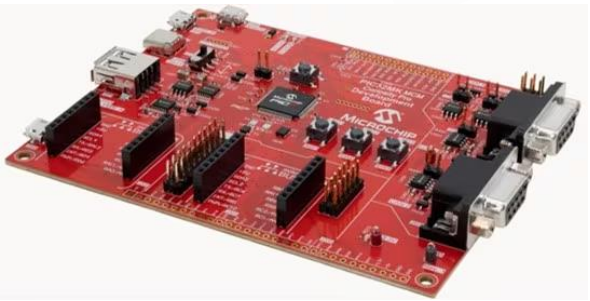
1. dream of an idea -- like a USB oscilloscope!

or

or



2. select a microcontroller (MCU)

I needed the fastest possible analog to digital converters, as well as a USB interface!

32-bit PIC® and SAM Microcontrollers Peripheral Integration

Quick Reference Guide

Product Family	Core	Max. Operation Freq. (MHz)	Program Flash Memory (KB)	RAM (KB)	Pin Count	Automotive (AEC-Q100 Grade 1 or Grade 2)	Peripheral Function Focus: Intelligent Analog: ADC (channels/bits)	ADC Speed (sps)	DAC (channels/bits)	Analog Comparator (+Op Amp)	Waveform Control: Output Compare/Input Capture/ Waveform Output Channels	Motor Control PWM Pairs/Single Ended MC PWM (3)	Timing and Measurements: 16-bit/32-bit Timer Channels (TC)	Quadrature Encoder/Decoder for Motor Control: QEI/QDEC/PDEC(3)	Safety and Monitoring: Functional Safety Ready	Class B Safety Library	Communication: USB (FS/HS) + PHY (Transceiver)	CAN (2.0B or FD)	Ethernet (10/100)	UART	I²C	SPI [3]	SDIO/SD/eMMC	PCC or PIO as CMOS Camera Interface	SQI/QSPI	I2S for Audio CODEC [3]	Peripheral Bus Interface EBI/ PMP [3]	User Interface: Hardware Peripheral Touch, PTC (channels/Driven Shield +) [3]	Segment/Graphics LCD Controller	LCD Controller (External, Low-Cost Controllerless, Integrated)	Security: Embedded Hardware Security Module (HSM)	Crypto Engine (AES, SHA, ECC, RSA/ DSA, TRNG)	TrustZone [3]	Secure Boot [3]	Tamper Detection	System Flexibility: Dual Panel/Bank Flash [3]	Intelligent Low Power Peripheral Event System (channels) [3]	DMA (channels)	Ultra Small Package (WLCSP)
PIC32C Family (Arm® Cortex®-M)																																						
PIC32CM LX	CM23	48	256-512	32-64	48 -100	G1	24/12	1M	2/10	4	16/16/30	4/4	5/2	0			1F+P			6	6	6					1		P256				A,S,T	✓*	✓*	✓*		✓*	12	
PIC32CM MC [4]	CM0+	48	64-128	8-16	32-48		14/12	1M	1/10	2	16/16/30	4/4	5/2	1						4	4	4						E									12	12	
PIC32CM JH [4]	CM0+	48	256-512	32-64	32-100	G1	12/12	1M	1/10	4	16/16/30	4/-	4/-	1	✓			2FD*		8	8	8						P256		E		S					12	12	
PIC32CX SG	CM4F	120	1024	256	100-128	G1	16/12	1M	2/10	4	33/33/39	8/13	8/4	1			1F+P	2FD*		8	8	8		✓	✓	1		P+AE35: AR35256		E	✓	A,S,E,R,T		✓	✓		32	32	
PIC32CK SG / GC	CM33	120	512-2048	128-512	64-144	G1	12/12	2M		2	40/40/40	10	8/4	1			1F+P	2FD*	1	8	8	8	2		1	1	1	P256		E	✓	A,S,E,R,T	✓	✓	✓	✓	32	12	
PIC32CZ CA 80 / 90	CM7F	300	2048 - 8192	512-1024	208		36/12	4M		2	40/40/40	10					2H+P	6FD	1	10	10	10	2		2	2	1	P256		E	✓	A,S,E,R,T		✓	✓	✓	32	32	
PIC32M Family (MIPS32®)																																						
PIC32MM GPL	microAptiv™	25	16-64	4-8	20-36	G1	14/12	200k	1/5	2	3/3/3		7/3			✓				2		2				2										✓			
PIC32MM GPM	microAptiv	25	64-256	16-32	28-64	G1	24/12	200k	1/5	3	3/3/3		21/9			✓	1F+P			3	3	3				3											4	
PIC32MX 1/2*/5+	M4K®	50	16-512	4-64	28-100		48/10	1M		3	5/5/5		5/2			✓	1F+P*+	1+		5	2	4				4	✓			E							8	
PIC32MX 1/2* XLP	M4K	72	128-256	32-64	28-44		13/10	1M		3	5/5/5		5/2			✓	1F+P*			2	2	2				2	✓	E									4	
PIC32MX 3/4*	M4K	120	32-512	8-128	64-100		28/10	1M		2	5/5/5		5/2			✓	1F+P*			5	2	2				2	✓			E/L							4	
PIC32MX 5×/6*/7+	M4K	80	64-512	16-128	64-100		16/10	1M		2	5/5/5		5/2			✓	1F+P	1×/2+	1*+	6	5	4					✓	E/L									8	
PIC32MK GP/MC	microAptiv	120	128-1024	64-256	28-100		42/12	25M	3/12	5/4	16/16/16	12/12	9/8	6		✓	2F+P	4FD		6	4	6				6	✓			E/L						✓	8	
PIC32MZ EF	M-Class	252	512-2048	128-512	64-144	G1	48/12	18M		2	9/9/9		9/4			✓	1H+P	2	1	6	5	6			✓	6	✓	E/L				A,S,T				✓	8	
PIC32MZ DA [2]	microAptiv	200	1024-2048	256-640	169-288	G2	45/12	18M		2	9/9/9		9/4			✓	1H+P	2	1	6	5	6	1		✓	6	✓		G	I		A,S,T				✓	8	
SAM Family (Arm Cortex-M)																																						
SAM D09	CM0+	48	8-16	4	14-24		10/12	350k			2/2/2		2/1							2	2	2															6	6	
SAM D10/D11*	CM0+	48	8-16	4	14-24		10/12	350k	1/10	2	6/6/10	4*/-	2/1				1F+P*			3	3	3						P72									6	6	✓
SAM D20/D21*	CM0+	48	16-256	2-32	32-64	G1	20/12	350k	1/10	2	22/22/32	8*/-	5/2		✓*	✓	1F+P*			6	6	6				1*		P256		E							12	12*	✓
SAM D21L	CM0+	48	32-128	4-16	32-48	G1	18/12	350k	1/10	4	22/22/32	8/-	5/2		✓	✓				6	6	6						E									12	12	
SAM DA1	CM0+	48	16-64	4-8	32-64	G2	20/12	350k	1/10	2	18/18/24	8/-	5/2		✓	✓	1F+P			6	6	6				1		P256		E							12	12	
SAM L10/L11*	CM23	32	16-64	4-16	24-32	G1	10/12	1M	1/10	2O3	6/6/6		3/1			✓				3	3	3						P100, D+		E		A*,S*,T	✓*	✓*	✓		8	8	✓
SAM L21	CM0+	48	32-256	4-32	32-64		20/12	1M	2/12	2O3	12/12/12	4/-	5/2		✓		1F+P			6	6	6						P169		E		A,T					12	16	✓
SAM L22	CM0+	32	64-256	8-32	48-100		20/12	1M		2	12/12/12	4/-	4/2				1F+P			6	6	6						P256	S320	E		A,T			✓		8	16	✓
SAM C20/C21* [4]	CM0+	48	32-256	4-32	32-100	G1	12/12	1M	1/10*	4	16/16/30	4/4	8/4		✓*	✓		2FD*		8	8	8						P256		E							12	12	✓
SAM4N	CM4	100	512-1024	64-80	48-100		16/10	510k	1/10		6/6/10		6/-	2						7	3	4																23	
SAM4S	CM4	120	128-2048	64-160	48-100		16/12	1M	2/12	1	6/6/10		6/-	2			1F+P			4	2	3	1	✓		1	✓									✓	14	22	✓
SAM4E	CM4F	120	512-1024	128	100-144		24/16	300k	2/12	1	9/9/13		-/9	3			1F+P	2	1	4	2	3	1	✓			✓					A			✓			33	
SAM4L	CM4	48	128-512	32-64	48-100		16/12	300k	1/12	4	6/6/6		3/-				1F+P			4	4	1		✓		1		P32	S160			A,T					4	16	✓
SAM G	CM4F	120	256-512	64-176	49-100		8/12	500k			6/6/6		6/-				1F+P			8	8	8				2									✓		6	30	✓
SAM D5x+/E5x*	CM4F	120	256-1024	128-256	48-128	G1	32/12	1M	2/12	2	33/33/39	8/13	8/4	1		✓	1F+P	2FD*	1*	8	8	8	2	✓	✓	1		P+AE35: AR35256		E		A,S,E,R,T			✓	✓	32	32	✓+
SAM S7x (2)/E7x	CM7	300	512-2048	256-384	64-144		24/12	1.7M	2/12	1	12/12/16	8	12/-	4			1H+P	2FD*	1*	8	3	5	1	✓	✓	2	✓	E/L				A,S,T			✓		12	24	
SAM V7x	CM7	300	512-2048	256-384	64-144	G2	24/12	1.7M	2/12	1	12/12/16	8	12/-	4			1H+P	2FD	1	8	3	5	1	✓	✓	2	✓	E/L				A,S,T			✓		12	24	

1: USARTs with SPI mode are taken into account 2: DRAM Memory Support: PIC32MZ DA with DDR2 (32 MByte embedded or 128 MB external) 3: Terminology in the back 4: SAM C20/C21, PIC32CM MC / JH are true 5V devices; SAM C21 & PIC32CM MC also come with 16-bit Sigma Delta ADC and integrated temp sensor

MICROCHIP

microchip.com/32bit

3. use an MCU prototype board as first hardware

Using Microchip PIC32MK MCM CURIOSITY PRO DEVELOPMENT BOARD

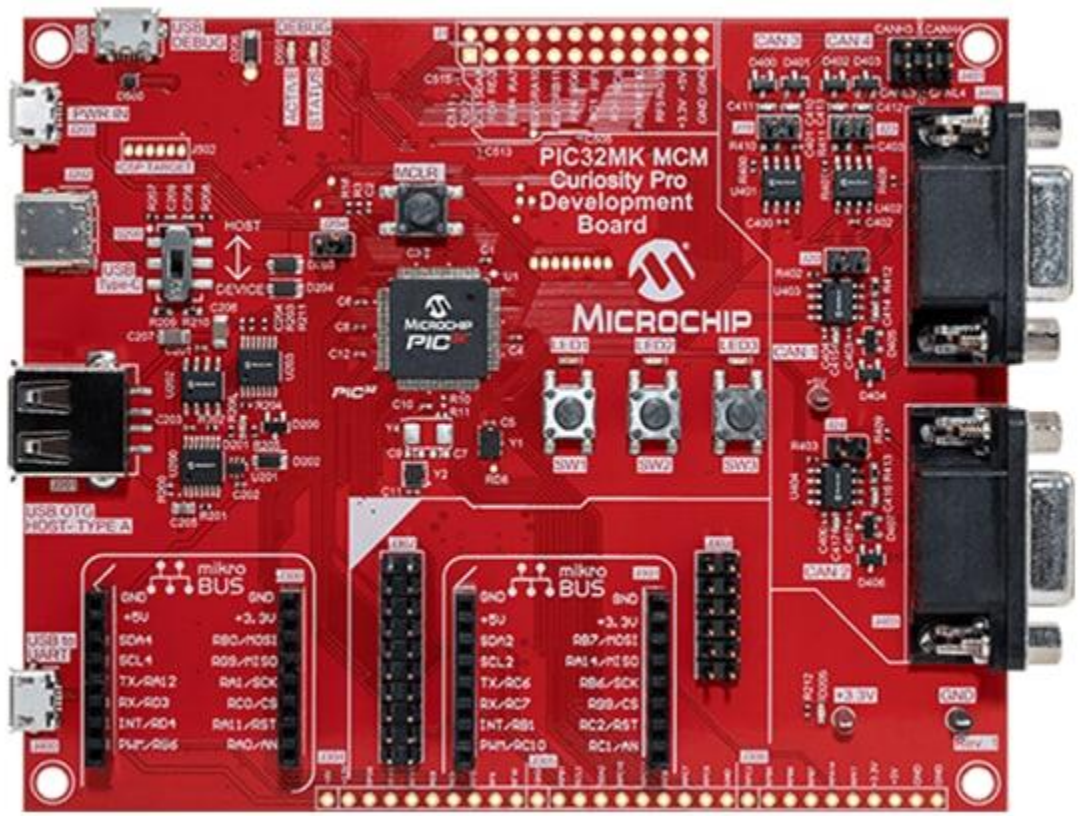
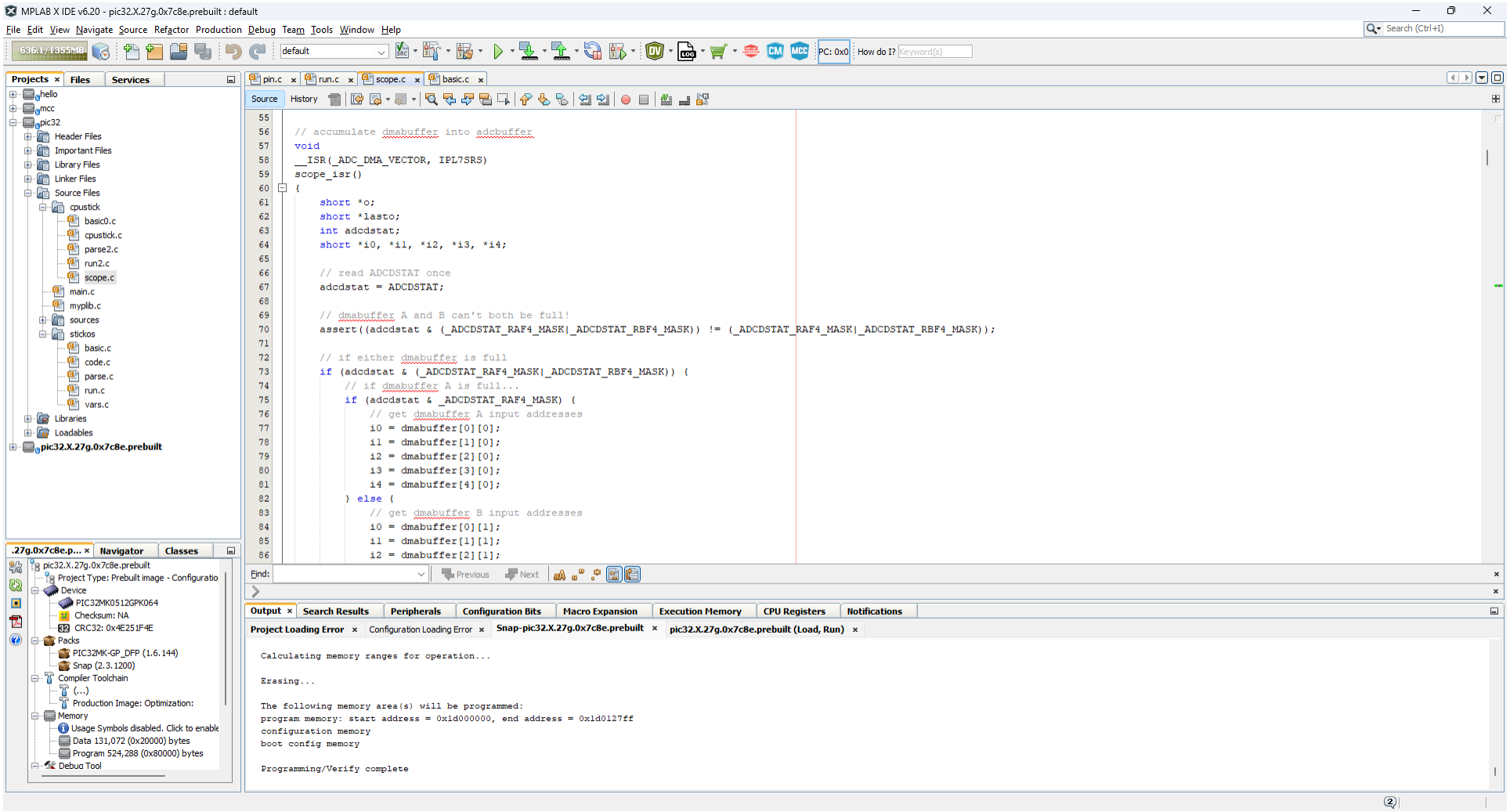


Figure 2

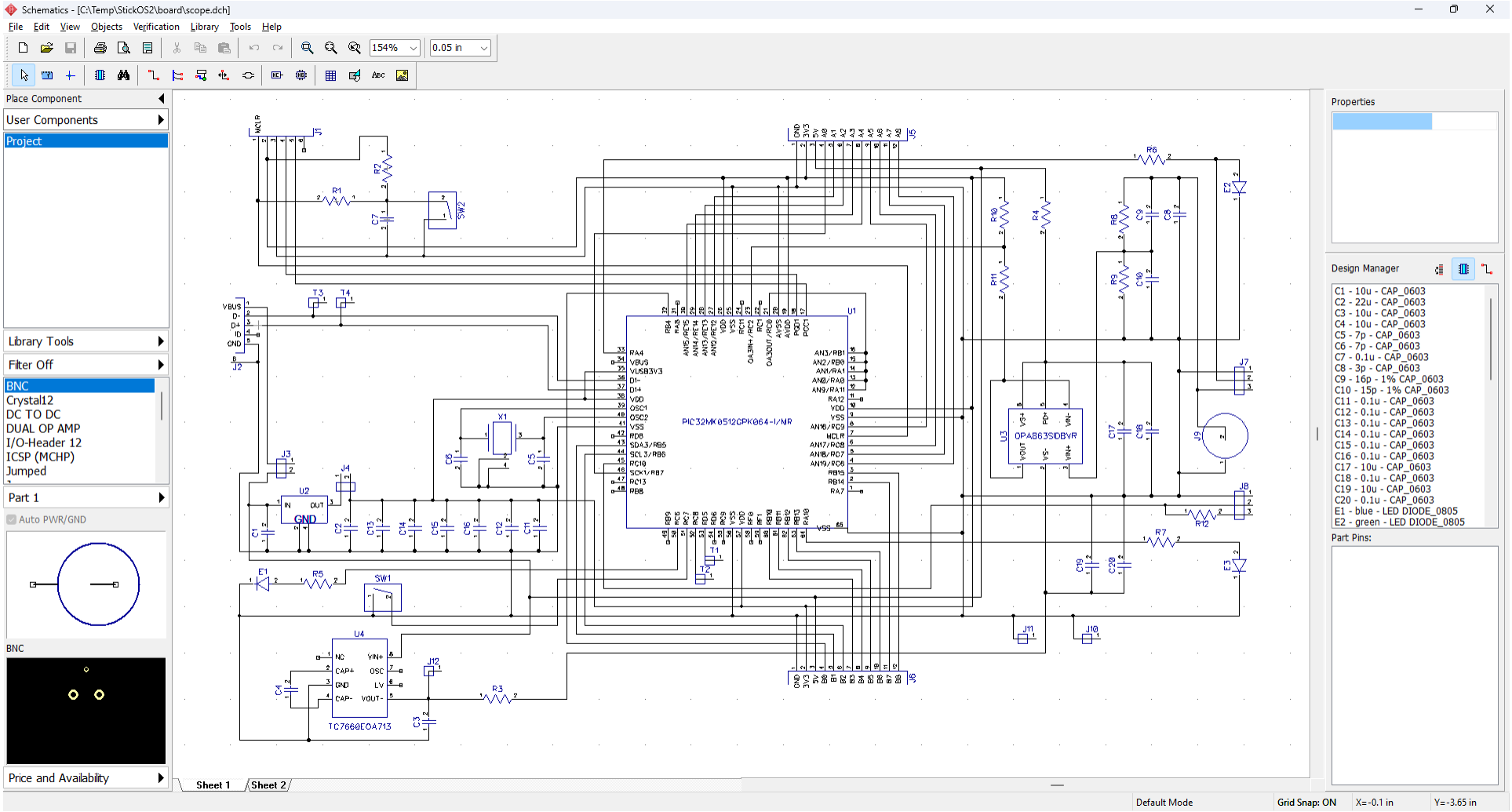
4. design the firmware

Using Microchip MPLAB X software



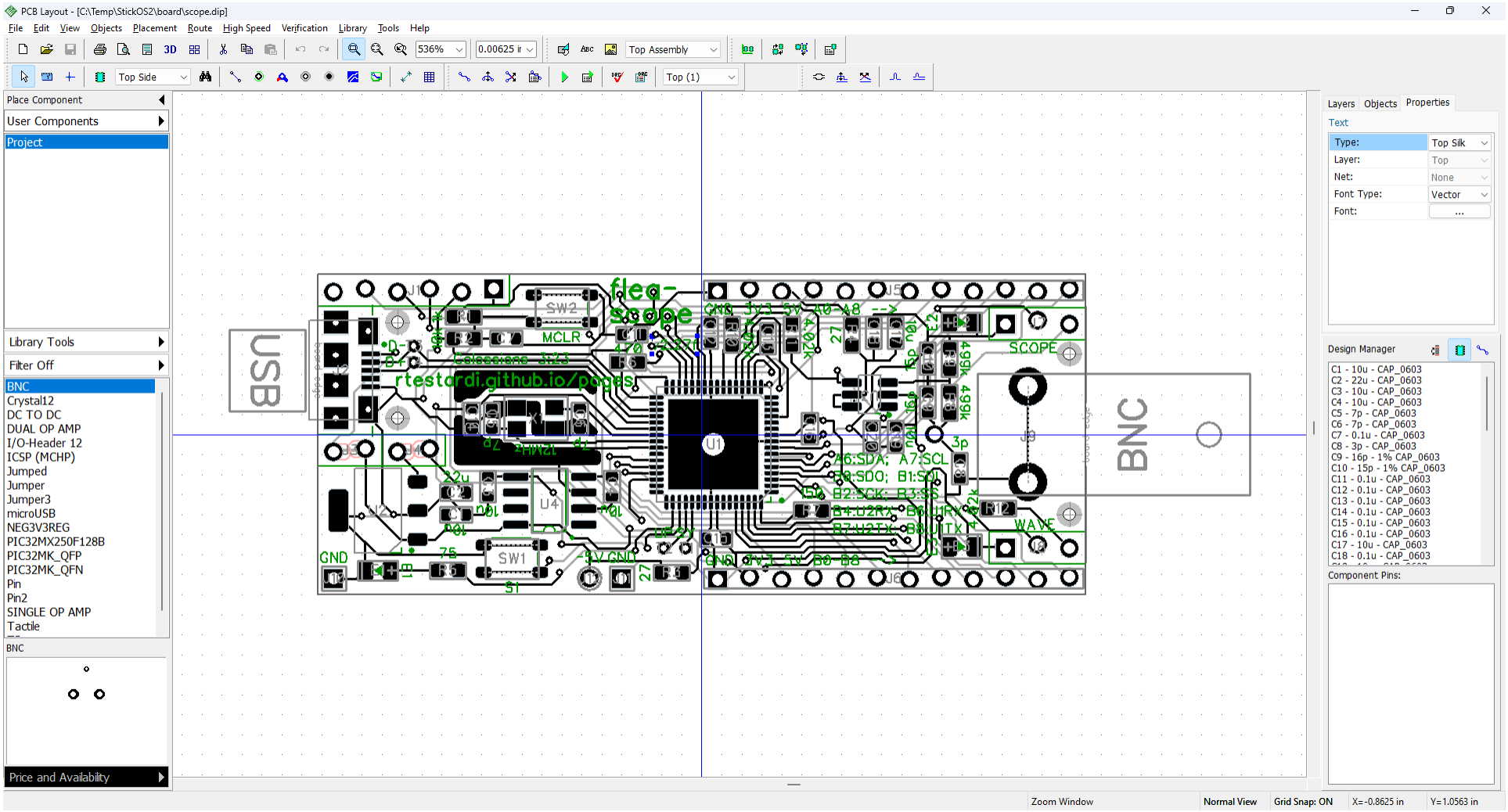
5. design a custom printed circuit board schematic

Using DipTrace Schematic



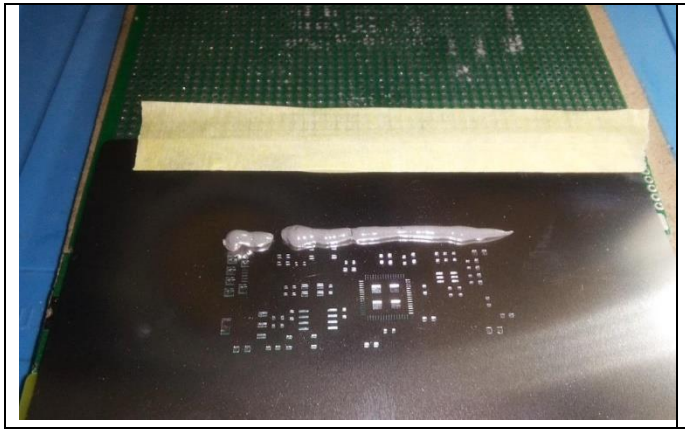
6. design a custom printed circuit board layout

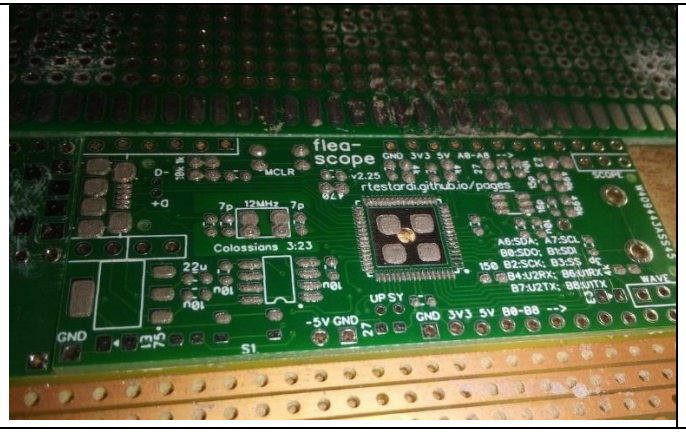
Using DipTrace PCB Layout

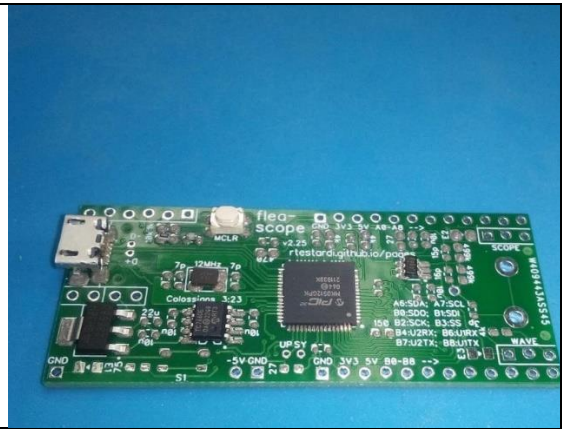


7. assemble the printed circuit board

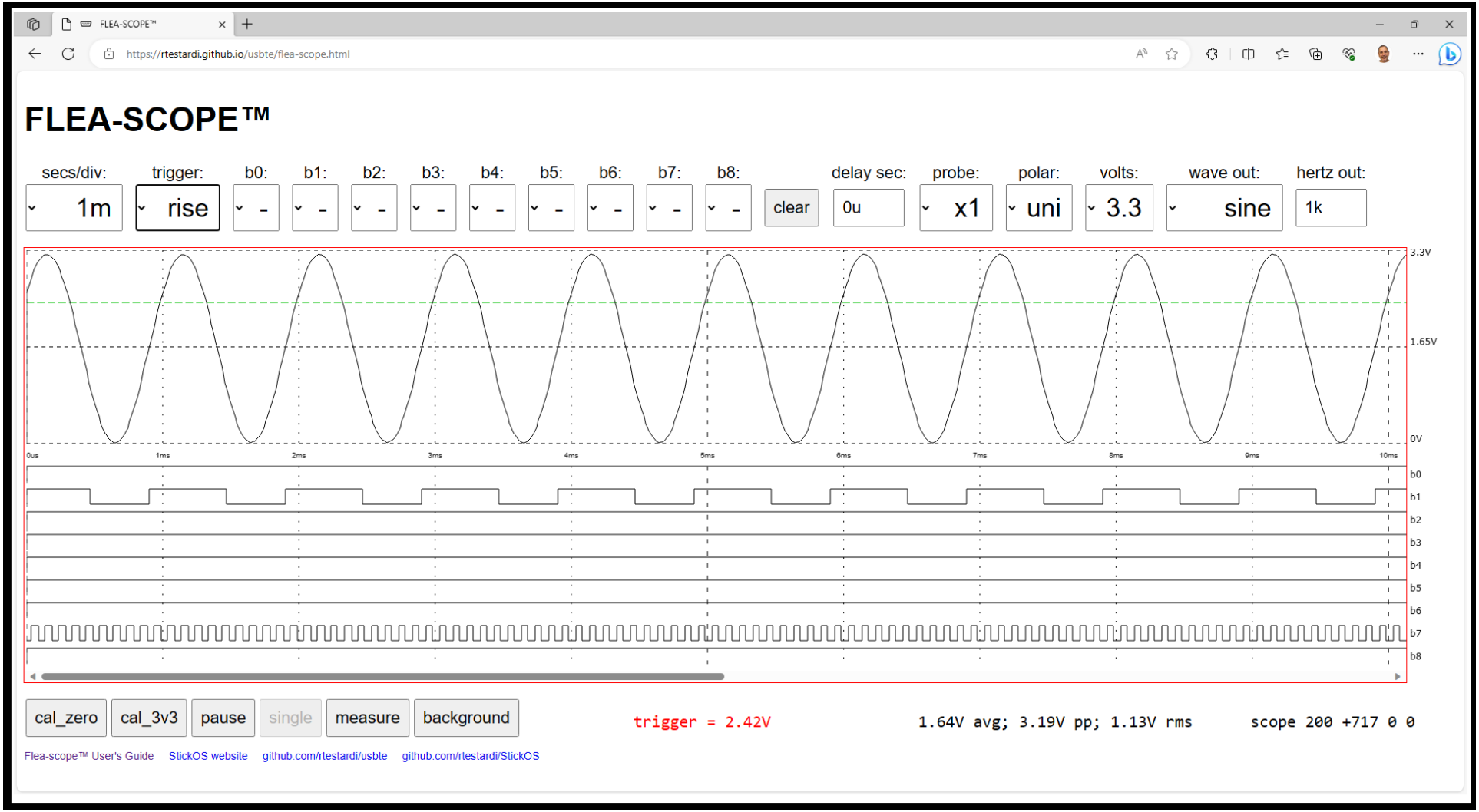
In my toaster oven at home!







8. design the webpage



9. always overdeliver

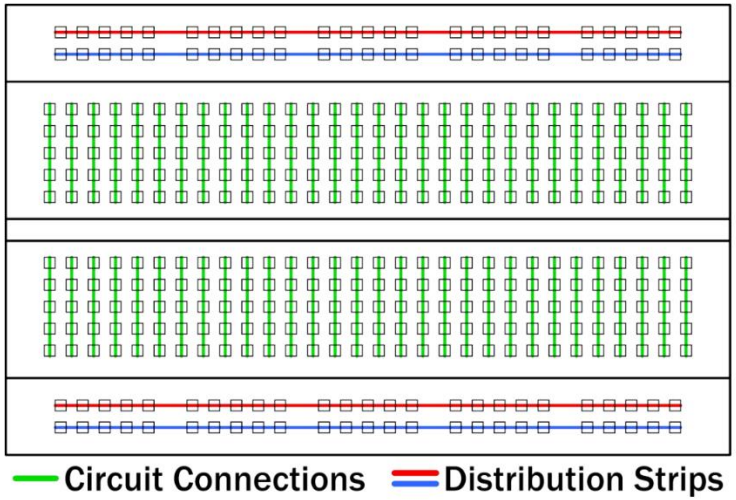
Colossians 3:23 NIV

23 Whatever you do, work at it with all your heart, as working for the Lord, not for human masters,

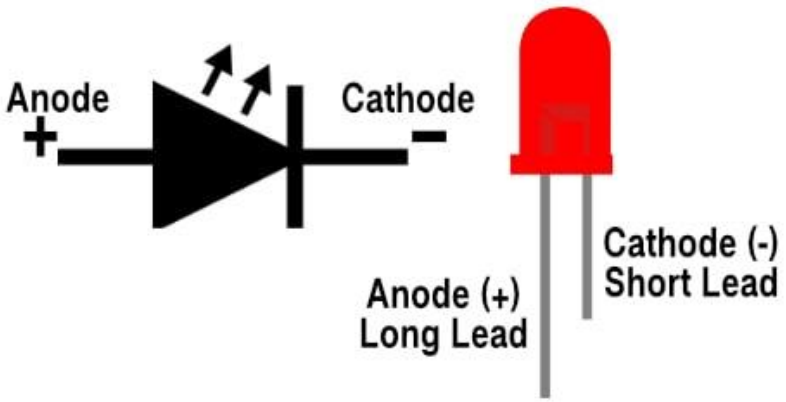
simon game hints

See the Flea-Scope documentation and simon game instructions here:
https://rtestardi.github.io/pages/

The holes in the solderless breadboard are connected as below:



The long lead of the LED is positive and is connected to the control signal; the short lead is negative and is connected to ground:



using a multimeter to measure voltage, current, resistance, or capacitance

"V=-" measure volts DC (like batteries)

- DC = direct current

"V~~" measure volts AC (like household wiring or transformers)

- AC = alternating current

"µA", "mA", "A" measure current (amps, can be DC or AC)

"Ω" measure resistance (ohms, like resistors or fuses)

- a good fuse (or a wire) has a resistance near 0 ohms
- a blown fuse (or an open circuit) has an infinite resistance (O.L.)

"-||-" measure capacitance (farads, like capacitors)

<u>resistors</u>

<u>capacitors</u>

<u>fuses</u>

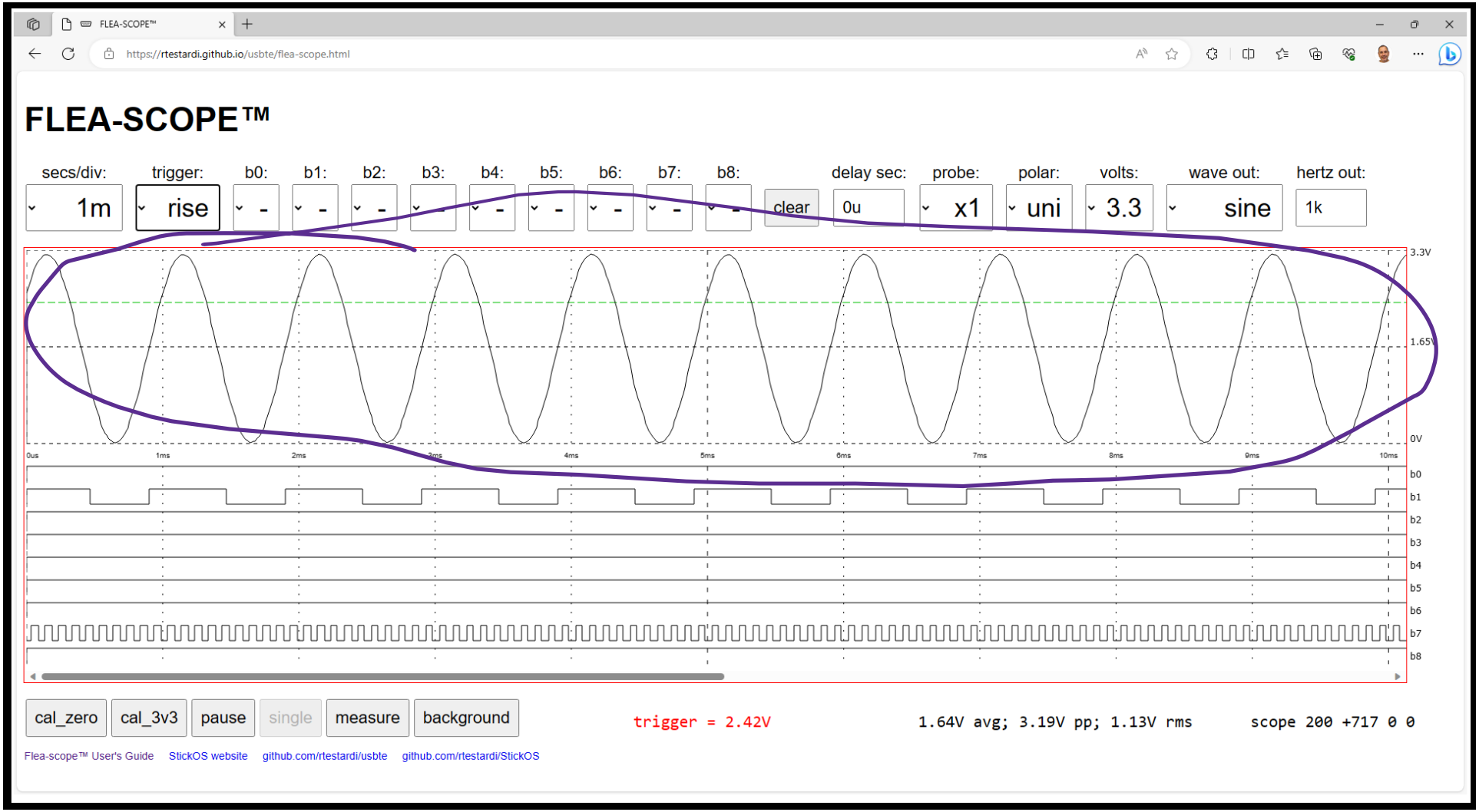
using an oscilloscope to measure voltage changing with time

Y-axis shows voltage (in volts)

- you can change full scale of the graph using “volts:” selection

X-axis shows time since the start of trace (in seconds)

- you can change the time per horizontal division using “secs\div:” selection



using a logic analyzer to monitor digital signals changing with time

Y-axis shows multiple digital signals

- displayed in binary (0 or 1)

X-axis shows time since the start of trace (in seconds)

- you can change the time per horizontal division using “secs\div:” selection