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



or



min

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

				이 Peripheral Function Focus 한 Intelligent Analog Waveform Timing and Safety and Communication								cus			User I	Security				System Flexibility														
Product Family	Core	Max. Operation Freq. (MHz)	Program Flash Memory (KB)	RAM (KB)	Pin Count	Automotive (AEC-Q100 Grade 1 or Gr ADC (channels/bits)	ADC Speed (sps)	DAC (channels/bits)	Analog Comparator (+Op Amp)	Output Compare/Input Capture/ Waveform Output Channels	Motor Control PWM Pairs/Single	16-bit/32-bit Timer Channels (TC)	Quadrature Encoder/Decoder for Motor Contorl: QEI/QDEC/PDEC(3)	Functional Safety Ready	Class B Safety Library	USB (FS/HS) + PHY (Transceiver)	CAN (2.0B or FD)	Ethernet (10/100)	UART	P-C SPI (3)	SDIO/SD/eMMC PCC or PIO as CMOS Camera	Interface sol/OSPI	125 for Audio CODEC ⁽³⁾	Peripheral Bus Interface EBI/ PMP ⁽³⁾	Hardware Peripheral Touch, PTC (channels/Driven Shield +) ⁽³⁾	Segment/Graphics LCD Controller	LCD Controller (External, Low- Cost Controllerless, integrated)	Embedded Hardware Security Module (HSM) Crypto Engine (AES. SHA, ECC,		TrustZone ¹³⁾ Secure Boot ^[3]	Tamper Detection	Dual Panel/Bank Flash (*) Intelligent Low Power Peripheral	Event System (channels) ⁽³⁾ DMA (channels)	Ultra Small Package (WLCSP)
PIC32C Family (Ar	PIC32C Family (Arm* Cortex*-M)																																	
PIC32CM LX	CM23	48	256-512	32-64	48 -100	G1 24/1	2 1M	2/10	4	16/16/30	4/4	5/2	0			1F+P			6 6	66			1		P256			A, S,	T 🗸	/* √*	 √* 	- 1	* 12	2
PIC32CM MC ¹⁴⁰	CM0+	48	256-512	32.64	32-48	G1 12/1	2 1M	1/10	2	16/16/30	4/4	5/2	1	1			2ED*		4 4	4 4 8 8			-	-	E P256		F	5				1	2 12	2
PIC32CX SG	CM4F	120	1024	256	100.128	G1 16/1	2 1.14	2/10	4	33/33/39	8/13	8/4	1			1E+D	250*		9 9				1		P+AE35:		E	V ASE	рт	1	1	3	2 2	2
PIC32CK SG / GC	CM33	120	512-20/18	128-512	64-144	G1 12/1	2 7M	2/10	-4	40/40/40	10	8/4	1			1E+D	2FD*	1	8 9	8 8	2	1	1	1	AR35256	5	F		RT -		-	× 3	2 13	2
PIC32CZ CA 80 / 90	CM7F	300	2048 - 8192	512-1024	208	36/1	2 4M		2	40/40/40	10	0.4				2H+P	6FD	1	10 1	0 10	2	2	2	1	P256		E	✓ A,S,E,	R,T	√	1	√ 3	2 32	2
PIC32M Family (M	IPS32®)																																	
PIC32MM GPL	microAptiv ^{**}	25	16-64	4-8	20-36	G1 14/1	2 200k	1/5	2	3/3/3		7/3			~				2	2			2											
PIC32MM GPM	microAptiv	25	64-256	16-32	28-64	G1 24/1	2 200k	1/5	3	3/3/3		21/9			~	1F+P			3 3	3 3			3										4	
PIC32MX 1/2*/5+	M4K®	50	16-512	4-64	28-100	48/1	D 1M		3	5/5/5		5/2			~	1F+P*+	1+		5 2	2 4			4	~			E						8	
PIC32MX 1/2* XLP	M4K	72	128-256	32-64	28-44	13/1	0 1M		3	5/5/5		5/2			~	1F+P*			2 2	2 2			2	~	E								4	
PIC32MX 3/4*	M4K	120	32-512	8-128	64-100	28/1	D 1M		2	5/5/5		5/2			~	1F+P*			5 2	2 2			2	~			E/L						4	
PIC32MX 5×/6*/7+	M4K	80	64-512	16-128	64-100	16/1	D 1M		2	5/5/5		5/2			~	1F+P	1×/2+	1*+	6 5	5 4				~	E/L								8	
PIC32MK GP/MC	microAptiv	120	128-1024	64-256	28-100	42/1	2 25M	3/12	5/4	16/16/16	12/12	9/8	6		~	2F+P	4FD		6 4	4 6			6	1			E/L					~	8	
PIC32MZ EF	M-Class	252	512-2048	128-512	64-144	G1 48/1	2 18M		2	9/9/9		9/4			~	1H+P	2	1	6 5	56		1	6	~	E/L			A, S,	г			~	8	;
PIC32MZ DA (2)	microAptiv	200	1024-2048	256-640	169-288	G2 45/1	2 18M		2	9/9/9		9/4			~	1H+P	2	1	6 5	5 6	1	~	6	~		G	1	A, S,	Г			~	8	
SAM Family (Arm	Cortex-M)																																	
SAM D09	CM0+	48	8-16	4	14-24	10/1	2 350k			2/2/2		2/1							2 2	2 2												6	6 6	;
SAM D10/D11*	CM0+	48	8-16	4	14-24	10/1	2 350k	1/10	2	6/6/10	4*/-	2/1				1F+P*			3 3	3 3					P72							6	6 6	1
SAM D20/D21*	CM0+	48	16-256	2-32	32-64	G1 20/1	2 350k	1/10	2	22/22/32	8*/-	5/2		√*	~	1F+P*			6 6	5 6			1*		P256		E					1	2 12	* 🗸
SAM D21L	CM0+	48	32-128	4-16	32-48	G1 18/1	2 350k	1/10	4	22/22/32	8/-	5/2		~	~				6 6	5 6					E							1	2 12	2
SAM DA1	CM0+	48	16-64	4-8	32-64	G2 20/1	2 350k	1/10	2	18/18/24	8/-	5/2		1	1	1F+P			6 6	5 6			1		P256		E					1	2 12	2
SAM L10/L11*	CM23	32	16-64	4-16	24-32	G1 10/1	2 1M	1/10	203	6/6/6		3/1			~				3 3	3 3					P100, D+		E	A*,5*	;T ¥	* *	1	8	8 8	1
SAM L21	CM0+	48	32-256	4-32	32-64	20/1	2 1M	2/12	203	12/12/12	4/-	5/2		1		1F+P			6 6	6 6					P169		E	A,T				1	2 16	5 ✓
SAM L22	CM0+	32	64-256	8-32	48-100	20/1	2 1M		2	12/12/12	4/-	4/2				1F+P			6 6	5 6					P256	5320	E	A,T		-	×	8	B 16	5 🗸
SAM C20/C21* (4)	CM0+	48	32-256	4-32	32-100	G1 12/1	2 1M	1/10*	4	16/16/30	4/4	8/4		√*	~		2FD*		8 8	8 8		-		-	P256		E					1	2 12	2 🗸
SAM4N	CM4	100	512-1024	64-80	48-100	16/1	510k	1/10		6/6/10		6/-	2						7 3	3 4			-							-			23	5
SAM4S	CM4	120	128-2048	64-160	48-100	16/1	2 1M	2/12	1	6/6/10		6/-	2			1F+P	-		4 2	Z 3	1 .		1	×								✓ 1	4 22	2 🗸
SAM4E	CM4F	120	128 512	128	49.100	24/1	5 300k	2/12	1	9/9/13		-/9	3			1E+P	2	1	4	4 4	1,	-		~	022	5160		A			~		33	5
SAM4L	CM4F	48	256.512	52-64	48-100	9/1	2 300k	1/12	4	6/6/6		5/-				1E+P			4 4	+			1	-	P32	5160		A, I					+ 1t c 3/	
CAM DEvis (EEvit	CM4P	120	200-012	120.255	49-100	0/14	500K	2/12	2	0/0/0	0/17	0/-				1010	200		0 0		2				P+AE35:			100			Y	4 2	0 30	
SAM D5x+/E5x*	CM4F	120	256-1024	128-256	48-128	G1 32/1	2 1M	2/12	2	33/33/39	8/13	8/4	1		~	1F+b	ZFD*	1.*	8 8	5 8	2 .		1		AR35256		E	A,S,E,	K, I		-	× 3	2 3	2 +
SAM S7x (2)/E7x	CM7	300	512-2048	256-384	64-144	24/1	2 1.7M	2/12	1	12/12/16	8	12/-	4			1H+P	2FD*	1*	8 3	3 5	1 .		2	~	E/L			A, S,	Г	_	1	1	2 24	4
SAM V7x	CM7	300	512-2048	256-384	64-144	G2 24/1	2 1.7M	2/12	1	12/12/16	8	12/-	4			1H+P	2FD	1	8 3	3 5	1	1	2	1	E/L			A, S,	T		V .	1	2 24	4



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

😰 MPLAB X IDE v6.20 - pic32.X.27g.0x7c8e.prebuilt : d	fault	- ō ×
<u>File Edit View Navigate Source Refactor Production</u>	n Debug Team Tools Window Help	Q Search (Ctrl+I)
636.1/1355MB 🔞 🎦 🎦 🕒 🦉) 🥐 🛛 default 🔍 🖾 = 🎼 = 👪 = 🕨 = 🦉 = 🏪 = 🏠 🚯 = 🞯 = 🞰 = 🥰 = 🤹 💷 🚾 PC: 0x0 How do 12 (keyword(s)	
Projects × Files Services	epin.c x errun.c x errun.c x errun.c x	
🗄 💼 🕒 🔒 👘		P
ie 💭 🔤 🔤 👘 د د		
pic32	56 // accumulate dmahuffer into adchuffer	
Header Files	57 yoid	
Important Files	58 ISR(ADC DNA VECTOR, IPL/SRS)	1
Library Files	59 scope isr()	1
Source Files	61 short *o;	
	62 short *lasto;	
Dasicu.c	63 int adodstat;	
	64 short *i0, *i1, *i2, *i3, *i4;	
parsez.c	65	
	66 // read ADCDSTAT once	
scope.c	67 adcdstat = ADCDSTAT;	
main.c	68	
E Sources	69 // dmabuffer A and B can't both be full!	
stickos	70 assert((adodstat & (_ADCDSTAT_RAF4_MASK _ADCDSTAT_RBF4_MASK)) != (_ADCDSTAT_RAF4_MASK _ADCDSTAT_RBF4_MASK));	
and hasic c	71	
code.c	72 // if either dmabuffer is full	
a parse.c	73 if (adodstat & (_ADCDSTAT_RAF4_MASK)_ADCDSTAT_RBF4_MASK)) (
- Inn.c	74 // if dmabuffer A is full	
vars.c	75 if (adcdstat & ADCDSTAT_RAF4_MASK) (
	76 // get dmahuffer A input addresses	
Endables	77 i0 = dmabuffer[0][0];	
in pic32.X.27a.0x7c8e.prebuilt	78 il = dmabuffer[1][0];	
- ·····	79 i2 = dmabuffer[2][0];	
	<pre>80 i3 = dmabuffer[3][0];</pre>	
	81 i4 = dmabuffer[4][0];	
	82 } else {	
	83 // get dmabuffer B input addresses	
	<pre>84 i0 = dmabuffer[0][1];</pre>	
27a 0x7a9a a y Novienter Classes	85 il = dmabuffer[1][1];	
.27g.ox7cee.p × Navigator Classes	86 i2 = dmabuffer[2][1];	
Project Type: Prebuilt image - Configuratio	End: V - Previous Previous Next and " Rext a	,
PIC32MK0512GPK064		
Checksum: NA	Utput x Search Results Perpherals Configuration Bits Macro Expansion Execution Memory CPU Registers Notifications	
CRC32: 0x4E251F4E	Project Loading Error × Configuration Loading Error × Snap-pic32.X.2/g.Ux/C8e.prebuilt × pic32.X.27g.0x7/C8e.prebuilt (Load, Run) ×	
PIC32MK-GP_DFP (1.6.144)	Calculating memory ranges for operation	
Snap (2.3.1200)		
- ⁽¹⁾ ()		
Production Image: Optimization:	The following memory area(s) will be programmed:	
👾 💭 Memory	program memory: start address = 0x1d000000, end address = 0x1d0127ff	
Usage Symbols disabled. Click to enable	configuration memory	
Data 131,072 (0x2000) bytes	boot config memory	
Program 524,288 (0x80000) bytes		
	Programming/veriry complete	1
	JL	
		(2)

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

I ordered online from pcbway.com and assembled 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)





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

