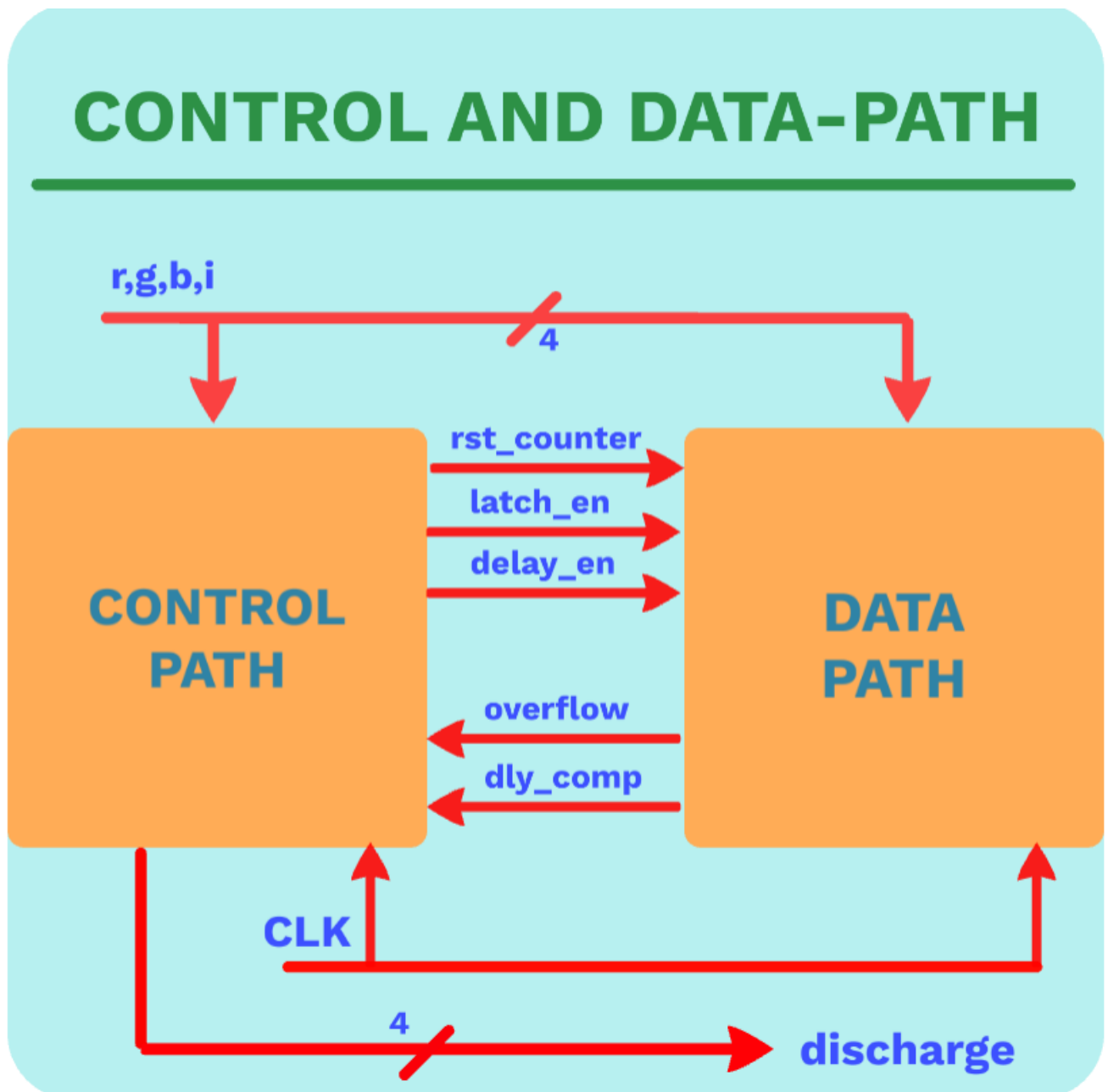


Figure 9: Control and Data Path

CONTROL PATH:

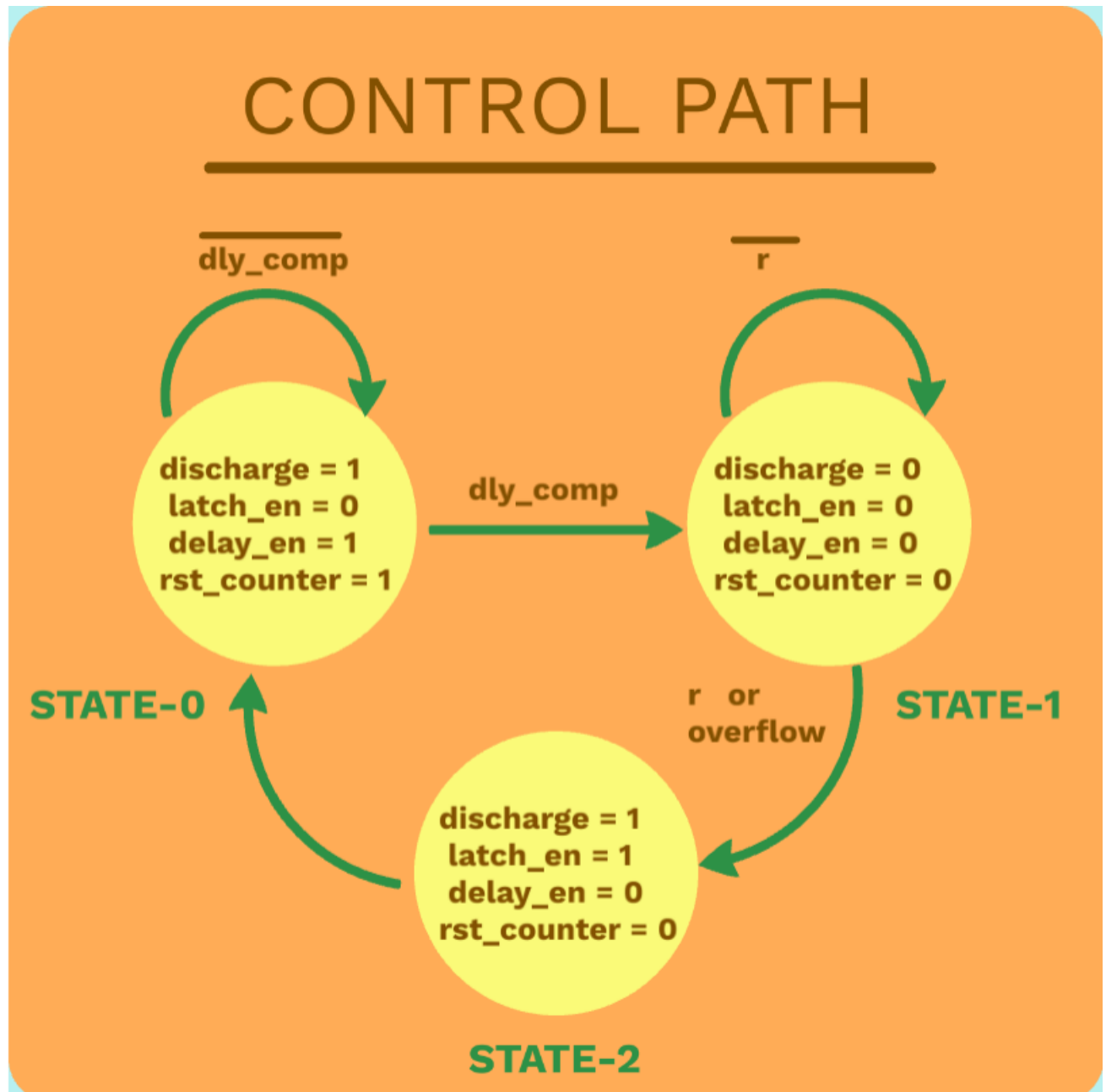


Figure 10: Control Path

ELEMENTS OF DATA PATH:

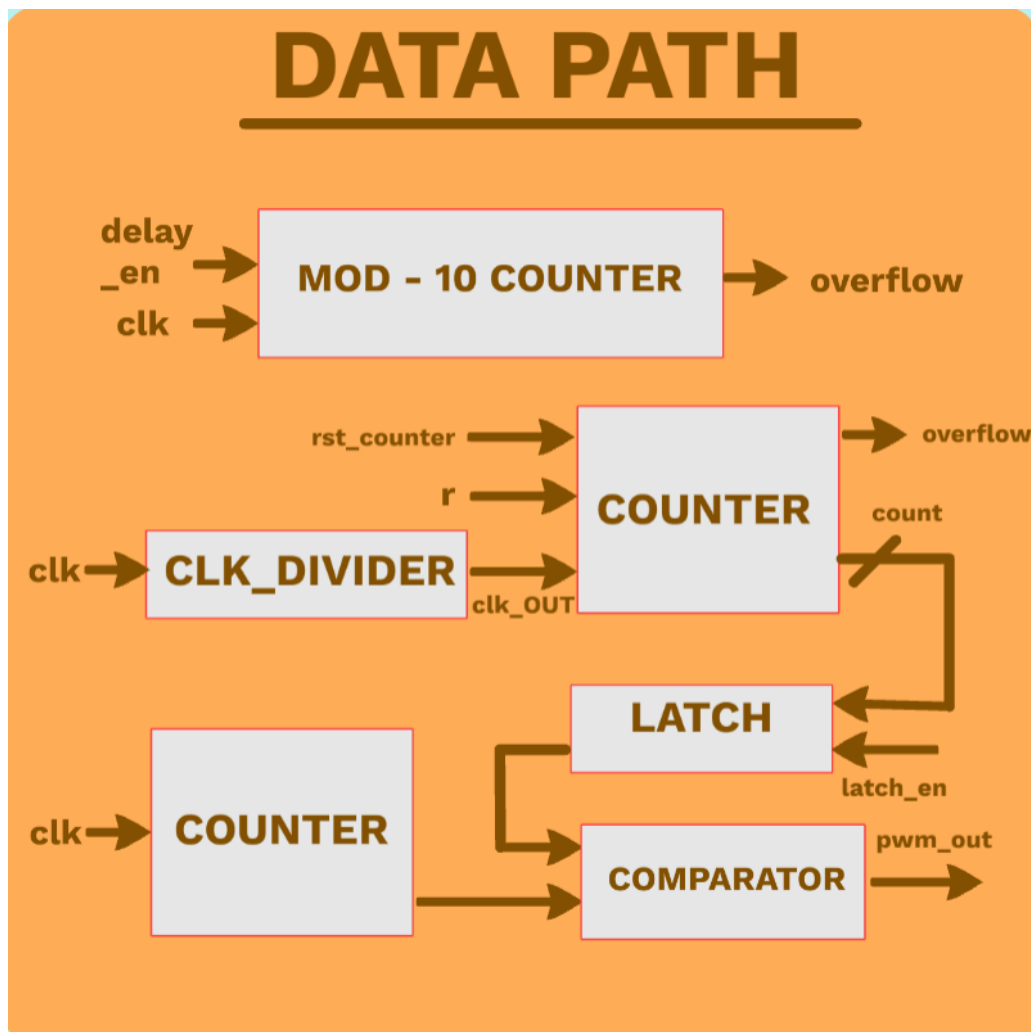


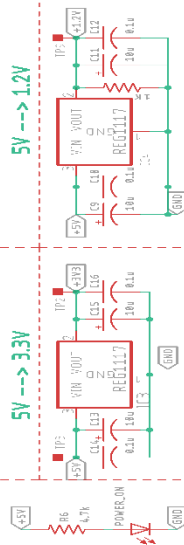
Figure 11: Data Path

- 1. Mod - 10 Counter:** This is used to generate some delay to discharge the capacitor to start the new cycle.
- 2. 8 bit Counter1:** It is used to count until the compare match happens on the external comparator to measure the analog input voltage.
- 3. Clock Divider:** As certain part of the project demands a slower operating clock so forming a suitably slow clock, clock dividers are required.
- 4. 8 bit Counter2:** This counter is used to generate the PWM output.
- 5. 8 bit Latch:** Latch is used to hold the counter1 value so that it can be cleared for the next cycle.
- 6. 8 bit Comparator:** It is needed to compare the values of the latch and the counter and hence its output would be the PWM signal.

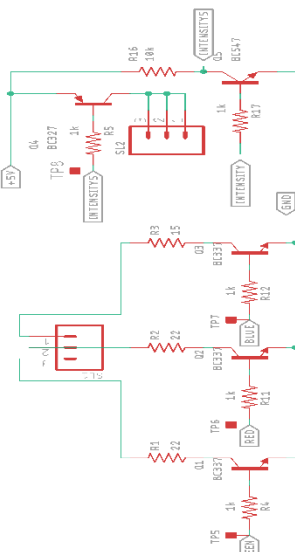
Schematic made using EAGLE:

FPGA BASED 4x SINGLE SLOPE ADCs + 4x PWM

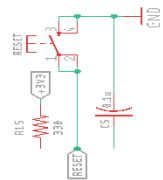
POWER SUPPLY



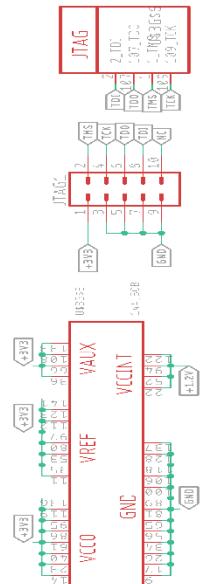
RGB - LED (3W)



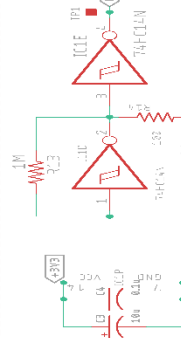
RESET#



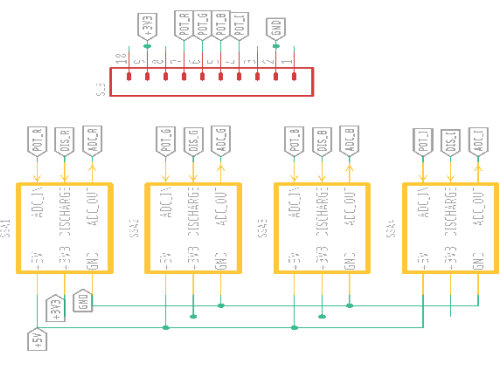
SPARTAN-3AN FGA 144 PIN BOB



SYSTEM CLOCK - 12MHZ



4 ADCs + 4 POTs



SIDE 1		SIDE 3		SIDE 0	
37C IC 294C	34	155 BOC 3	3	3.10.132.3	
38C IC 294B	35	152 IC 0.12M 300C3	4	4.10.131.3	
39C IC 294B	36	152 IC 0.12M 300C3	5	5.10.130.3	
40C IC 294B	37	152 IC 0.12M 300C3	6	6.10.131.3	
41C IC 294B	38	152 IC 0.12M 300C3	7	7.10.133.3	05301
42C IC 294B	39	152 IC 0.12M 300C3	8	8.10.130.3	
43C IC 294B	40	152 IC 0.12M 300C3	9	9.10.130.3	
44C IC 294B	41	152 IC 0.12M 300C3	10	10.10.130.3	
45C IC 294B	42	152 IC 0.12M 300C3	11	11.10.130.3	
46C IC 294B	43	152 IC 0.12M 300C3	12	12.10.130.3	
47C IC 294B	44	152 IC 0.12M 300C3	13	13.10.130.3	
48C IC 294B	45	152 IC 0.12M 300C3	14	14.10.130.3	
49C IC 294B	46	152 IC 0.12M 300C3	15	15.10.130.3	
50C IC 294B	47	152 IC 0.12M 300C3	16	16.10.130.3	
51C IC 294B	48	152 IC 0.12M 300C3	17	17.10.130.3	
52C IC 294B	49	152 IC 0.12M 300C3	18	18.10.130.3	
53C IC 294B	50	152 IC 0.12M 300C3	19	19.10.130.3	
54C IC 294B	51	152 IC 0.12M 300C3	20	20.10.130.3	
55C IC 294B	52	152 IC 0.12M 300C3	21	21.10.130.3	
56C IC 294B	53	152 IC 0.12M 300C3	22	22.10.130.3	
57C IC 294B	54	152 IC 0.12M 300C3	23	23.10.130.3	
58C IC 294B	55	152 IC 0.12M 300C3	24	24.10.130.3	
59C IC 294B	56	152 IC 0.12M 300C3	25	25.10.130.3	
60C IC 294B	57	152 IC 0.12M 300C3	26	26.10.130.3	
61C IC 294B	58	152 IC 0.12M 300C3	27	27.10.130.3	
62C IC 294B	59	152 IC 0.12M 300C3	28	28.10.130.3	
63C IC 294B	60	152 IC 0.12M 300C3	29	29.10.130.3	
64C IC 294B	61	152 IC 0.12M 300C3	30	30.10.130.3	
65C IC 294B	62	152 IC 0.12M 300C3	31	31.10.130.3	
66C IC 294B	63	152 IC 0.12M 300C3	32	32.10.130.3	
67C IC 294B	64	152 IC 0.12M 300C3	33	33.10.130.3	
68C IC 294B	65	152 IC 0.12M 300C3	34	34.10.130.3	
69C IC 294B	66	152 IC 0.12M 300C3	35	35.10.130.3	
70C IC 294B	67	152 IC 0.12M 300C3	36	36.10.130.3	
71C IC 294B	68	152 IC 0.12M 300C3	37	37.10.130.3	
72C IC 294B	69	152 IC 0.12M 300C3	38	38.10.130.3	
73C IC 294B	70	152 IC 0.12M 300C3	39	39.10.130.3	
74C IC 294B	71	152 IC 0.12M 300C3	40	40.10.130.3	
75C IC 294B	72	152 IC 0.12M 300C3	41	41.10.130.3	
76C IC 294B	73	152 IC 0.12M 300C3	42	42.10.130.3	
77C IC 294B	74	152 IC 0.12M 300C3	43	43.10.130.3	
78C IC 294B	75	152 IC 0.12M 300C3	44	44.10.130.3	
79C IC 294B	76	152 IC 0.12M 300C3	45	45.10.130.3	
80C IC 294B	77	152 IC 0.12M 300C3	46	46.10.130.3	
81C IC 294B	78	152 IC 0.12M 300C3	47	47.10.130.3	
82C IC 294B	79	152 IC 0.12M 300C3	48	48.10.130.3	
83C IC 294B	80	152 IC 0.12M 300C3	49	49.10.130.3	
84C IC 294B	81	152 IC 0.12M 300C3	50	50.10.130.3	
85C IC 294B	82	152 IC 0.12M 300C3	51	51.10.130.3	
86C IC 294B	83	152 IC 0.12M 300C3	52	52.10.130.3	
87C IC 294B	84	152 IC 0.12M 300C3	53	53.10.130.3	
88C IC 294B	85	152 IC 0.12M 300C3	54	54.10.130.3	
89C IC 294B	86	152 IC 0.12M 300C3	55	55.10.130.3	
90C IC 294B	87	152 IC 0.12M 300C3	56	56.10.130.3	
91C IC 294B	88	152 IC 0.12M 300C3	57	57.10.130.3	
92C IC 294B	89	152 IC 0.12M 300C3	58	58.10.130.3	
93C IC 294B	90	152 IC 0.12M 300C3	59	59.10.130.3	
94C IC 294B	91	152 IC 0.12M 300C3	60	60.10.130.3	
95C IC 294B	92	152 IC 0.12M 300C3	61	61.10.130.3	
96C IC 294B	93	152 IC 0.12M 300C3	62	62.10.130.3	
97C IC 294B	94	152 IC 0.12M 300C3	63	63.10.130.3	
98C IC 294B	95	152 IC 0.12M 300C3	64	64.10.130.3	
99C IC 294B	96	152 IC 0.12M 300C3	65	65.10.130.3	
100C IC 294B	97	152 IC 0.12M 300C3	66	66.10.130.3	
101C IC 294B	98	152 IC 0.12M 300C3	67	67.10.130.3	
102C IC 294B	99	152 IC 0.12M 300C3	68	68.10.130.3	
103C IC 294B	100	152 IC 0.12M 300C3	69	69.10.130.3	
104C IC 294B	101	152 IC 0.12M 300C3	70	70.10.130.3	
105C IC 294B	102	152 IC 0.12M 300C3	71	71.10.130.3	
106C IC 294B	103	152 IC 0.12M 300C3	72	72.10.130.3	
107C IC 294B	104	152 IC 0.12M 300C3	73	73.10.130.3	
108C IC 294B	105	152 IC 0.12M 300C3	74	74.10.130.3	
109C IC 294B	106	152 IC 0.12M 300C3	75	75.10.130.3	
110C IC 294B	107	152 IC 0.12M 300C3	76	76.10.130.3	
111C IC 294B	108	152 IC 0.12M 300C3	77	77.10.130.3	
112C IC 294B	109	152 IC 0.12M 300C3	78	78.10.130.3	
113C IC 294B	110	152 IC 0.12M 300C3	79	79.10.130.3	
114C IC 294B	111	152 IC 0.12M 300C3	80	80.10.130.3	
115C IC 294B	112	152 IC 0.12M 300C3	81	81.10.130.3	
116C IC 294B	113	152 IC 0.12M 300C3	82	82.10.130.3	
117C IC 294B	114	152 IC 0.12M 300C3	83	83.10.130.3	
118C IC 294B	115	152 IC 0.12M 300C3	84	84.10.130.3	
119C IC 294B	116	152 IC 0.12M 300C3	85	85.10.130.3	
120C IC 294B	117	152 IC 0.12M 300C3	86	86.10.130.3	
121C IC 294B	118	152 IC 0.12M 300C3	87	87.10.130.3	
122C IC 294B	119	152 IC 0.12M 300C3	88	88.10.130.3	
123C IC 294B	120	152 IC 0.12M 300C3	89	89.10.130.3	
124C IC 294B	121	152 IC 0.12M 300C3	90	90.10.130.3	
125C IC 294B	122	152 IC 0.12M 300C3	91	91.10.130.3	
126C IC 294B	123	152 IC 0.12M 300C3	92	92.10.130.3	
127C IC 294B	124	152 IC 0.12M 300C3	93	93.10.130.3	
128C IC 294B	125	152 IC 0.12M 300C3	94	94.10.130.3	
129C IC 294B	126	152 IC 0.12M 300C3	95	95.10.130.3	
130C IC 294B	127	152 IC 0.12M 300C3	96	96.10.130.3	
131C IC 294B	128	152 IC 0.12M 300C3	97	97.10.130.3	
132C IC 294B	129	152 IC 0.12M 300C3	98	98.10.130.3	
133C IC 294B	130	152 IC 0.12M 300C3	99	99.10.130.3	
134C IC 294B	131	152 IC 0.12M 300C3	100	100.10.130.3	
135C IC 294B	132	152 IC 0.12M 300C3	101	101.10.130.3	
136C IC 294B	133	152 IC 0.12M 300C3	102	102.10.130.3	
137C IC 294B	134	152 IC 0.12M 300C3	103	103.10.130.3	
138C IC 294B	135	152 IC 0.12M 300C3	104	104.10.130.3	
139C IC 294B	136	152 IC 0.12M 300C3	105	105.10.130.3	
140C IC 294B	137	152 IC 0.12M 300C3	106	106.10.130.3	
141C IC 294B	138	152 IC 0.12M 300C3	107	107.10.130.3	
142C IC 294B	139	152 IC 0.12M 300C3	108	108.10.130.3	
143C IC 294B	140	152 IC 0.12M 300C3	109	109.10.130.3	
144C IC 294B	141	152 IC 0.12M 300C3	110	110.10.130.3	
145C IC 294B	142	152 IC 0.12M 300C3	111	111.10.130.3	
146C IC 294B	143	152 IC 0.12M 300C3	112	112.10.130.3	
147C IC 294B	144	152 IC 0.12M 300C3	113	113.10.130.3	
148C IC 294B	145	152 IC 0.12M 300C3	114	114.10.130.3	
149C IC 294B	146	152 IC 0.12M 300C3	115	115.10.130.3	
150C IC 294B	147	152 IC 0.12M 300C3	116	116.10.130.3	
151C IC 294B	148	152 IC 0.12M 300C3	117	117.10.130.3	
152C IC 294B	149	152 IC 0.12M 300C3	118	118.10.130.3	
153C IC 294B	150	152 IC 0.12M 300C3	119	119.10.130.3	
154C IC 294B	151	152 IC 0.12M 300C3	120	120.10.130.3	
155C IC 294B	152	152 IC 0.12M 300C3	121	121.10.130.3	
156C IC 294B	153	152 IC 0.12M 300C3	122	122.10.130.3	
157C IC 294B	154	152 IC 0.12M 300C3	123	123.10.130.3	
158C IC 294B	155	152 IC 0.12M 300C3	124	124.10.130.3	
159C IC 294B	156	152 IC 0.12M 300C3	125	125.10.130.3	
160C IC 294B	157	152 IC 0.12M 300C3	126	126.10.130.3	
161C IC 294B	158	152 IC 0.12M 300C3	127	127.10.130.3	
162C IC 294B	159	152 IC 0.12M 300C3	128	128.10.130.3	
163C IC 294B	160	152 IC 0.12M 300C3	129	129.10.130.3	
164C IC 294B	161	152 IC 0.12M 300C3	130	130.10.130.3	
165C IC 294B	162	152 IC 0.12M 300C3	131	131.10.130.3	
166C IC 294B	163	152 IC 0.12M 300C3	132	132.10.130.3	
167C IC 294B	164	152 IC 0.12M 300C3	133	133.10.130.3	
168C IC 294B	165	152 IC 0.12M 300C3	134	134.10.130.3	
169C IC 294B	166	152 IC 0.12M 300C3	135	135.10.130.3	
170C IC 294B	167	152 IC 0.12M 300C3	136	136.10.130.3	
171C IC 294B	168	152 IC 0.12M 300C3	137	137.10.130.3	
172C IC 294B	169	152 IC 0.12M 300C3	138	138.10.130.3	
173C IC 294B	170	152 IC 0.12M 300C3	139	139.10.130.3	
174C IC 294B	171	152 IC 0.12M 300C3	140	140.10.130.3	
175C IC 294B	172	152 IC 0.12M 300C3	141	141.10.130.3	
176C IC 294B	173	152 IC 0.12M 300C3	142	142.10.130.3	
177C IC 294B	174	152 IC 0.12M 300C3	143	143.10.130.3	
178C IC 294B	175	152 IC 0.12M 300C3	144	144.10.130.3	
179C IC 294B	176	152 IC 0.12M 300C3	145	145.10.130.3	
180C IC 294B	177	152 IC 0.12M 300C3	146	146.10.130.3	
181C IC 294B	178	152 IC 0.12M 300C3	147	147.10.130.3	
182C IC 294B	179	152 IC 0.12M 300C3	148	148.10.130.3	
183C IC 294B	180	152 IC 0.12M 300C3	149	149.10.130.3	
184C IC 294B	181	152 IC 0.12M 300C3	150	150.10.130.3	
185C IC 294B	182	152 IC 0.12M 300C3	151	151.10.130.3	
186C IC 294B	183	152 IC 0.12M 300C3	152	152.10.130.3	
187C IC 294B	184	152 IC 0.12M 300C3	153	153.10.130.3	
188C IC 294B	185	152 IC 0.12M 300C3	154	154.10.130.3	
189C IC 294B	186	152 IC 0.12M 300C3	155	155.10.130.3	
190C IC 294B	187	152 IC 0.12M 300C3	156	156.10.130.3	
191C IC 294B	188	152 IC 0.12M 300C3	157	157.10.130.3	
192C IC 294B	189	152 IC 0.12M 300C3	158	158.10.130.3	
193C IC 294B	190	152 IC 0.12M 300C3	159	159.10.130.3	
194C IC 294B	191	152 IC 0.12M 300C3	160	160.10.130.3	
195C IC 294B	192	152 IC 0.12M 300C3	161	161.10.130.3	
196C IC 294B	193	152 IC 0.12M 300C3	162	162.10.130.3	
197C IC 294B	194	152 IC 0.12M 300C3	163	163.10.130.3	
198C IC 294B	195	152 IC 0.12M 300C3	164	164.10.130.3	
199C IC 294B	196	152 IC 0.12M 300C3	165	165.10.130.3	
200C IC 294B	197	152 IC 0.12M 300C3	166	166.10.130.3	
201C IC 294B	198	152 IC 0.12M 300C3	167	1	

Board Layout:

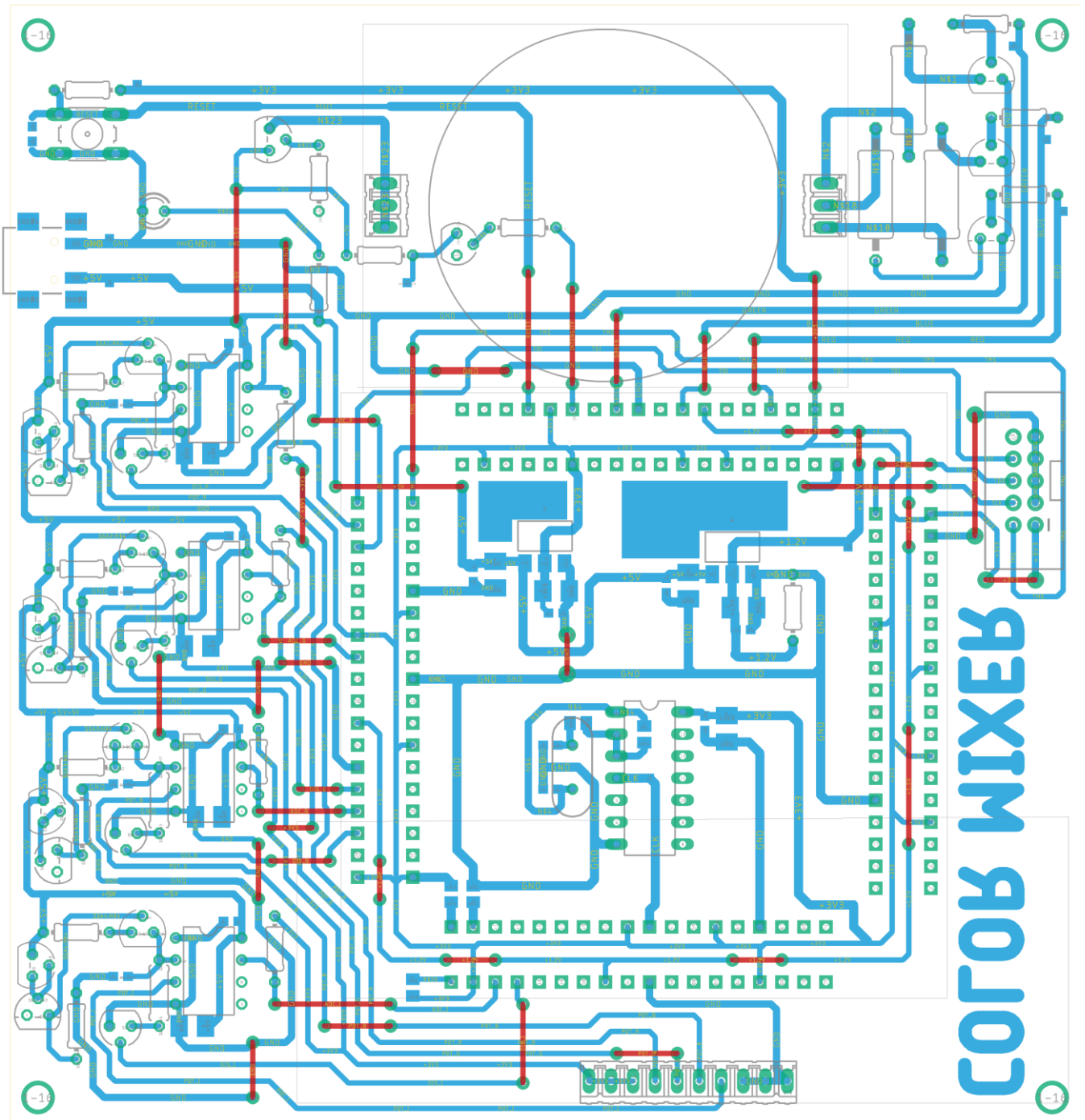


Figure 12: Board Layout

FINAL PCB:

1. Fabricated:

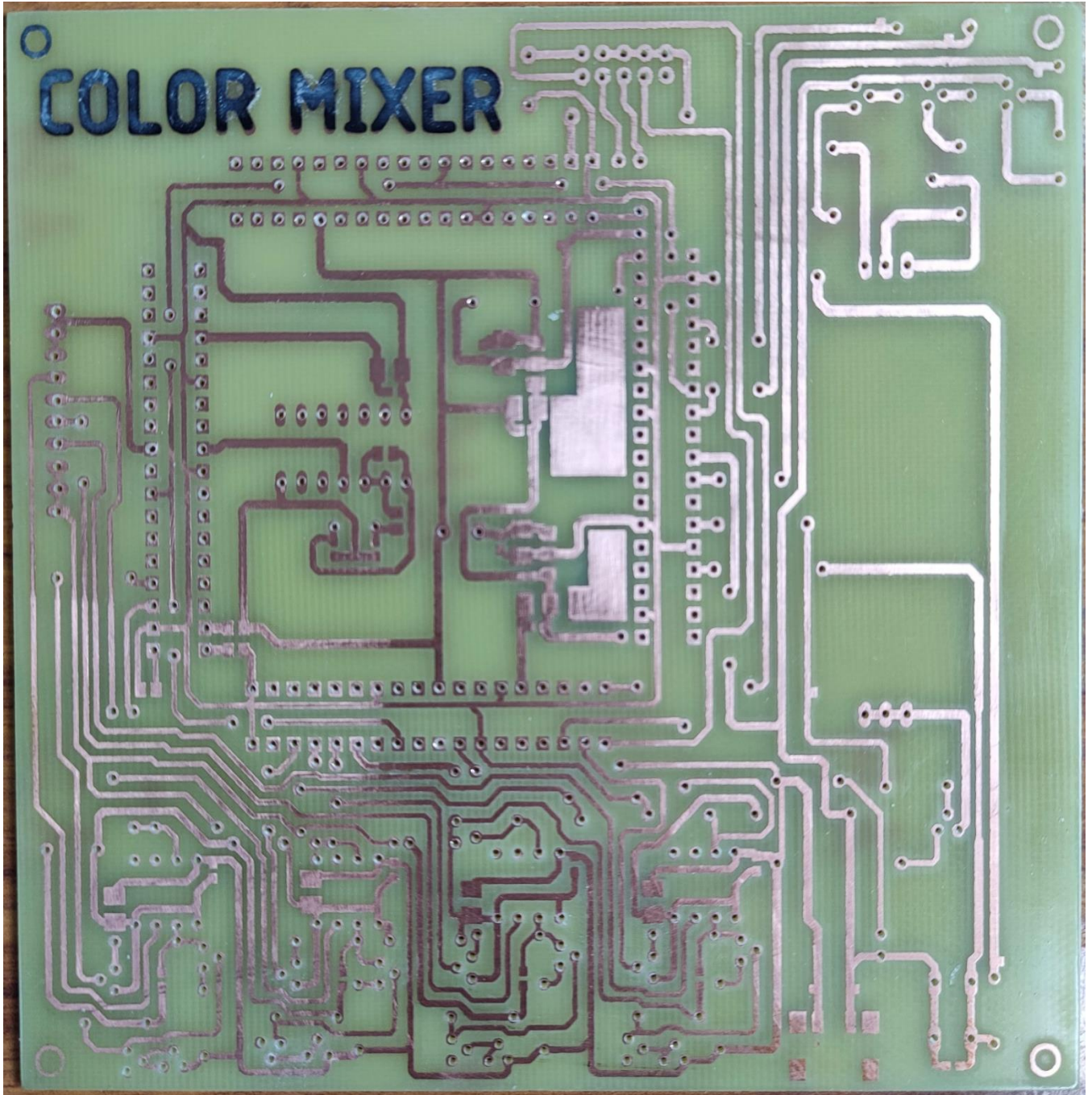


Figure 13: Fabricated PCB

2. Complete PCB with components soldered:



Figure 14: Completely Soldered PCB

References:

- Spartan 3AN XC3S50AN, Datasheet
- LM311, Datasheet
- REG1117, Datasheet
- <http://www.circuitstoday.com/understanding-fpga-and-cpld>
- <https://nptel.ac.in/courses/106/105/106105165/>
- https://www.tutorialspoint.com/vlsi_design/vlsi_design_verilog_introduction.htm
- <https://www.xilinx.com/products/silicon-devices/fpga/what-is-an-fpga.html>