University of Central Lancashire

School of Engineering

EL3250: Microcontrollers
B.Eng. (Hons.) Robotics Engineering

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Signal Measurement Assignment

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Date: 8-12-2019

1. Introduction

The project deals with signal generation using Oscilloscope and creating a system for measuring and recording the generated analogue signal. The system captures a varying voltage in the range 0-3.3 V to within +/- 1mV and performs some processing on it for display on the serial terminal. The system lights a warning LED if the voltage rises above 3.1 V at any time. Once the ‘sample’ button is pressed, the system captures 1000 samples of any signal generated on the oscilloscope, and computes and displays the signal characteristics like minimum and maximum voltage, average voltage, RMS voltage and frequency of the set of samples via the serial port to a program like ‘Terminal’. The code for the program is written in Keil using register-based C and ‘LL’ libraries.

2. System Connection

STM32L476RG Nucleo ARM board is used to create the signal capturing and recording system. Oscilloscope is used to generate the signals. Once setup for the generator is completed, the signal will be available via the “AUX OUT” connector of the oscilloscope. There are 3 ADCs in STM32L476RG. Each ADC has up to 12-bit resolution in its output. Registers are used to drive the ADC. Pin A0 of the ARM board is selected to take in the input analogue signal of specified waveform generated in oscilloscope for ADC1_IN5. Pin A0 is selected because it is an analog-in pin which can be easily used by removing the blue jumper pin on the ADC link on shield. Channel (CH1) of the oscilloscope is used to measure the output. ADC conversion is implemented through program and the output (push-pull - for DAC_OUT2) is displayed again into the oscilloscope using DAC through Pin PA5.

LED connected to PA6 pin on ARM board acts like warning led for any voltages greater than 3.1V. The LED stays on after detecting a voltage greater than 3.1V at any point during sampling. Push button (SW0) is connected to pin PA1 of the ARM board to capture and record the 1000 samples in array “float samples[1000]” of the program.

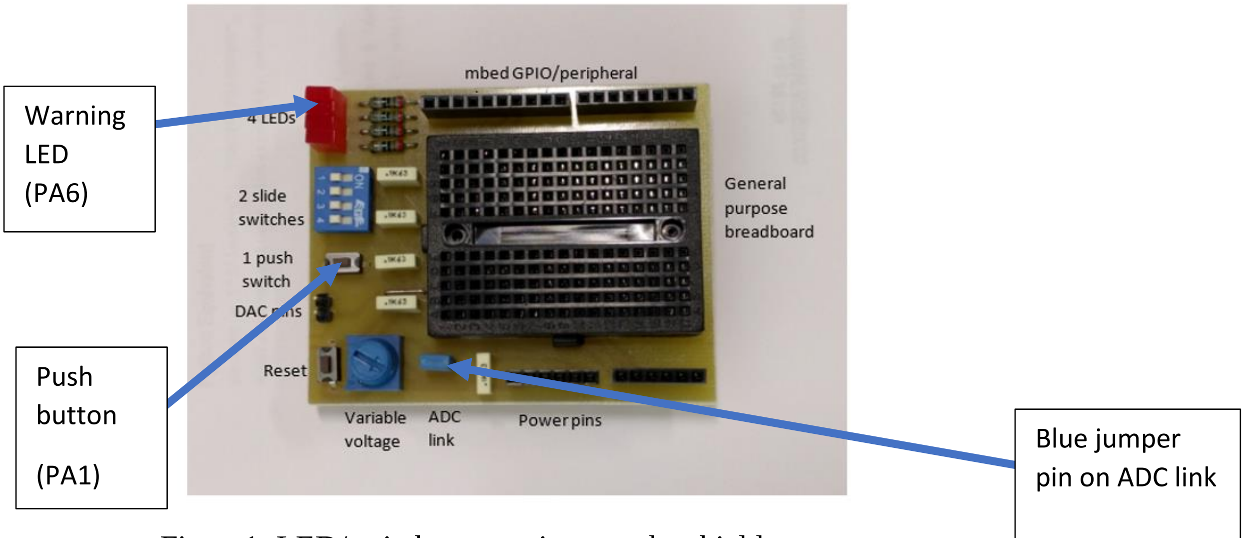


Figure1: LED/switch connections on the shield

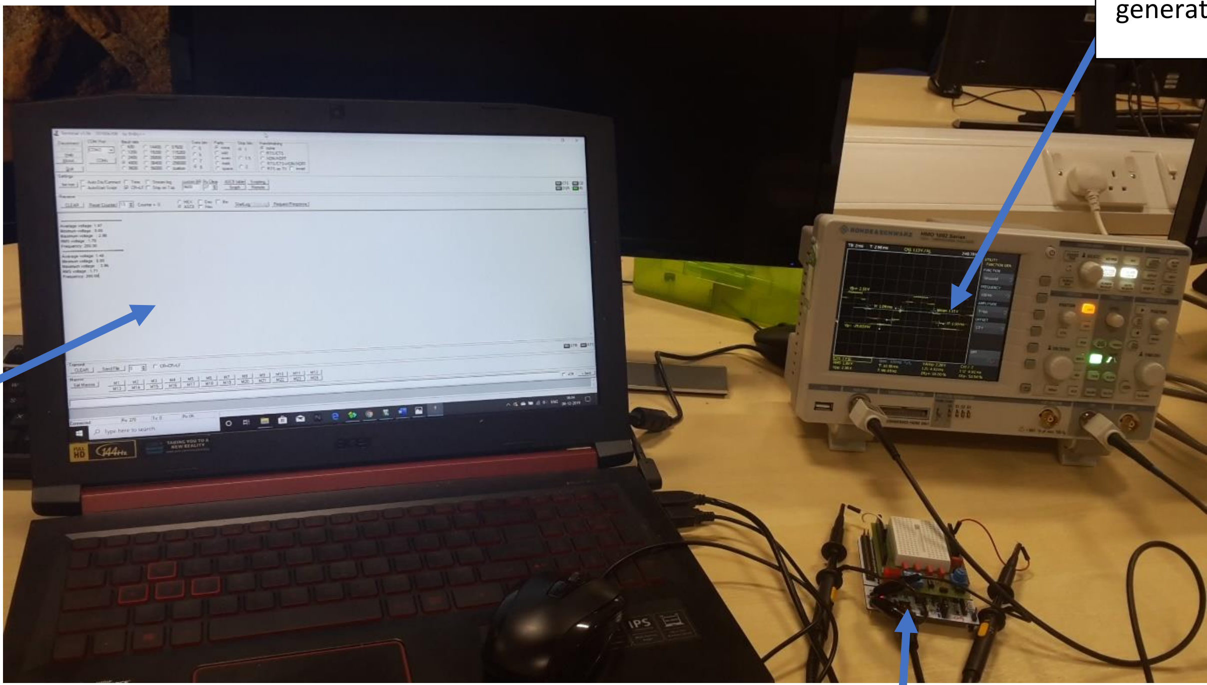


Figure2: System setup photo

A Windows PC is required for the project. The ST-Link USB connector is used for serial data communications as well as firmware downloading and debugging on the MCU. A Type-A to mini-B USB cable is connected between the board and the PC. The USART2 peripheral uses PA2 and PA3 pins, which are wired to the ST-Link connector. In addition, USART2 is selected to communicate with the PC via the ST-Link Virtual COM Port. A serial communication client, such as Terminal, needs to be installed on the PC to display the messages received from the board over the virtual communication Port as shown in figure2 above.

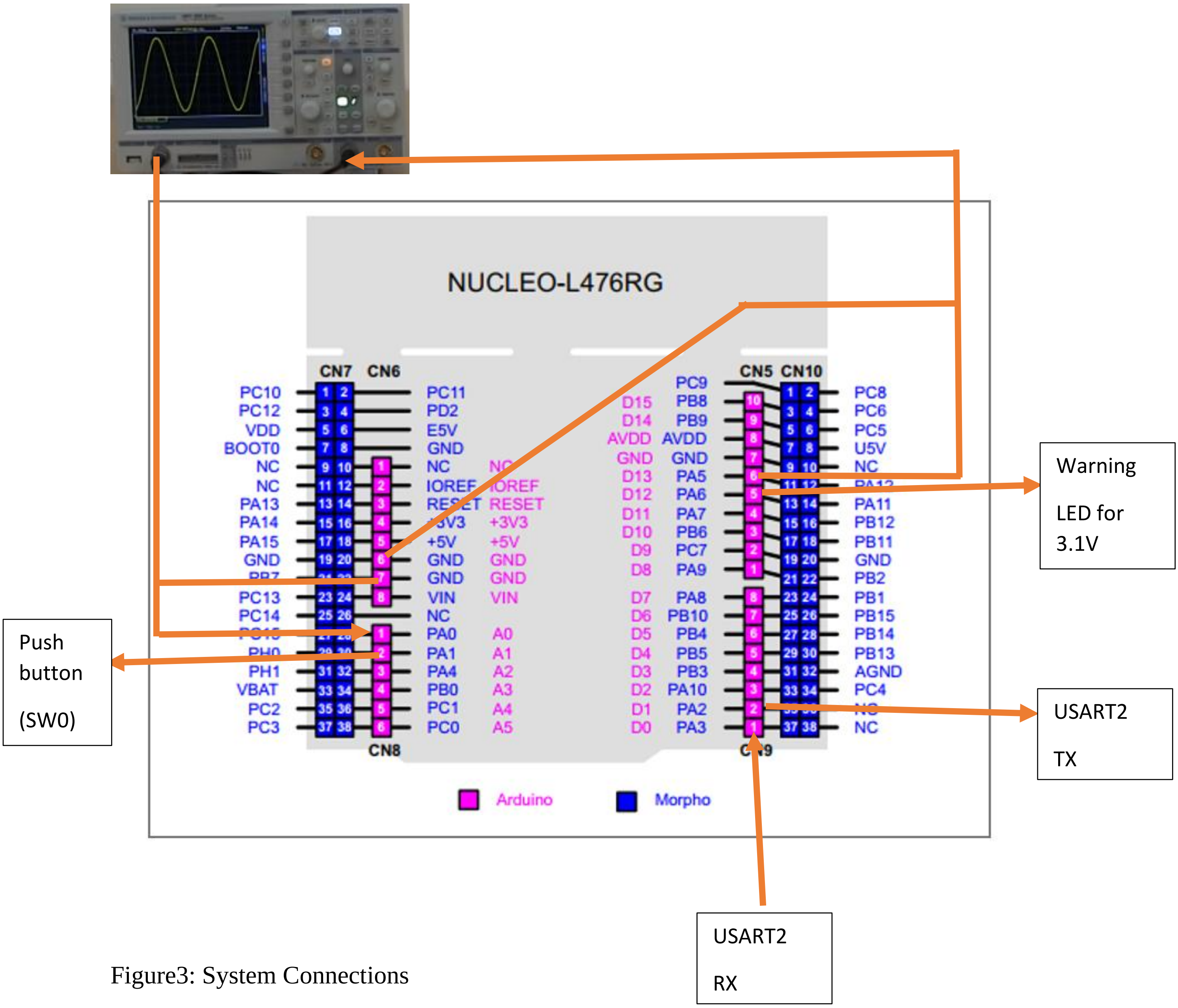


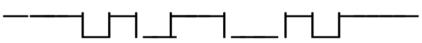
Figure3: System Connections

3. USART – Baudrate Calculation

Given the configuration of the USART, including the 8-bit data (here single character ‘M’) to be transmitted, what the waveform obtained from the TX line would be as follows:

we can plot the waveform for the TX line as follows:

1) Data to be transmitted: M
2) Data in binary: 01001101
3) Data in LSBF format: 10110010
4) Idle mode: 1
   Start bit: 0
   Stop bit: 1
5) Assemble a typical data frame: ~1010110010 1~
6) Waveform of the TX line:



~1 0 1 0 1 10010 1~

The collected waveform for one TX line of a USART is as shown in Figure1.

The baud rate from this screen dump can be checked as follows:

1. Mark the idle part and the transmission part (idle mode: 1)
2. Note down the time point for the transition from idle to transmission (T1).
3. Note down the time point for the transition from transmission to idle (T2).
4. Calculate the number of divisions on oscilloscope screen and multiply by time TB: 200 microseconds displayed on the upper left hand corner of oscilloscope to the to calculate the transmission time (T2 - T1). The number of divisions is 9.2 on the grid. So,

   $$(T2 - T1) = 9.2 \ x \ 200 \ x \ 10^{-6}$$

5. number of signals transmitted within the transmission part: n = 9
6. baud rate: 9bit / (t2 – t1) = 9bit / ($9.2 \ x \ 200 \ x \ 10^{-6}$) = 4891 bps

Therefore, the baud rate for the waveform shown in Fig. 1 is 4891bps. If we refer to the commonly used baud rates as numerical errors shall be taken into account, the real baud rate is estimated as 4800 bps.

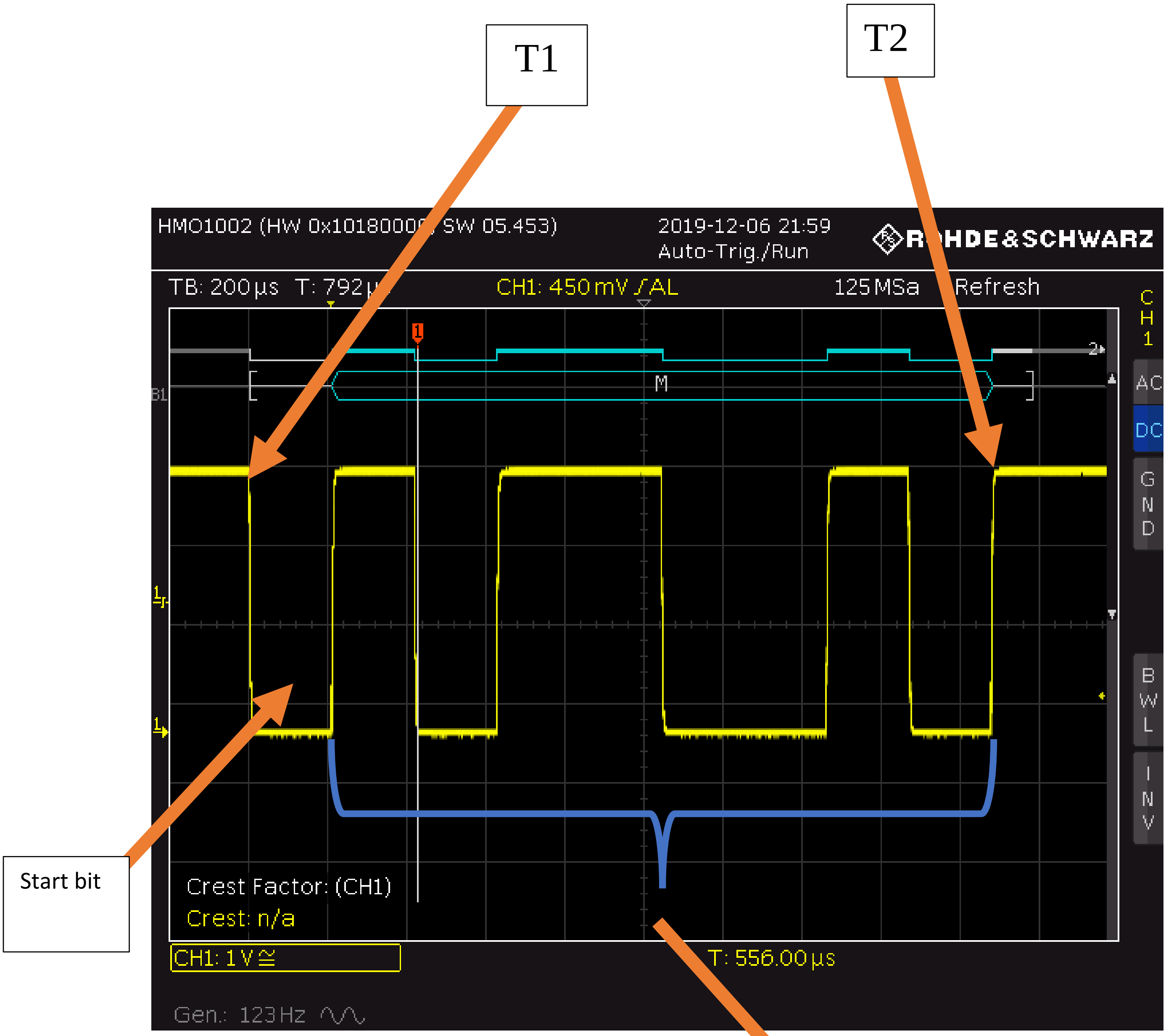


Figure4: Screenshot of USART single character ‘M’.

4. Testing

4.1 Table of Results for 4 different waveforms

[1.] Sinusoidal Waveform:

The following waveform is generated on the oscilloscope and fed into the ARM board as input signal using pin A0.

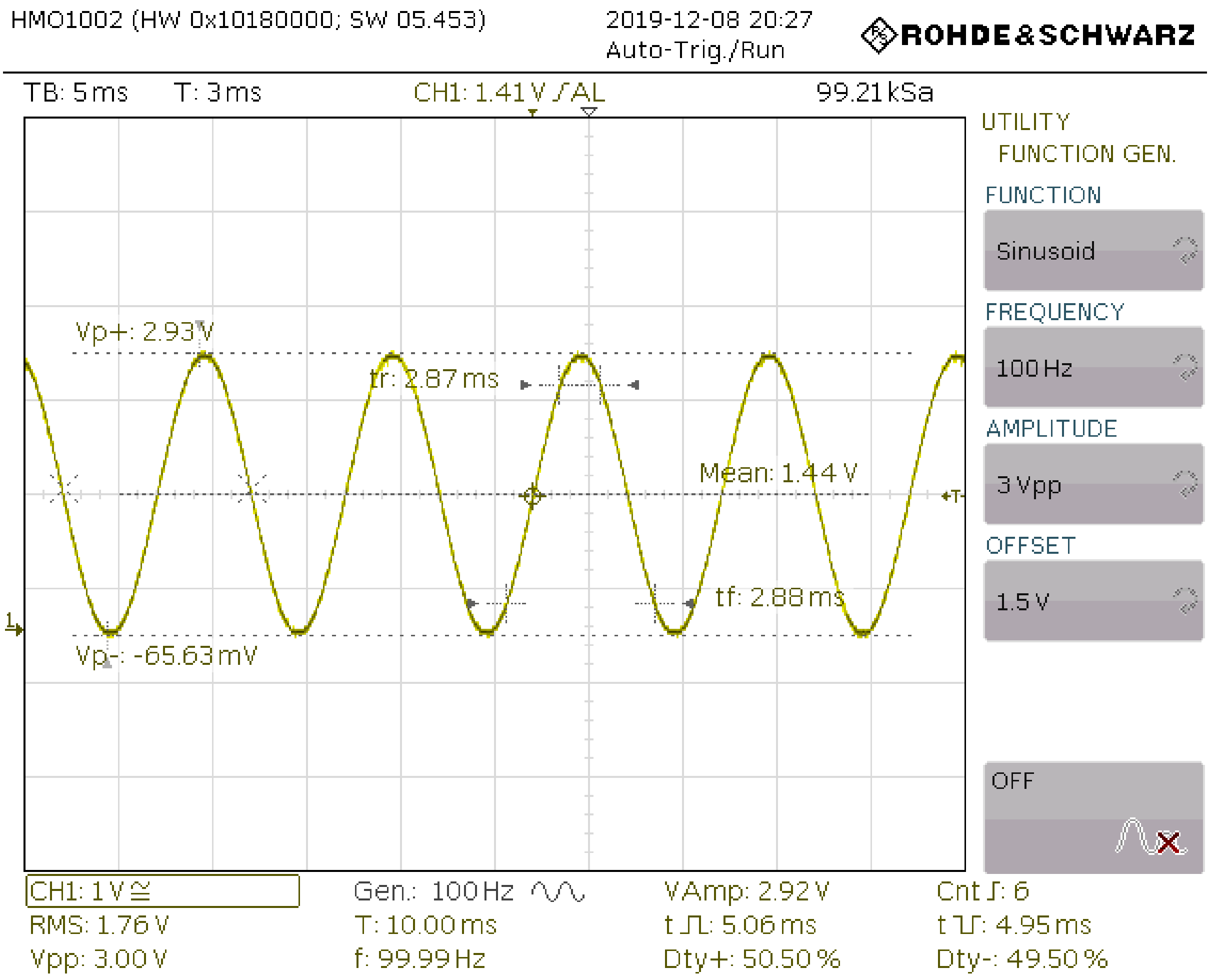


Figure5: Sinusoidal waveform from pin A0

The waveform below is obtained from pin PA5.

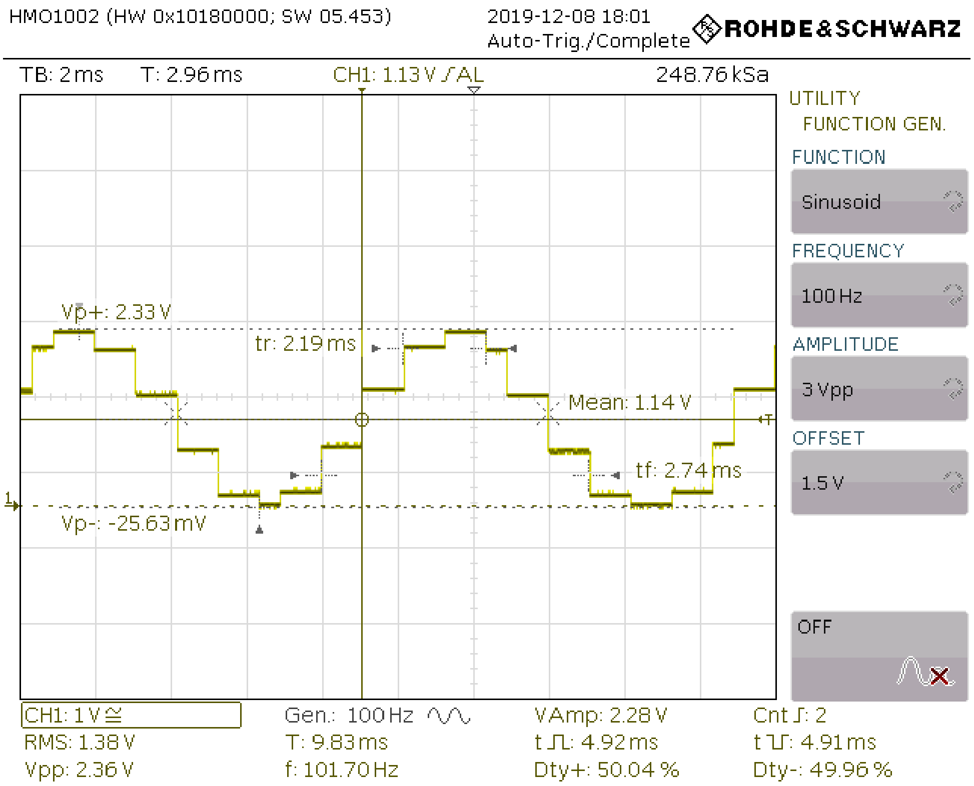
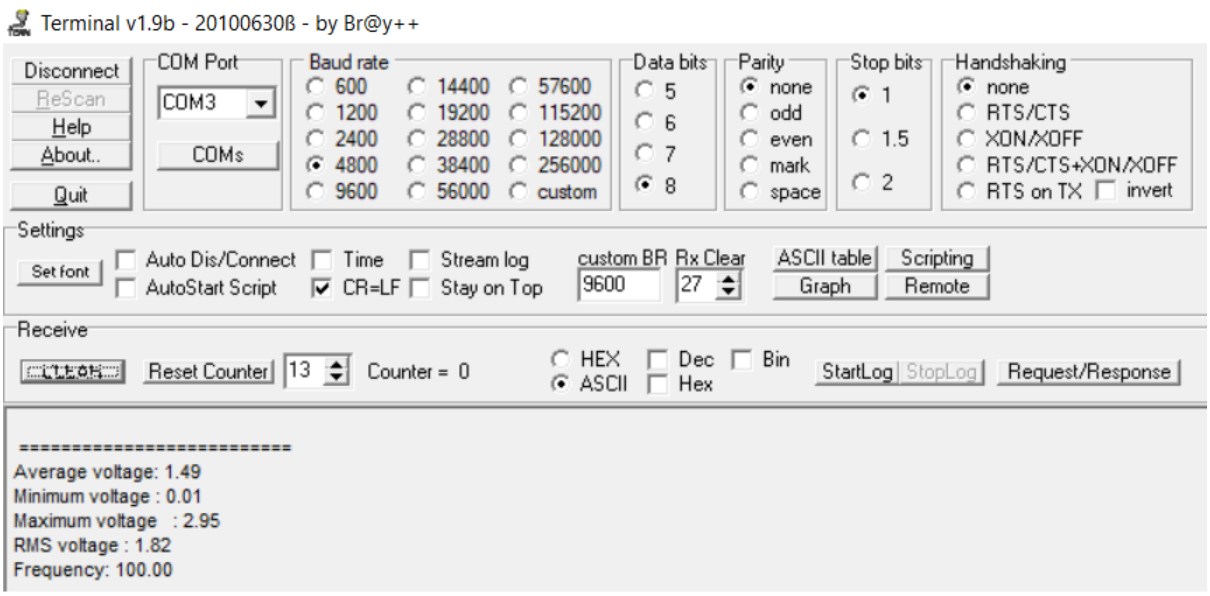


Figure6: Sinusoidal waveform from pin PA5

Result in terminal for the above sinusoidal waveform:



[2.] Triangle Waveform:

The following waveform is generated on the oscilloscope and fed into the ARM board as input signal using pin A0.

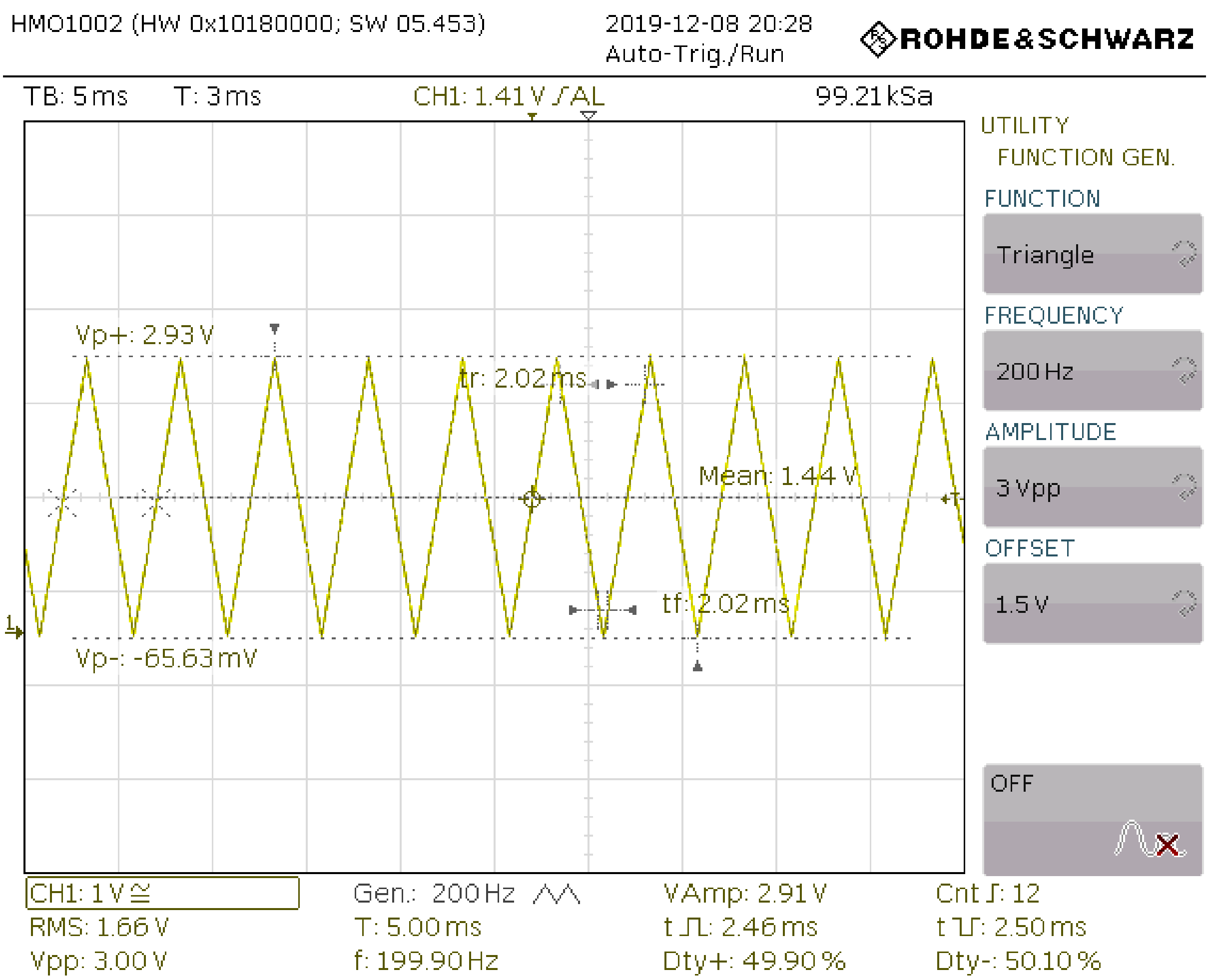


Figure7: Triangle waveform from pin A0

The triangle waveform below is obtained from pin PA5.

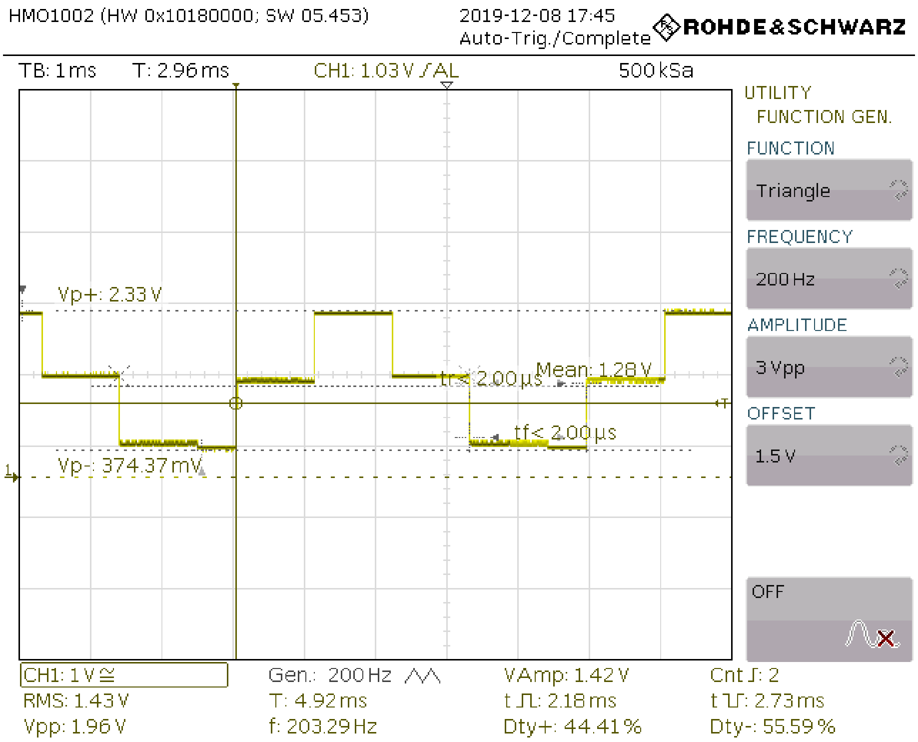
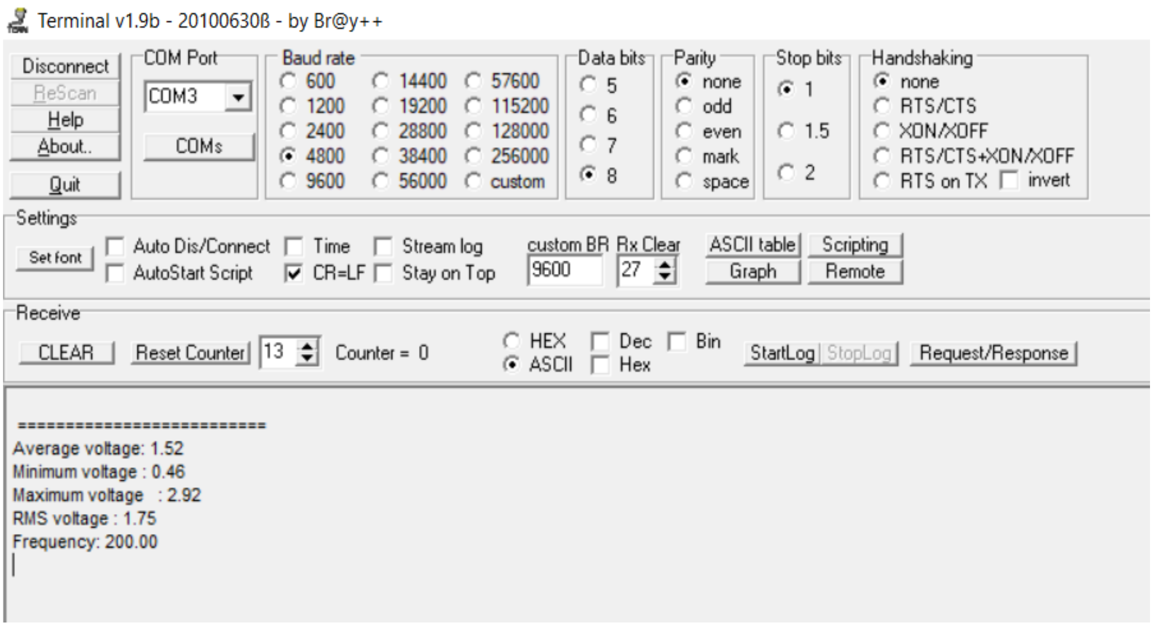


Figure8: Triangle waveform from pin PA5

<u>Result in terminal for the above triangle waveform:</u>



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[3.] Square Waveform:

The following waveform is generated on the oscilloscope and fed into the ARM board as input signal using pin A0.

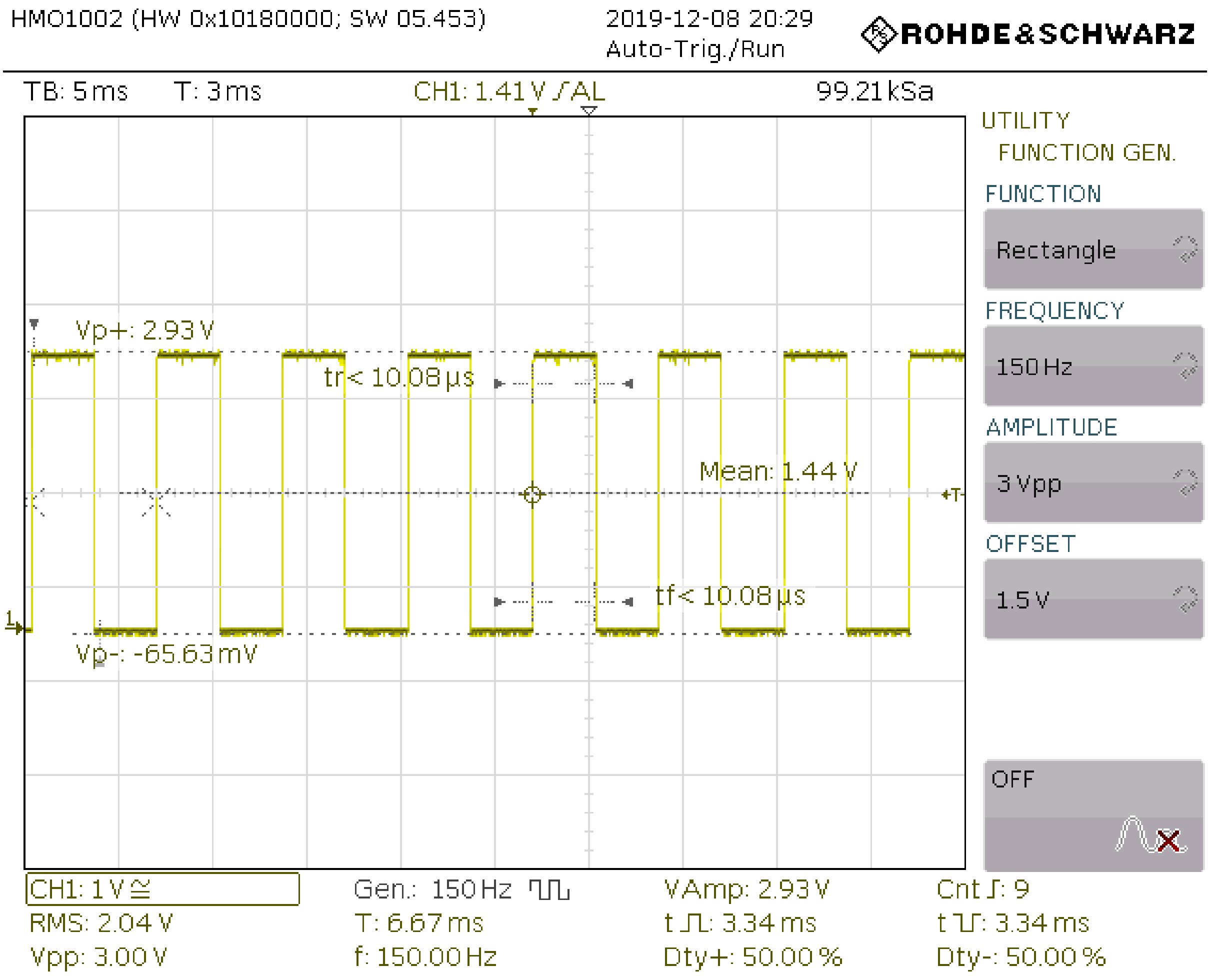


Figure9: Square (Rectangle) waveform from pin A0

The square (rectangle) waveform below is obtained from pin PA5.

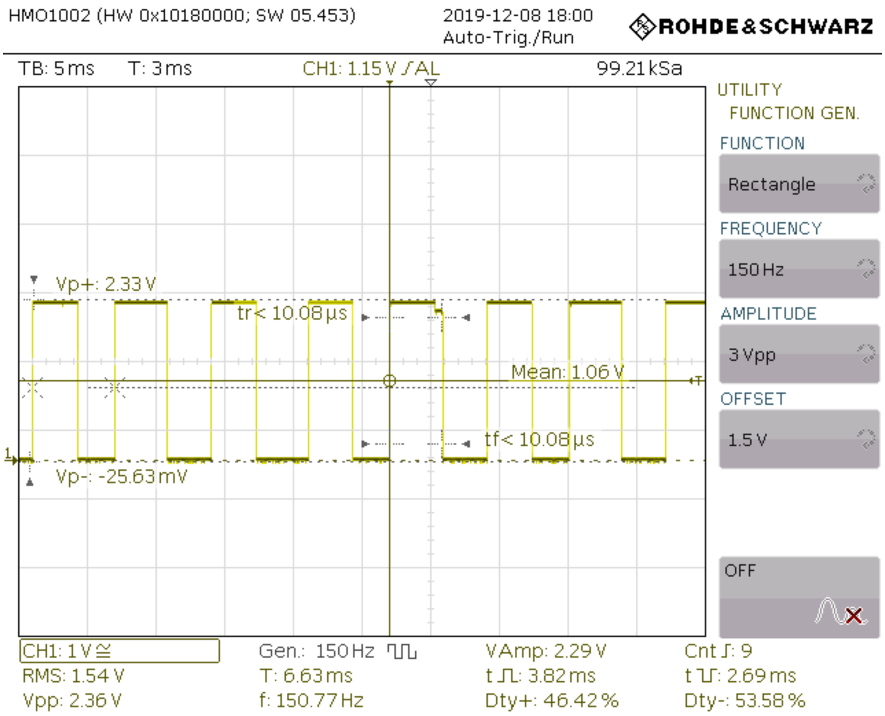
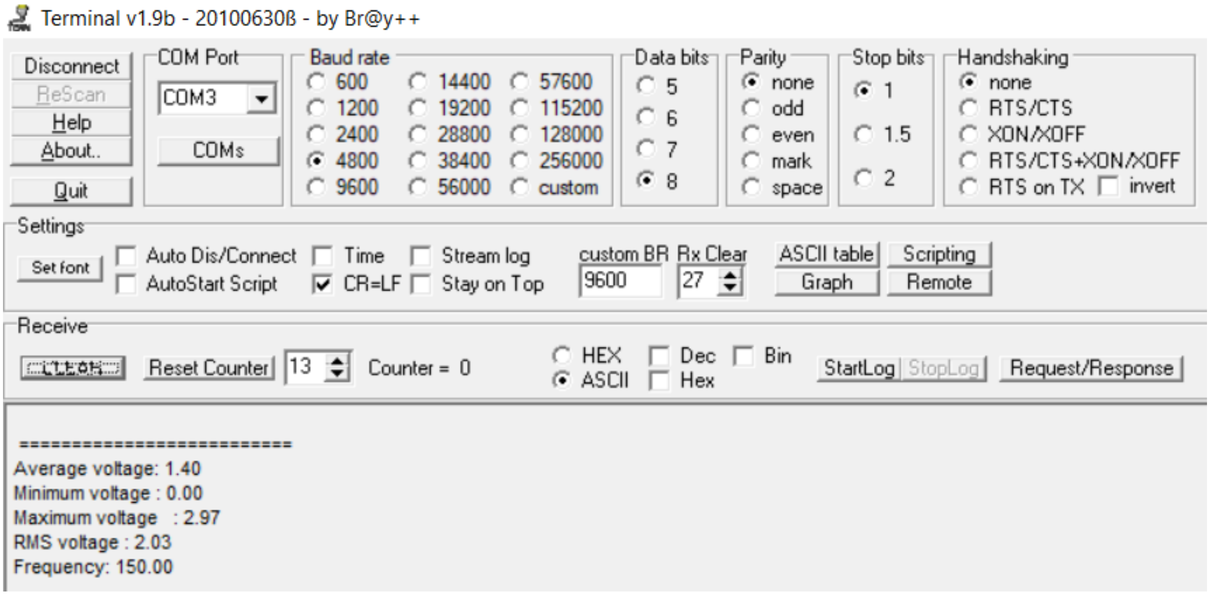


Figure10: Square (Rectangle) waveform from pin PA5

<u>Result in terminal for the above square (rectangle) waveform:</u>



[4.] Pulse Waveform:

The following waveform is generated on the oscilloscope and fed into the ARM board as input signal using pin A0.

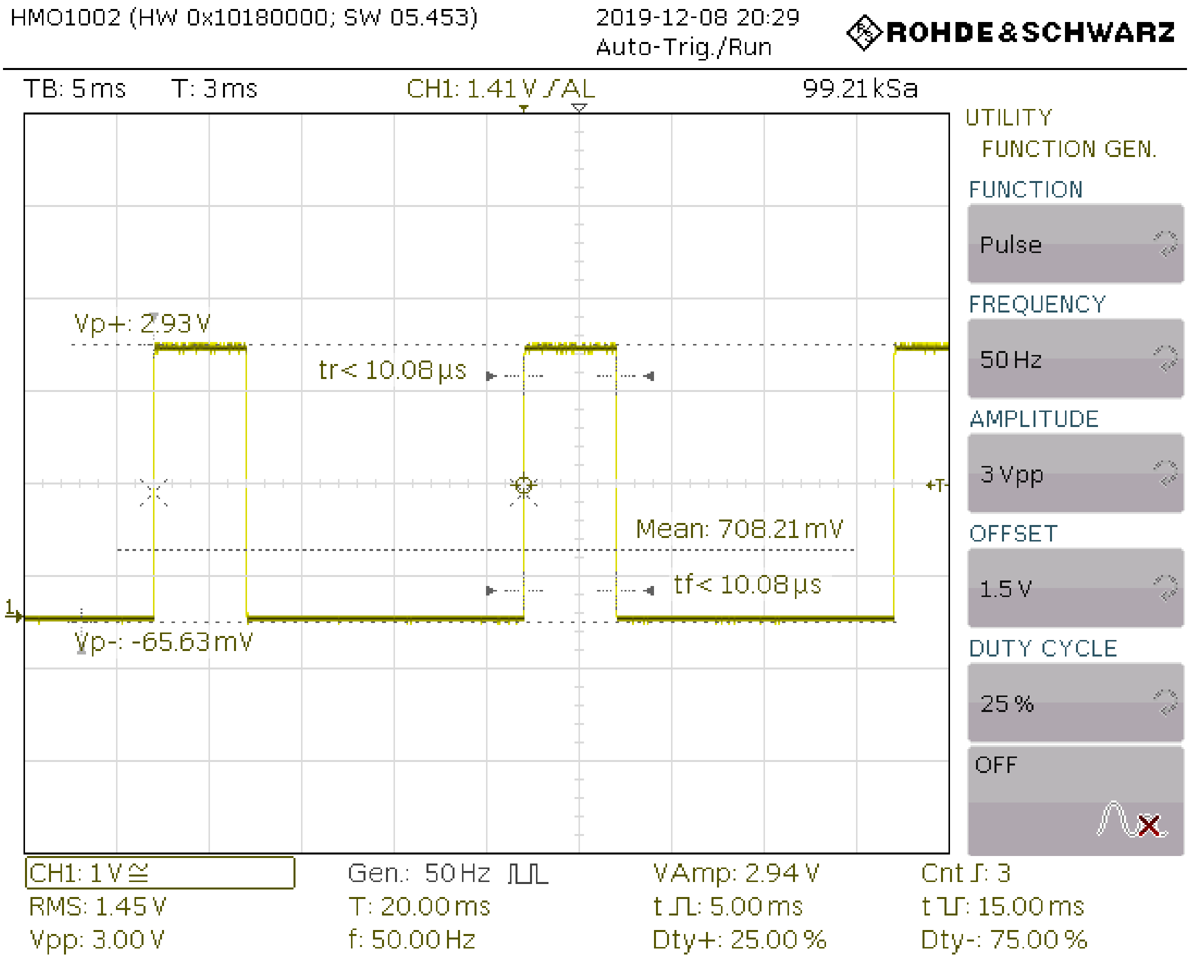


Figure11: Pulse waveform from pin A0

The following pulse waveform below is obtained from pin PA5.

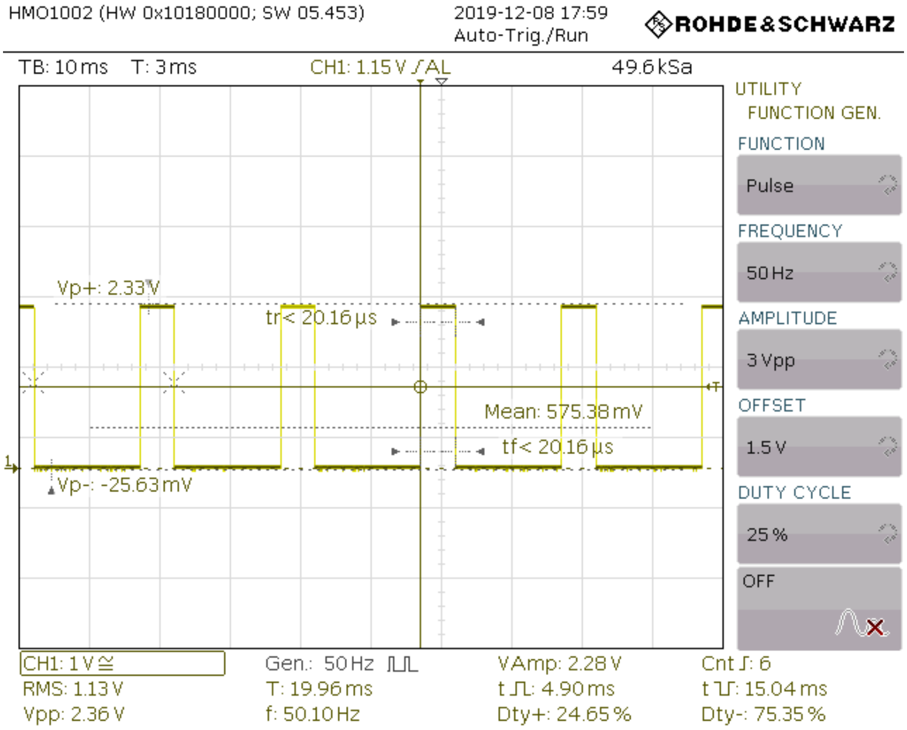
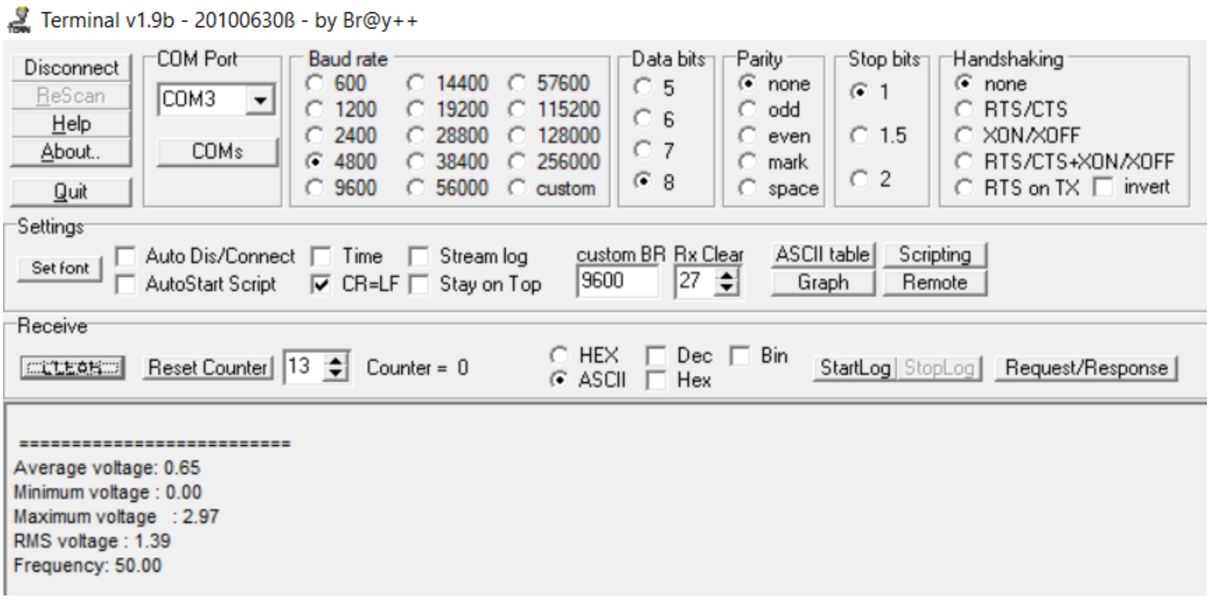


Figure12: Pulse waveform from pin PA5

<u>Result in terminal for the above pulse waveform:</u>



4.2 Logic Analyser in Keil.

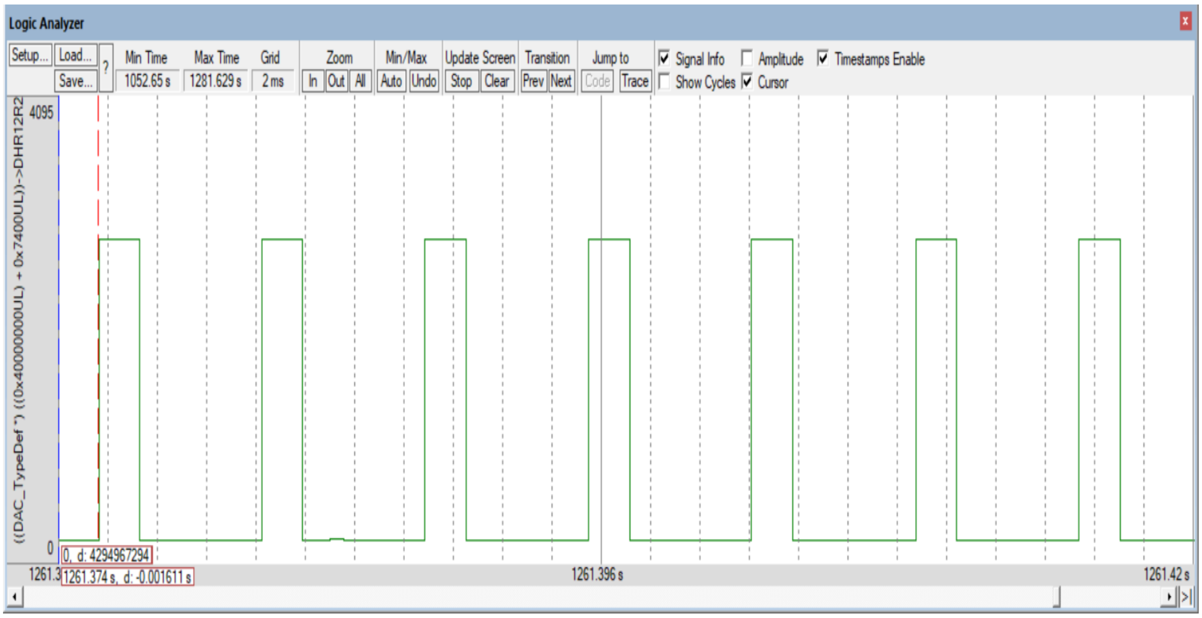


Figure13: Screenshot of Pulse waveform as captured on the Logic Analyser in Keil.

5. Conclusion

The system developed successfully met all the requirements of a signal capturing and recording system by implementing the three major parts of the analogue to digital converter and input system, the serial processing and output system, and the warning LED output for the four waveforms from the oscilloscope.

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Appendix

Appendix A

Table1: ASCII code: Character to Binary (http://whatasciicode.com/**)**

Dec	Hex	Binary	Char	Description	Dec	Hex	Binary	Char	Dec	Hex	Binary	Char	Dec	Hex	Binary	Char
0	0	0000 0000	NUL	Null character	32	20	0010 0000	space	64	40	0100 0000	@	96	60	0110 0000	`
1	1	0000 0001	SOH	Start of Heading	33	21	0010 0001	!	65	41	0100 0001	A	97	61	0110 0001	a
2	2	0000 0010	STX	Start of Text	34	22	0010 0010	"	66	42	0100 0010	B	98	62	0110 0010	b
3	3	0000 0011	ETX	End of Text	35	23	0010 0011	#	67	43	0100 0011	C	99	63	0110 0011	c
4	4	0000 0100	EOT	End of Tx	36	24	0010 0100	$	68	44	0100 0100	D	100	64	0110 0100	d
5	5	0000 0101	ENQ	Enquiry	37	25	0010 0101	%	69	45	0100 0101	E	101	65	0110 0101	e
6	6	0000 0110	ACK	Acknowledgement	38	26	0010 0110	&	70	46	0100 0110	F	102	66	0110 0110	f
7	7	0000 0111	BEL	Bell	39	27	0010 0111	'	71	47	0100 0111	G	103	67	0110 0111	g
8	8	0000 1000	BS	Backspace	40	28	0010 1000	(	72	48	0100 1000	H	104	68	0110 1000	h
9	9	0000 1001	HT	Horizontal Tab	41	29	0010 1001	)	73	49	0100 1001	I	105	69	0110 1001	i
10	A	0000 1010	LF	Line Feed	42	2A	0010 1010	*	74	4A	0100 1010	J	106	6A	0110 1010	j
11	B	0000 1011	VT	Vertical Tab	43	2B	0010 1011	+	75	4B	0100 1011	K	107	6B	0110 1011	k
12	C	0000 1100	FF	Form Feed	44	2C	0010 1100	,	76	4C	0100 1100	L	108	6C	0110 1100	l
13	D	0000 1101	CR	Carriage Return	45	2D	0010 1101	-	77	4D	0100 1101	M	109	6D	0110 1101	m
14	E	0000 1110	SO	Shift Out	46	2E	0010 1110	.	78	4E	0100 1110	N	110	6E	0110 1110	n
15	F	0000 1111	SI	Shift In	47	2F	0010 1111	/	79	4F	0100 1111	O	111	6F	0110 1111	o
16	10	0001 0000	DLE	Data Link Escape	48	30	0011 0000	0	80	50	0101 0000	P	112	70	0111 0000	p
17	11	0001 0001	DC1	Device Control 1	49	31	0011 0001	1	81	51	0101 0001	Q	113	71	0111 0001	q
18	12	0001 0010	DC2	Device Control 2	50	32	0011 0010	2	82	52	0101 0010	R	114	72	0111 0010	r
19	13	0001 0011	DC3	Device Control 3	51	33	0011 0011	3	83	53	0101 0011	S	115	73	0111 0011	s
20	14	0001 0100	DC4	Device Control 4	52	34	0011 0100	4	84	54	0101 0100	T	116	74	0111 0100	t
21	15	0001 0101	NAK	Negative ACK	53	35	0011 0101	5	85	55	0101 0101	U	117	75	0111 0101	u
22	16	0001 0110	SYN	Synchronous Idle	54	36	0011 0110	6	86	56	0101 0110	V	118	76	0111 0110	v
23	17	0001 0111	ETB	End of Tx Block	55	37	0011 0111	7	87	57	0101 0111	W	119	77	0111 0111	w
24	18	0001 1000	CAN	Cancel	56	38	0011 1000	8	88	58	0101 1000	X	120	78	0111 1000	x
25	19	0001 1001	EM	End of Medium	57	39	0011 1001	9	89	59	0101 1001	Y	121	79	0111 1001	y
26	1A	0001 1010	SUB	Substitute	58	3A	0011 1010	:	90	5A	0101 1010	Z	122	7A	0111 1010	z
27	1B	0001 1011	ESC	Escape	59	3B	0011 1011	;	91	5B	0101 1011	[	123	7B	0111 1011	{
28	1C	0001 1100	FS	File Separator	60	3C	0011 1100	<	92	5C	0101 1100	\	124	7C	0111 1100	|
29	1D	0001 1101	GS	Group Separator	61	3D	0011 1101	=	93	5D	0101 1101	]	125	7D	0111 1101	}
30	1E	0001 1110	RS	Record Separator	62	3E	0011 1110	>	94	5E	0101 1110	^	126	7E	0111 1110	~
31	1F	0001 1111	US	Unit Separator	63	3F	0011 1111	?	95	5F	0101 1111	_	127	7F	0111 1111	DEL

WhatASCIICode.com

Appendix B

Screenshots of waveforms in Logic Analyser of Keil

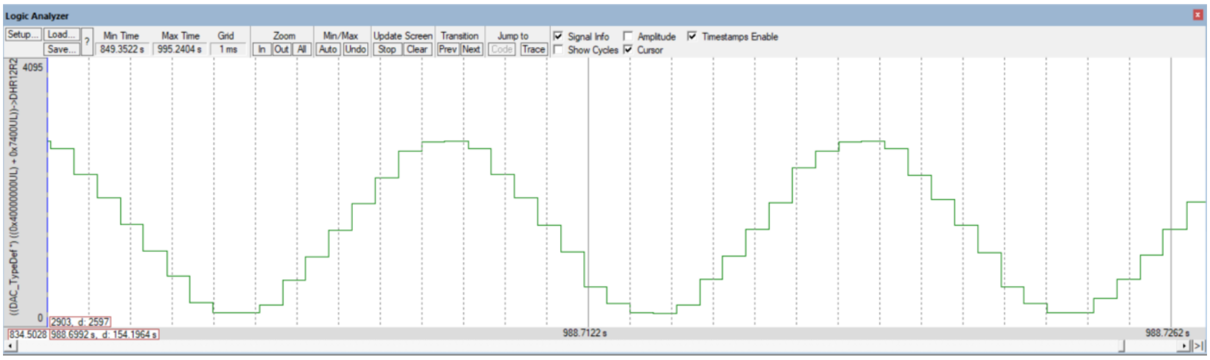

Figure14: Sine wave logic analyser

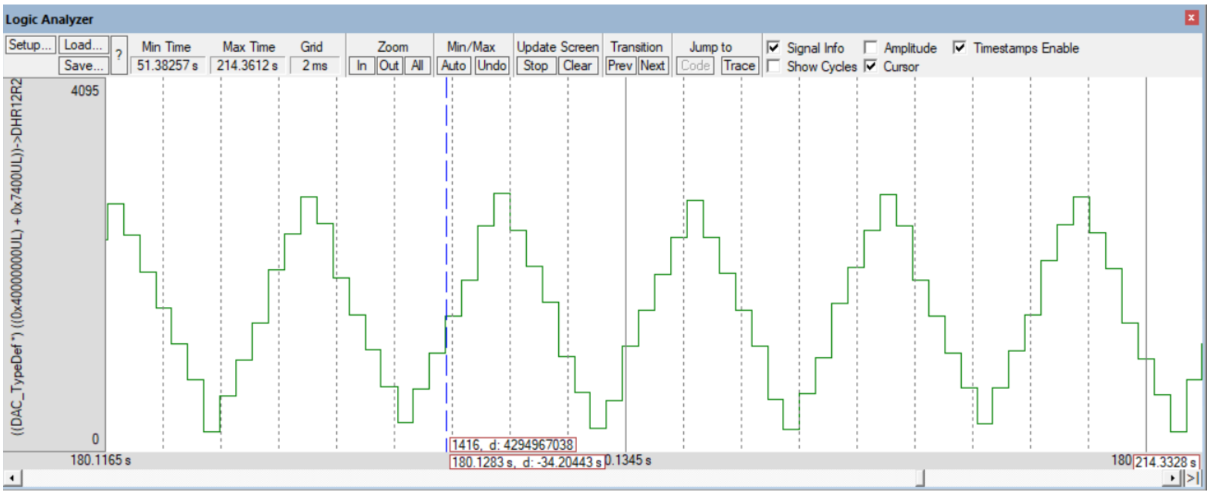

Figure15: Triangle wave logic analyser

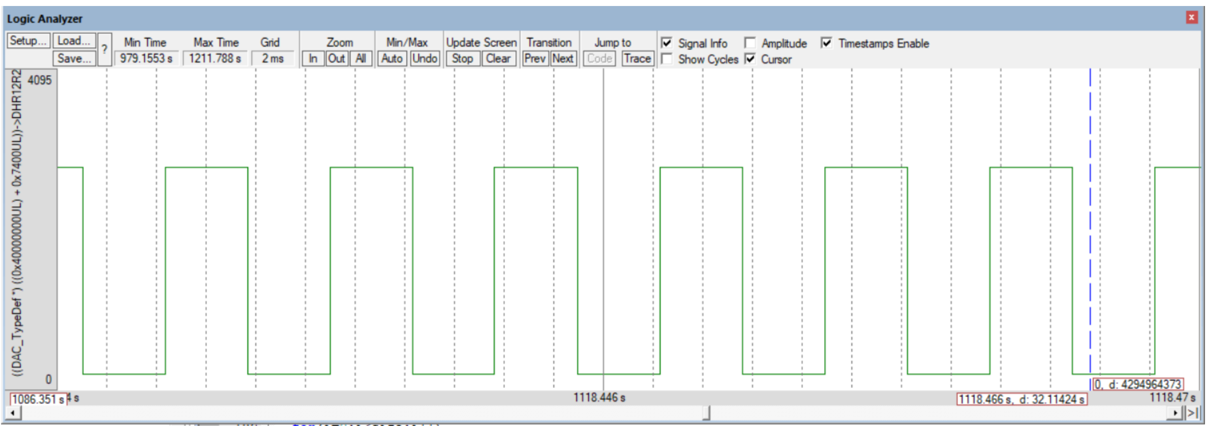

Figure16: Square wave logic analyser

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