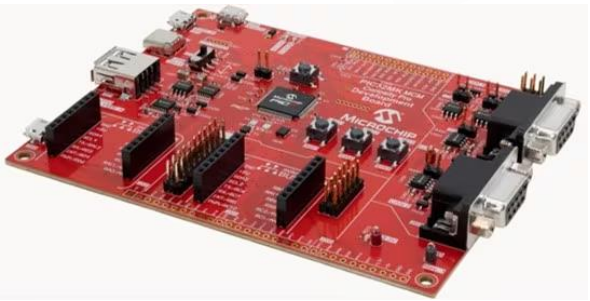
1. dream of an idea -- like a USB oscilloscope!

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

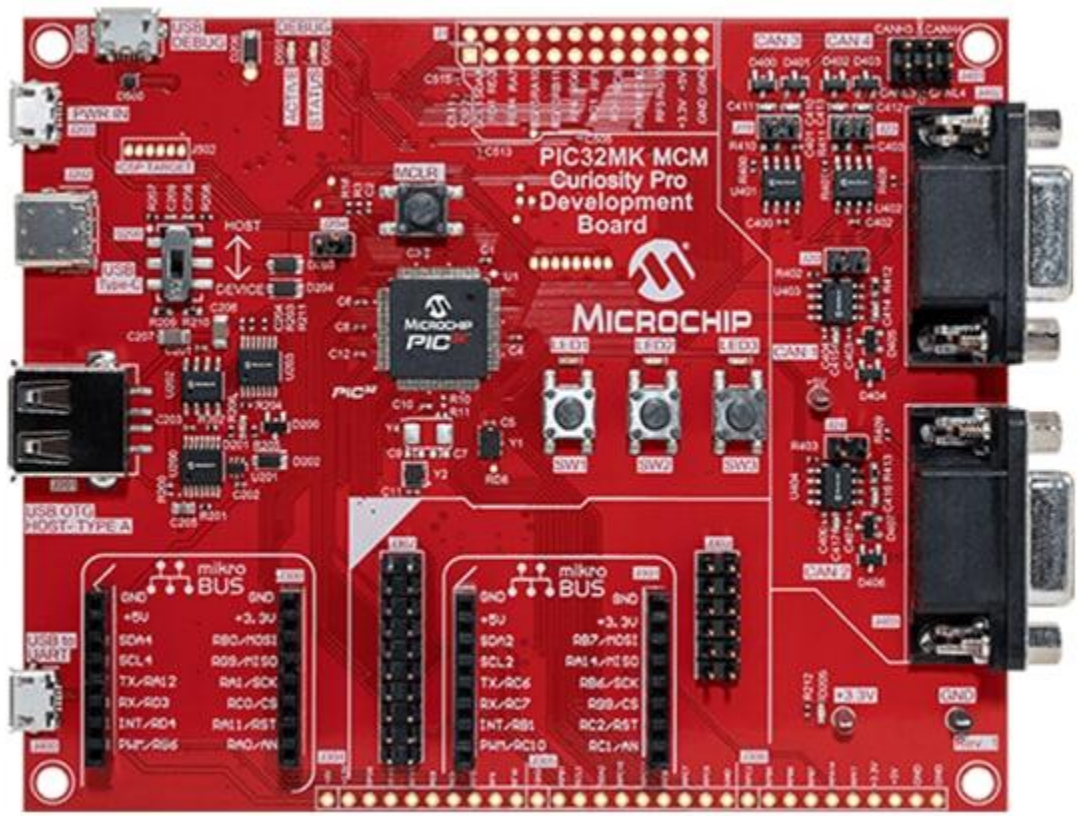
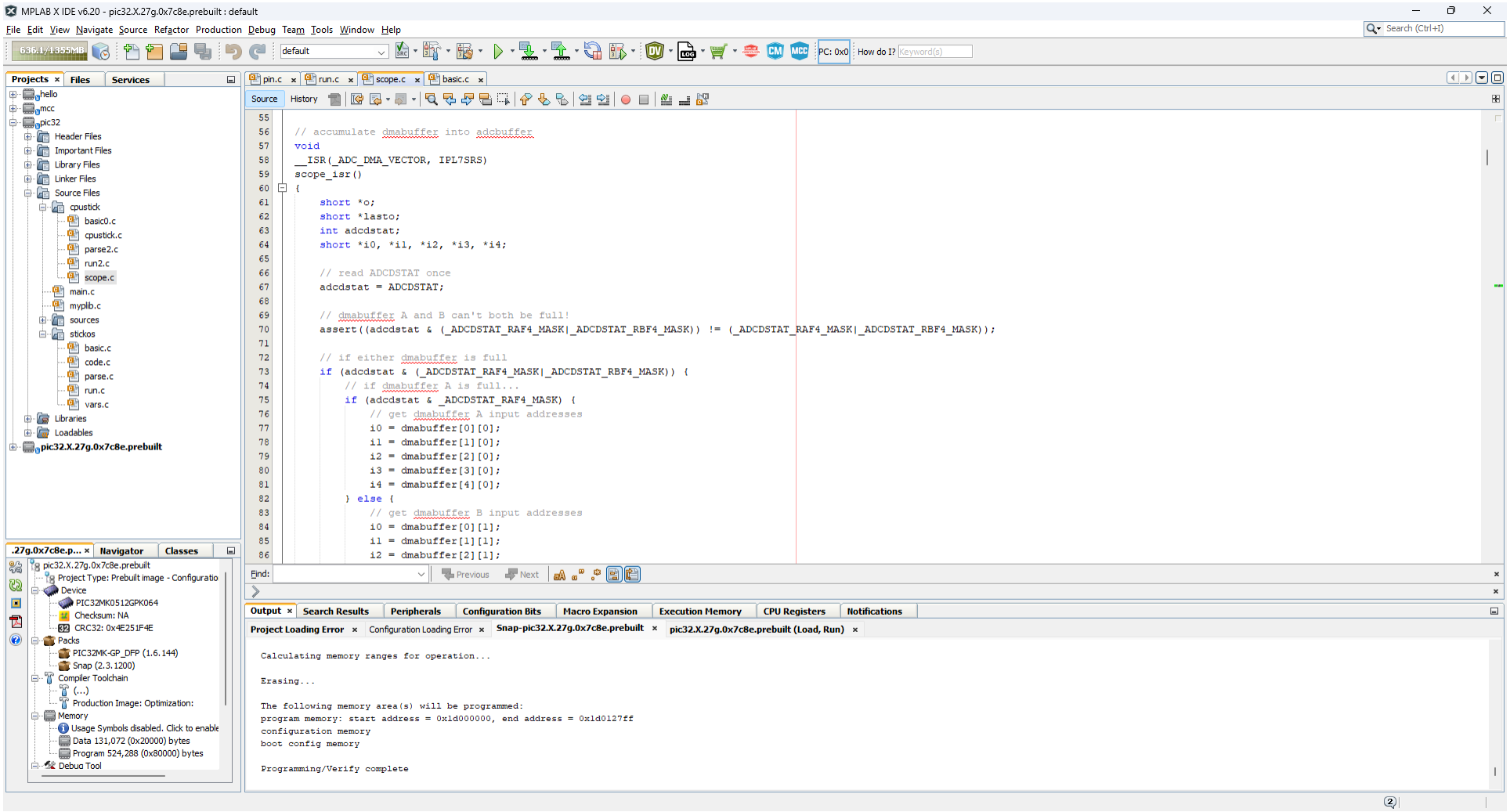


Figure 2

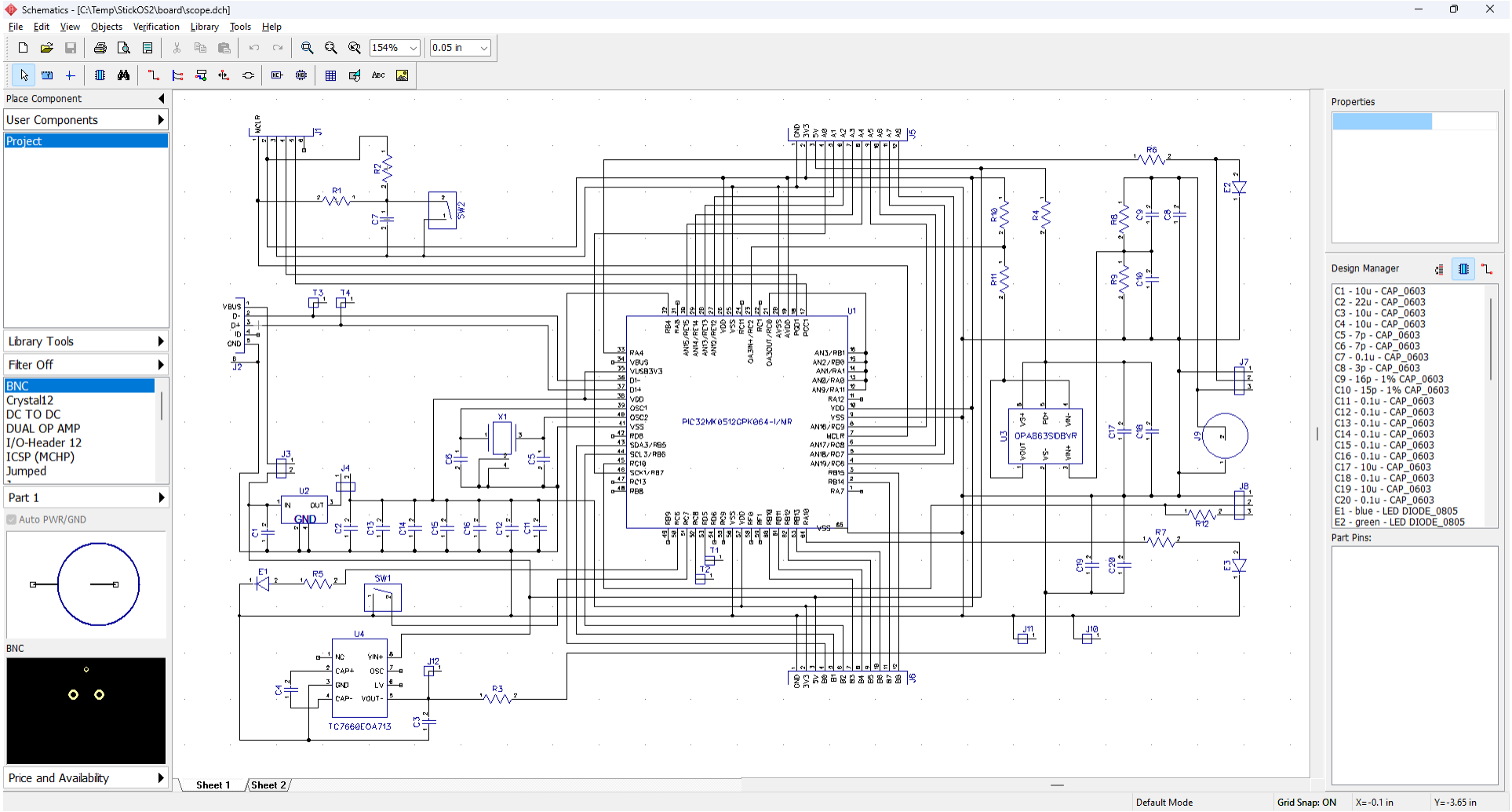
4. design the firmware

Using Microchip MPLAB X software



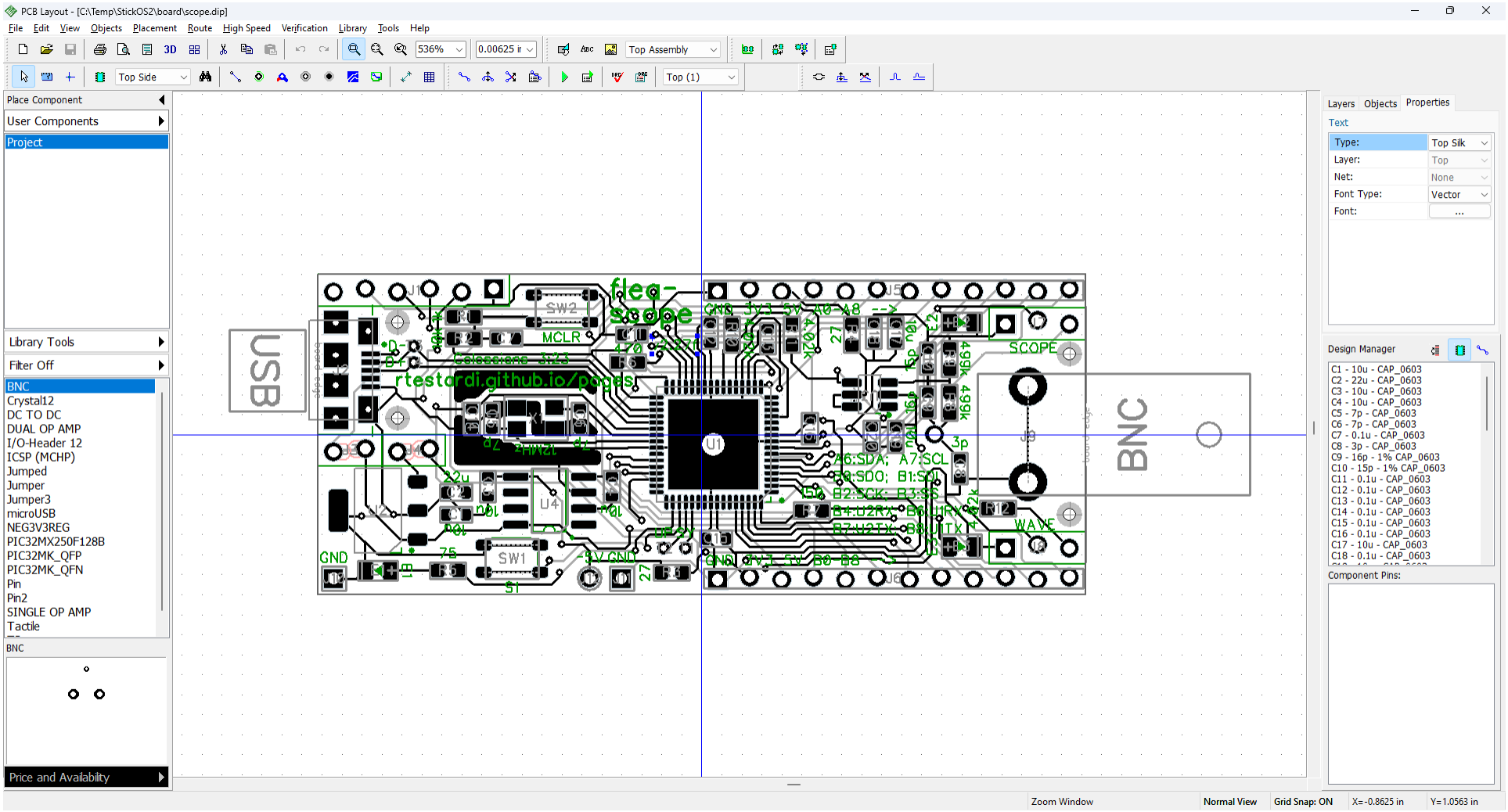
5. design a custom printed circuit board schematic

Using DipTrace Schematic



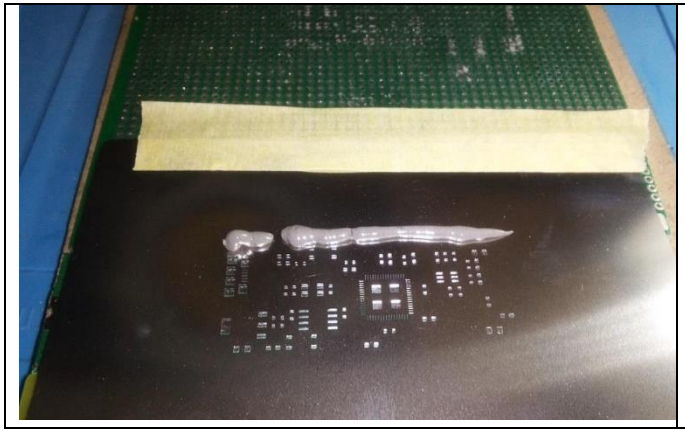
6. design a custom printed circuit board layout

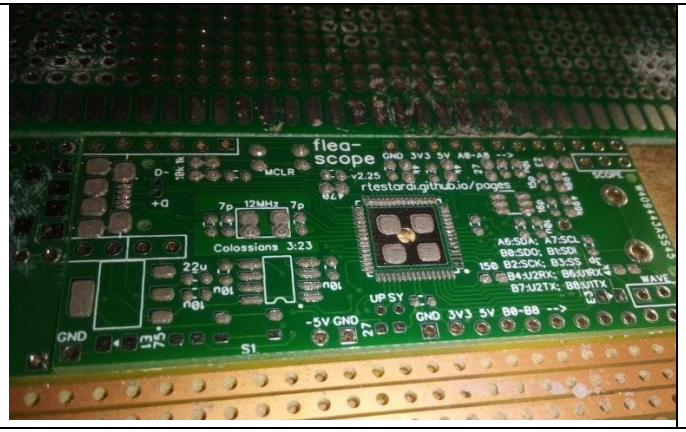
Using DipTrace PCB Layout

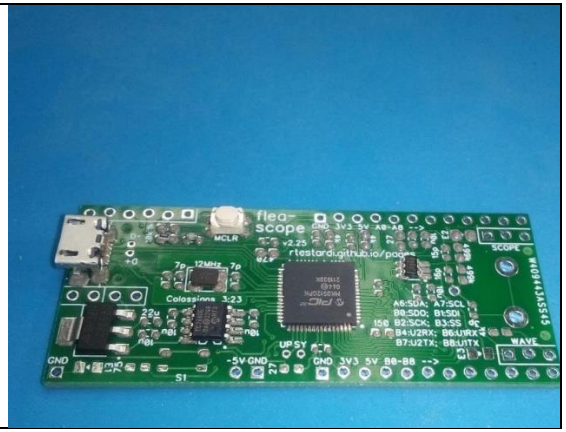


7. order and assemble the printed circuit board

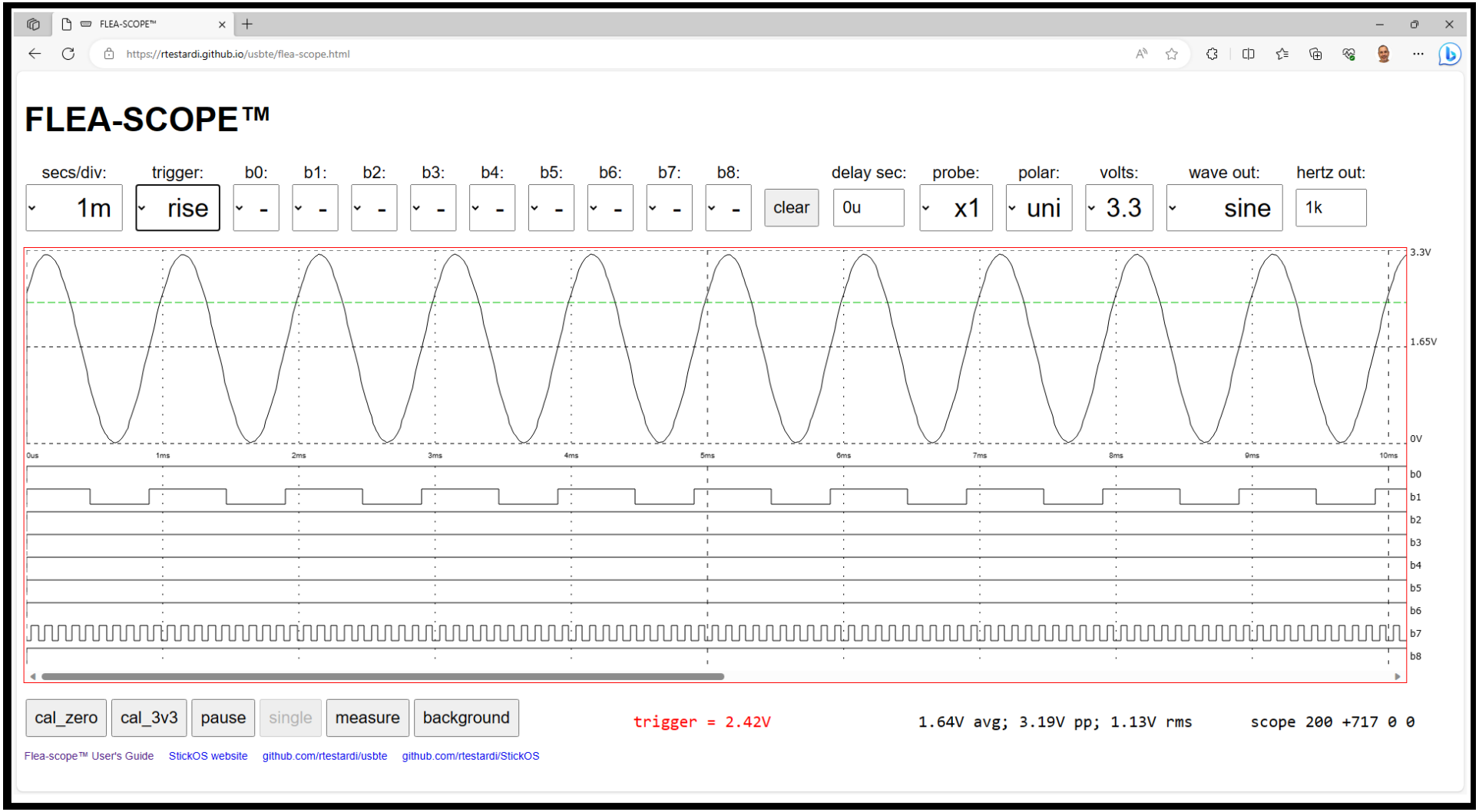
In my toaster oven at home!







8. design the webpage



9. always overdeliver

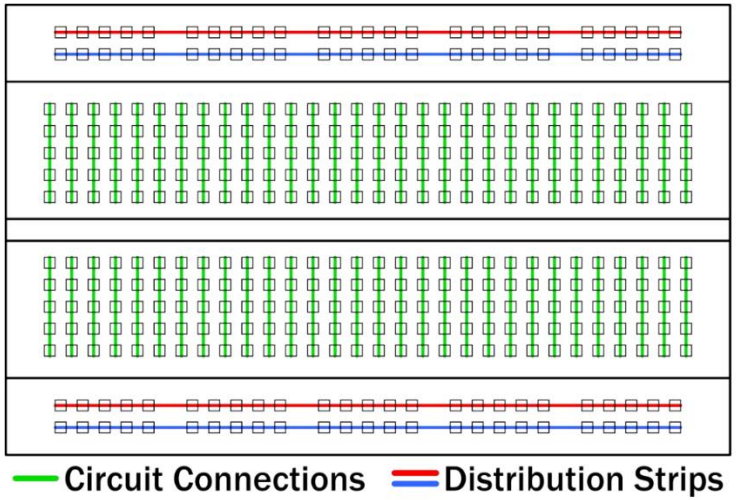
Colossians 3:23 NIV

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

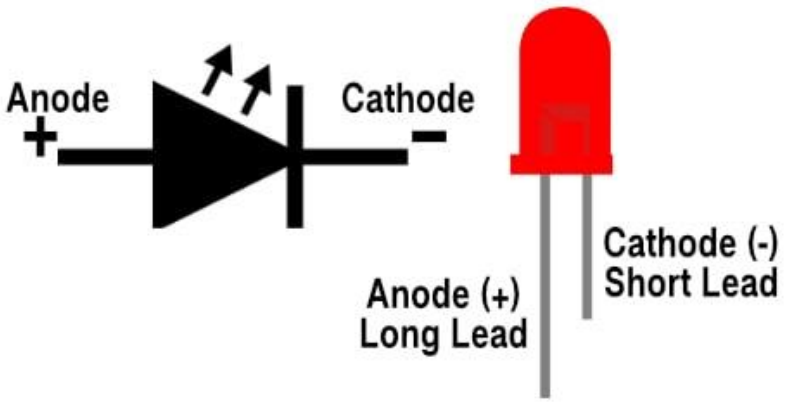
simon game hints

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>

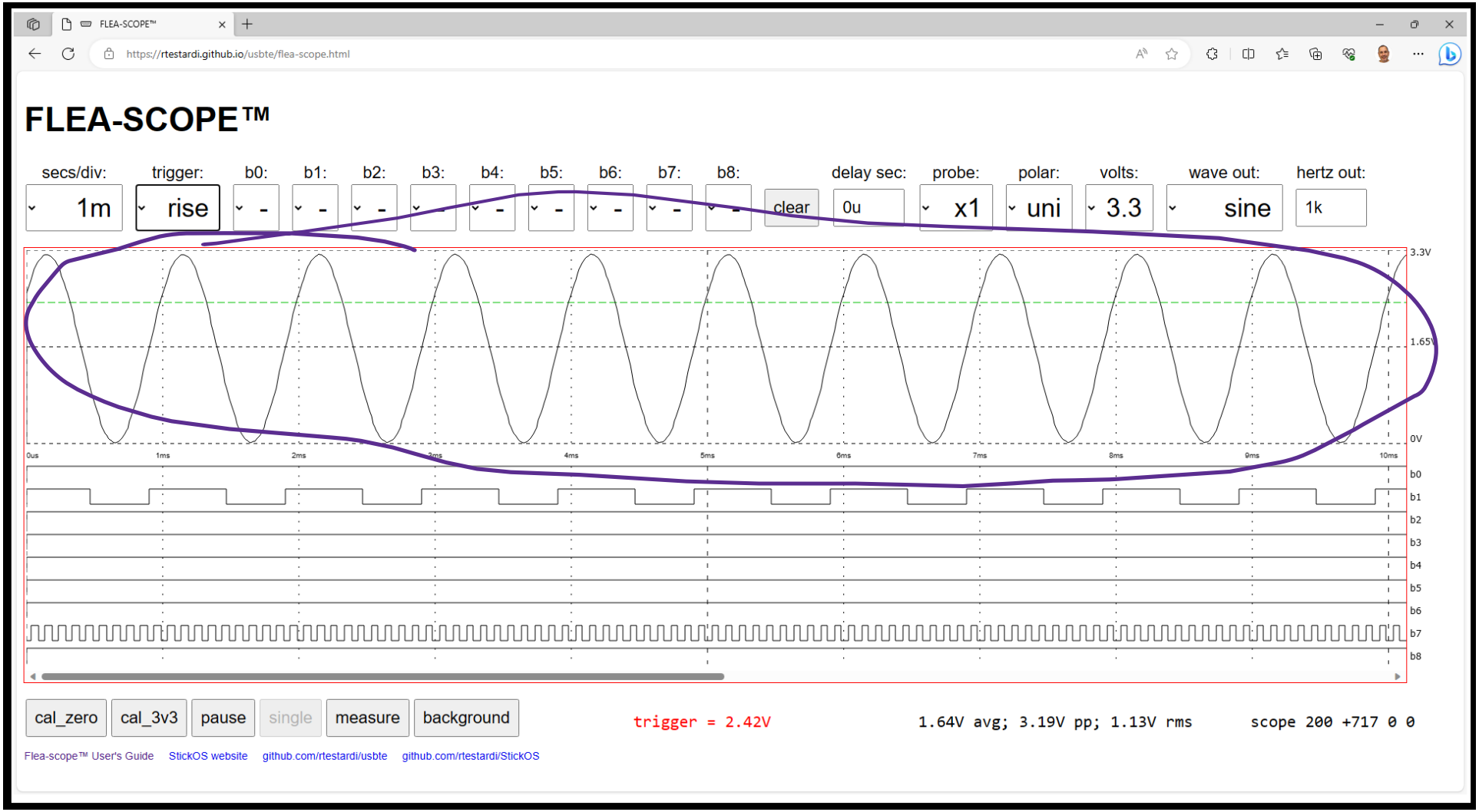
using an oscilloscope to measure voltage changing with time

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