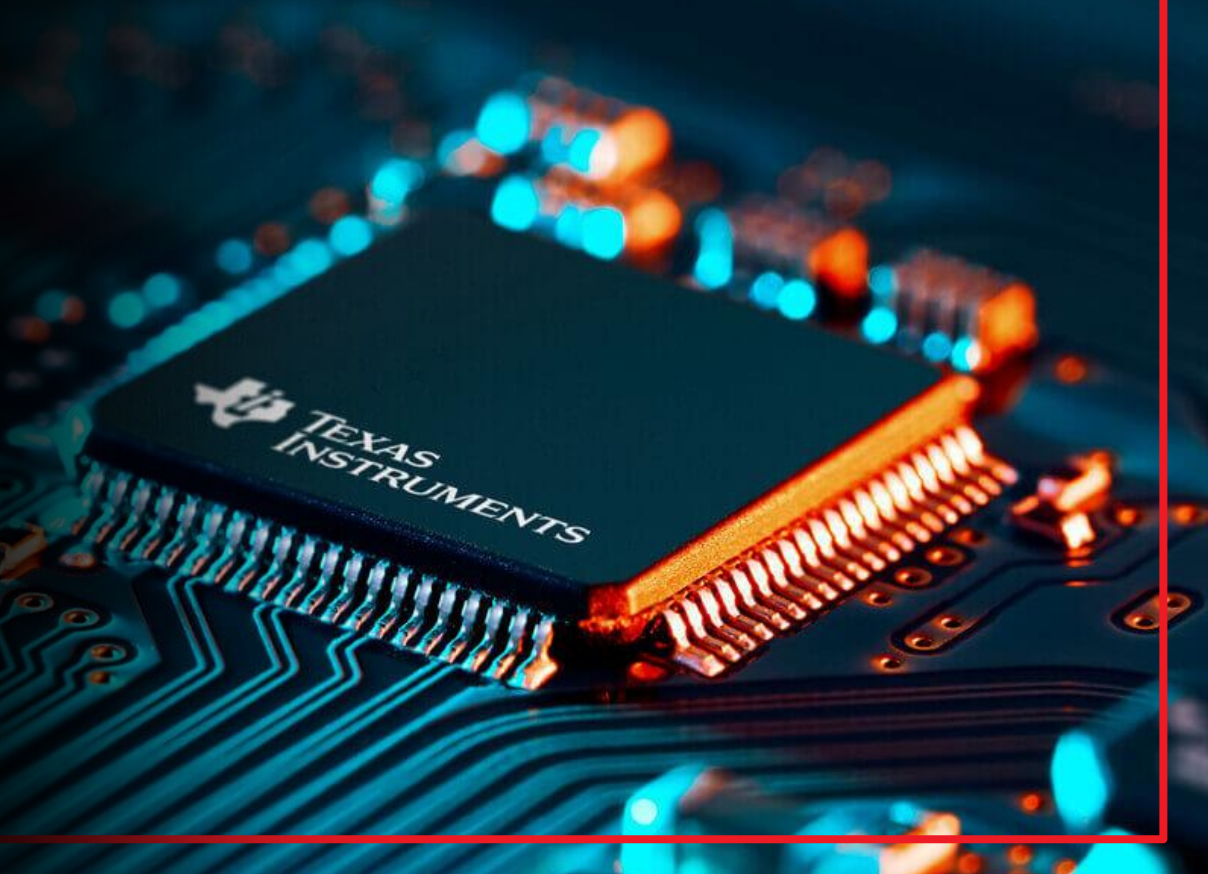
TEXAS INSTRUMENTS

2024 Embedded Seminar

Solve common MCU design challenges with TI MSPM0 subsystems



Dylan O'Brien

Applications Engineer

Agenda

- TI's ARM Cortex-M0+ MCU portfolio overview
- MSPM0 MCU software development kit overview
- MSPM0 MCU subsystem examples and demonstration
- Getting started with MSPM0 MCU subsystems page

MSPM0 MCUs | Reducing your system cost

Cost optimization

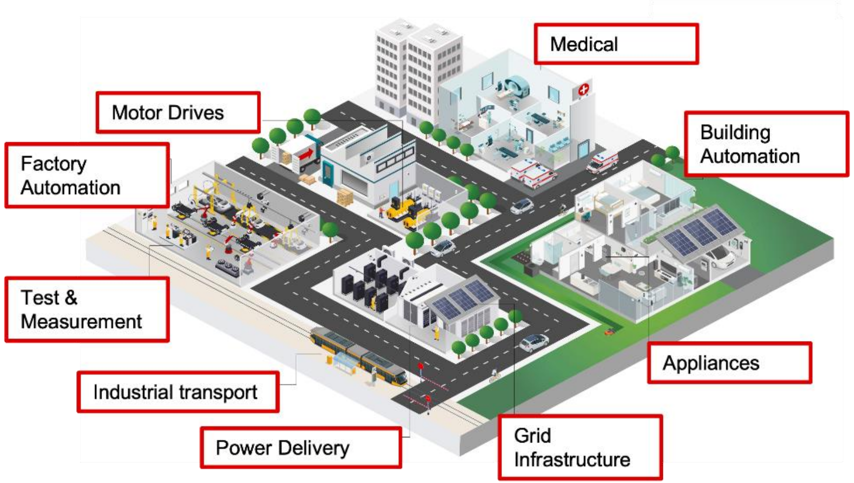
Best cost structure for microcontrollers with mix of digital, analog & memory

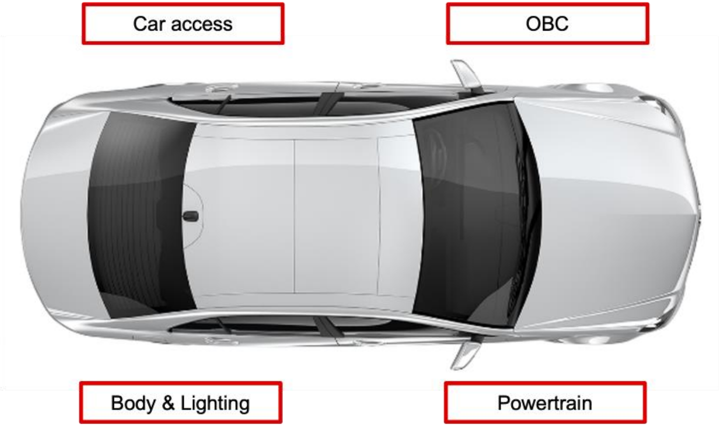
Smallest packages

Leverage the cost benefit of packages that are used by high volume analog

Advanced analog integration

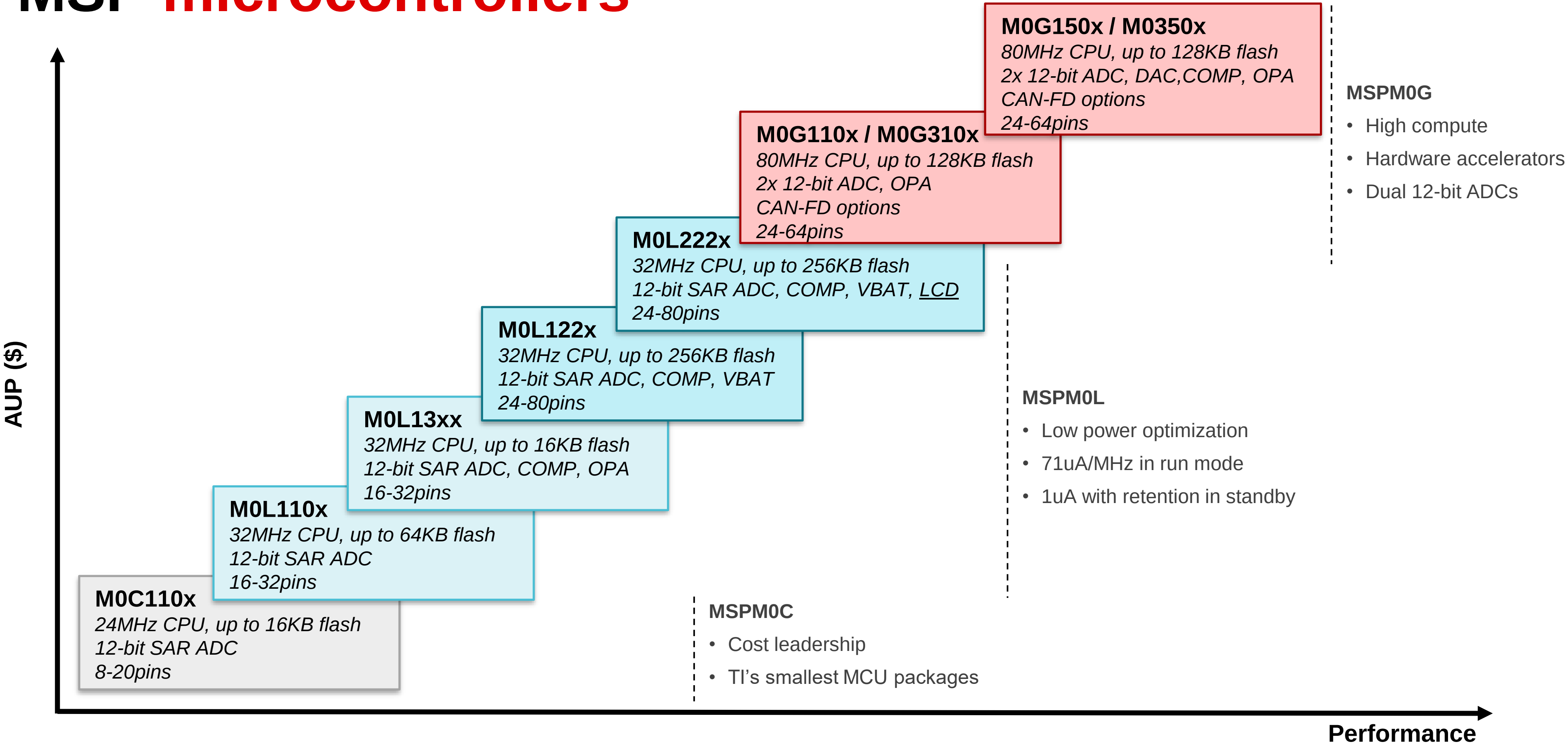
Save components, board space and simplify supply chain with integrated advanced analog





Devices optimized for broad range of industrial and automotive applications

MSP microcontrollers



MSPM0C1103/4 Family Overview

In production

8-bit replacement 24 MHz C-series MCUs up to 16kB flash and 20 pins

Key features and benefits

- Industry's **lowest cost** ARM Cortex-M0+ MCU featuring in-system programmable flash, delivering a standard MCU development experience OTP prices
- Choose from 6 of the industry's **smallest** MCU packages
  - Smallest 8-ball WCSP (YCJ8) with **0.86 x 1.6 mm total size** & 0.35mm pitch
  - Smallest no-lead 8-pin (WSON) with **2.0 x 2.0 mm total size** & 0.5mm pitch
  - Smallest leaded 8-pin (SOT) with **2.8 x 2.9 mm total size** & 0.65mm pitch
- Three **flexible timers** (1 advanced with **complementary outputs and dead-band**, 1 general purpose, and 1 interval) for PWM generation, capture/trigger, and wakeup
- 12-bit **1.5Msps** or 10-bit **1.7Msps**, 10-ch ADC for signal, supply, and temp monitoring
- **1-ch DMA** controller for boosting ADC throughput
- Up to **125C temperature grade** for industrial and automotive applications
- Up to **18 GPIOs** in 20-pin packages and 6 GPIOs in 8-pin packages

Get a cost reduction faster

- Direct pin-to-pin replacement for **STM8S003 TSSOP-20** footprint
- Port existing code easily according to the migration tool from STM8 to MSPM0C

MSPM0C1103/4

1.62 - 3.6V
-40 to 125 C

CPU
ARM Cortex-M0+
24 MHz
NVIC / 1-ch Basic DMA

On-chip Memory
- 8, or 16 kB flash
- 1 kB SRAM

Data Integrity & Security
- CRC accelerator (16 bit)

Programming & Debug
- ARM SWD interface

Power & Clocking
- POR / BOR
- Internal LF 32kHz (3%)
- Internal HF 24MHz (1%)

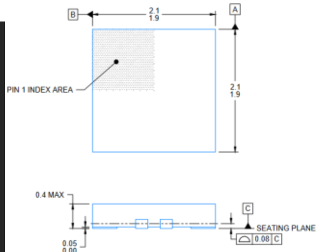
Communication
- UART w/ LIN (1)
- SPI (1)
- I2C (1) w/ FastMode+

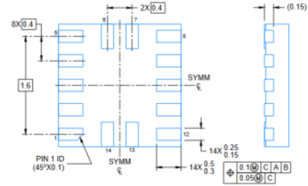
Precision Analog
- 12-bit SAR ADC (10-ch)
- Internal ADC reference (1.5%)

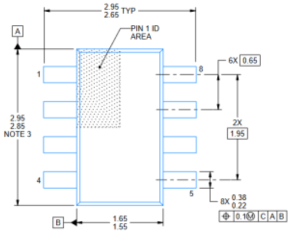
Timers
- Advanced control 16-bit 4 CC (1)
- General purpose 16-bit 4 CC (1)
- General purpose 16-bit 2 CC (1)
- Windowed watchdog

IO
- Up to 18 GPIO

Leaded packages: SOT-8/16, VSSOP-20, TSSOP-20
No-lead packages: WSON-8, WQFN-20 , WCSP-8







Variants:

MSPM0C1103	8 kB flash	1 kB SRAM	8-20 pins
MSPM0C1104	16 kB flash	1 kB SRAM	8-20 pins
MSPS003F3	*8 kB flash*	*1 kB SRAM*	*20 pins*
MSPS003F4	*16 kB flash*	*1 kB SRAM*	*20 pins*

MSPM0L13xx/110x Family overview

In production

Easy to use 32 MHz L-series MCUs up to 64kB flash and 32 pins

Key features and benefits

- **Cost optimized** 32MHz Arm Cortex-M0+ CPU (71µA/MHz), flexible 3-ch DMA controller
- Excellent high temperature standby current (**1µA** at 25 ºC/TYP, **6µA** at 85 ºC/MAX)
- Up to **8 PWM outputs** via 4 general purpose timers, operational in standby mode
- Protocol support for **LIN**, IrDA, DALI, Manchester, smart card, SMBus, PMBus, FM+
- 12-bit, **1.68-Msps**, 10-ch ADC with **11.2 ENOB**, averaging, window comparator, FIFO
- High-speed **(32ns)** / low-power (**0.7µA**) comparator with 8-bit reference DAC

Reduce your system cost and size

- Two zero-drift **chopper stabilized** 6MHz op-amps with 32x PGA & near-zero V_{os} enable **removal of discrete amplifiers** on the PCB, or **buffering of 8-bit DAC voltage**
  - Available **low I_b** (<10pA) to support transimpedance amplifier configurations
- **1.2% accurate** 4/32MHz on-chip oscillator from -40 to 85 ºC enables **crystal-less UART**
- 3% accurate 32kHz on-chip LF oscillator enables **accurate wake-up timing**
- Two 5V-tolerant open drain IO for **simplifying interfacing** to mixed-voltage systems
- Wide VDD range of **1.62-3.6V** supporting 1.8V and 3.3V supplies with ±10% tolerance
- Six package options (3 leaded, 3 no-lead) for **optimizing size, cost, and pin count**
  - Industry's **smallest 0.5mm pitch leaded packages** for smaller PCB designs

MSPM0L13xx/110x

1.62 - 3.6V
-40 to 125 C

CPU
Arm Cortex-M0+
32 MHz
NVIC / 3-ch DMA

On-chip Memory
- 8, 16, 32 or 64 kB flash
- 2 or 4 kB SRAM

Data Integrity & Security
- CRC accelerator (16 and 32 bit)

Programming & Debug
- ARM SWD interface
- UART & I2C bootloader

Power & Clocking
- POR / BOR / SVS
- Internal LF 32kHz (3%)
- Internal HF 4-32MHz (1%)

Communication
- UART w/ LIN (1)
- UART (1)
- SPI (1)
- I2C (2) w/ FastMode+

IO
- Up to 28 GPIO
- Up to 2 low Ib OPA inputs

Analog
- 12-bit ADC 1.45Msps (10-ch)
- Comparator w/ 8-bit DAC
- Zero-drift chopper op-amps (2)
- General purpose amp
- Internal ADC reference (1.5%)
- Temperature sensor

Timers
- Low power 16-bit 2 CC (4)
- Windowed watchdog

Leaded packages: SOT-16, VSSOP-20/28
No-lead packages: WQFN-16, VQFN-24/32

Variants:

MSPM0L130x	8-64 kB flash	2-4 kB SRAM	16-32 pins	ADC, CMP, 2x op-amps
MSPM0L134x	8-64 kB flash	2-4 kB SRAM	20-28 pins	ADC, CMP, 2x TIA op-amps
MSPM0L110x	32-64 kB flash	4 kB SRAM	16-32 pins	ADC

MSPM0Lx22x Family overview

Sampling now

32 MHz L-series MCUs up to 256kB flash, 80 pins, VBAT, LCD

Key features and benefits

- **Cost optimized** 32MHz Arm Cortex-M0+ CPU with flexible 7-ch DMA controller
- Low power **8x51 / 4x55** segmented LCD controller with charge pump & flexible biasing/muxing
- Robust backup **power island** with independent RTC, WDT, 32-byte memory, tamper IO
- Excellent high temperature standby current (**1.7µA** at 25 ºC/TYP, **7µA** at 85 ºC/MAX)
- **Dual-bank** main flash with W^X bank address swap for in-system firmware updates (with ECC)
- **Security enablers** for IoT (PSA-L1), including secure startup firewalls and IP protection
- Powerful AES 128/256 accelerator with GCM/CCM, local key store, and TRNG
- 12-bit, **1.68-Msps**, 26-ch ADC with **11.2 ENOB**, averaging, window comparator, FIFO
- ISO26262 **ASIL-B** functional safety, ASPICE-L3 ROM
- High-speed **(32ns)** / low-power (**1.5µA**) comparator with 8-bit reference DAC
- 5 UARTs (2 w/ LIN) all supporting standby mode (32kHz or edge wake), 2 SPI, 3 I2C
- Fully independent watchdog

Reduce your system cost and size

- Support for supercapacitor operation with supercapacitor charging
- **1.2% accurate** 4/32MHz on-chip oscillator from -40 to 85 ºC enables **crystal-less UART**
- Wide VDD range of **1.62-3.6V** supporting 1.8V and 3.3V supplies with ±10% tolerance
- 0.5mm and 0.4mm pitch options (for 80-pin LQFP)

MSPM0L222x/122x

1.62 - 3.6V
-40 to 125 C

CPU
Arm Cortex-M0+
32 MHz
NVIC / 7-ch DMA

On-chip Memory
- 128 or 256 kB flash [ECC]
- Dual-bank main flash with OTA
- 32 kB SRAM [ECC]

Data Integrity & Security
- CRC accelerator (16 and 32 bit)
- AES256 (w/ key store) + TRNG
- Firewalls, IP protection, W^X

Programming & Debug
- ARM SWD interface
- UART & I2C bootloader

Power & Clocking
- POR / BOR / SVS
- External HF 4-32MHz XTAL
- Internal HF 4-32MHz (1%)

Communication
- UART w/ LIN (2)
- UART (3)
- SPI (2)
- I2C (3) w/ FastMode+

VBAT Island
- External LF 32kHz XTAL
- Internal LF 32kHz (3%)
- Independent watchdog
- Real-time clock
- Tamper detection (3 IO)
- 32B backup memory
- Supercapacitor charging

Analog
- 12-bit ADC 1.68Msps (26-ch)
- Comparator w/ 8-bit DAC (1)
- Internal reference (1.5%)
- Temperature sensor

Timers
- Advanced control 16-bit 4 CC (1)
- General purpose 32-bit 2 CC (1)
- General purpose 16-bit 2 CC (2)
- Low power 16-bit 2 CC (2)
- Windowed watchdog

IO
- Up to 73 GPIO
- Segment LCD (8x51, 4x55)

Leaded packages: LQFP-48/64/80 | No-lead packages: VQFN-24/32/48, nFBGA
ISO26262 ASIL-B safety and Arm PSA Level 1 security

Variants:

MSPM0L222x	128-256 kB flash	32 kB SRAM	48-80 pins	ADC, CMP, LCD, VBAT
MSPM0L122x	128-256 kB flash	32 kB SRAM	24-80 pins	ADC, CMP, VBAT

MSPM0Gx50/Gx10x Family overview

In production

Powerful 80 MHz G-series MCUs up to 128kB flash and 64 pins

Key features and benefits

- Cost optimized **80MHz** Arm Cortex-M0+ CPU (96µA/MHz), with **math accelerator**
- Flexible communications: **CAN-FD** controller, 4 UARTs (1 w/ LIN), 2 SPI, 2 I2C
- Two **simultaneous sampling** 12-bit, **4-Msps** ADCs (with **11.2 ENOB**, averaging to **14-bit / 250ksps**, window comparator, and FIFO), 17 total external channels for industry-leading precision in energy monitoring and real-time control applications
- 3x high-speed **(32ns)** / low-power (**1µA**) comparators with 8-bit reference DACs for 1-shunt to 3-shunt monitoring in control applications or low power monitoring of multiple signals
- 12-bit 1Msps **DAC** with output buffer for waveform generation or biasing
- Advanced control timers with complementary outputs, dead-band, cycle-by-cycle limiting, quadrature/hall sensing, and synchronization for real-time control applications
- ECC-protected flash with SRAM parity and dual WWDT for robust operation

Reduce your system cost and size

- Two zero-drift **chopper stabilized** 6MHz op-amps with 32x PGA & near-zero V_{os} enable **removal of discrete amplifiers** on the PCB, or **buffering of 8-bit DAC voltages**
- **1.2% accurate** 4/32MHz on-chip oscillator from -40 to 85 ºC enables **crystal-less UART**
- Two 5V-tolerant open drain IO for **simplifying interfacing** to mixed-voltage systems
- Nine package options (4 leaded, 3 no-lead, 1 BGA/1 WCSP) for **optimizing size and cost**
- Industry's **smallest 0.5mm pitch leaded packages** with CAN-FD for smaller PCB designs

MSPM0G3505/6/7

1.62 - 3.6V
-40 to 125 C

CPU
ARM Cortex-M0+
80 MHz
NVIC / MPU / 7-ch DMA

Accelerators
- Math (DIV, SQRT, TRIG, MAC)

On-chip Memory
- 32, 64, or 128 kB flash[ECC]
- 16 or 32 kB SRAM

Data Integrity & Security
- CRC accelerator (16 and 32 bit)
- AES256 accelerator + TRNG

Programming & Debug
- ARM SWD interface
- ROM UART & I2C BSL

Power & Clocking
- POR / BOR / SVS
- External LF 32kHz XTAL
- External HF 4-48MHz XTAL
- Internal LF 32kHz (5%)
- Internal HF 4-32MHz (1%)
- PLL (up to 80 MHz)

Communication
- UART w/ LIN (1)
- UART (3)
- SPI (2)
- I2C (2) w/ FastMode+
- CAN-FD (1)

IO
- Up to 60 GPIO

Precision Analog
- 12-bit SAR ADCs 4Msps (9-ch)
- 12-bit SAR ADCs 4Msps (8-ch)
- ULP/HS Comparators w/ 8-bit DAC (3)
- 12-bit 1Msps buffered DAC (1)
- Zero-drift chopper op-amps (2)
- General purpose amp (1)
- Internal reference (1.5%)
- Temperature sensor

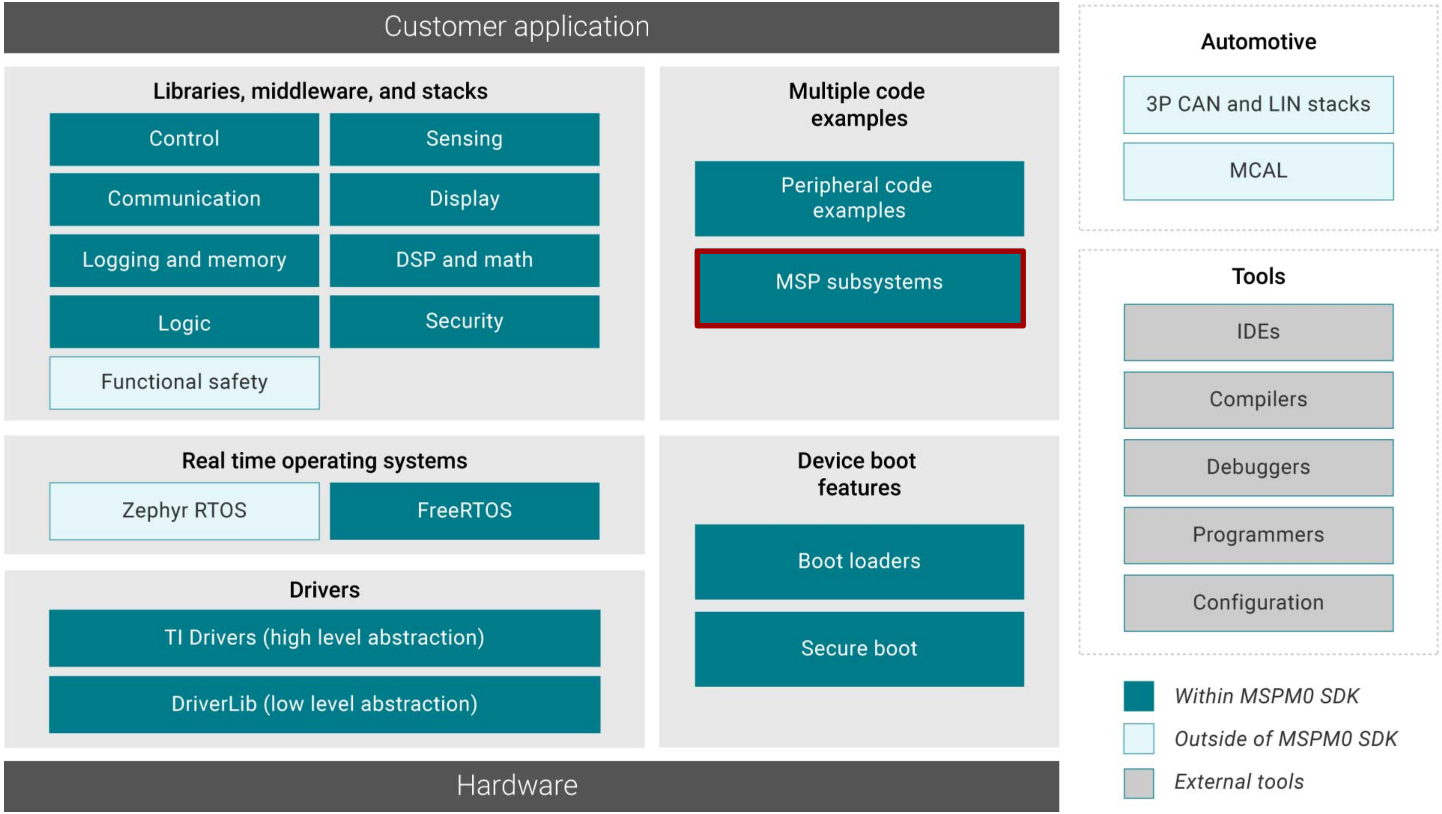
Timers
- Advanced control 16-bit 4 CC (1)
- Advanced control 16-bit 2 CC (1)
- General purpose 32-bit 2 CC (1)
- General purpose 16-bit 2 CC (1)
- General purpose 16-bit 2 CC w/ QEI (1)
- Low Power 16-bit 2 CC (2)
- Windowed watchdog (2)
- Real-time clock (1)

Leaded packages: VSSOP-20/28, LQFP-48/64
No-lead packages: VQFN-24/32/48, nFBGA-64, WCSP-28

Variants:

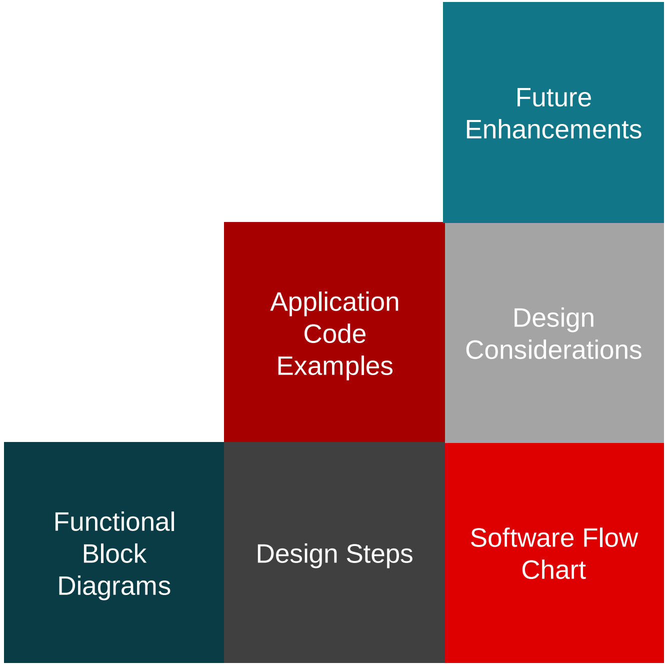
MSPM0G350x	32-128 kB flash	16-32 kB SRAM	28-64 pins	ADC, CMP, DAC, OPA, AES/TRNG, MATHACL, CAN-FD
MSPM0G310x	32-128 kB flash	16-32 kB SRAM	20-64 pins	ADC, AES/TRNG, CAN-FD
MSPM0G150x	32-128 kB flash	16-32 kB SRAM	28-64 pins	ADC, CMP, DAC, OPA, AES/TRNG, MATHACL
MSPM0G110x	32-128 kB flash	16-32 kB SRAM	28-64 pins	ADC

MSPM0 SDK | All the SW you need in one place



What are subsystems?

Building blocks for common MCU design challenges



Subsystem Design

Dynamic Programmable Gain Amplifier

TEXAS INSTRUMENTS

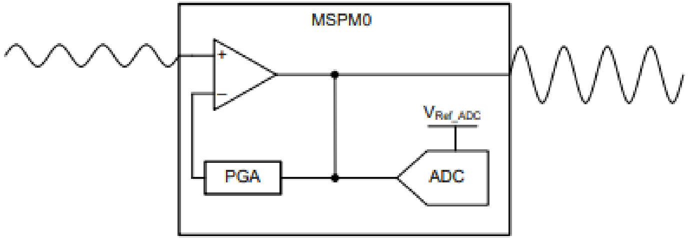


Figure 1-1. Subsystem Functional Block Diagram

```
#include "ti_msp_dl_config.h"

#define HIGHMARGIN 3890 // 4095*0.75 = 75% of max ADC value
#define LOWMARGIN  1638 // 4095*0.25 = 25% of max ADC value
#define MAXGAIN  DL_OPA_GAIN_N7_P8 // Maximum GAIN level of OPA wanted
#define MINGAIN  DL_OPA_GAIN_N1_P2 // Minimum GAIN level of OPA wanted.
//For non-inverting PGA mode this is an OPA GAIN of 2x. See advisory in TRM for MIN GAIN.

int main(void)
{
    SYSCFG_DL_init();

    //Set ADC Window Compare thresholds
    DL_ADC12_disableConversions(ADC12_0_INST);
    DL_ADC12_configWinCompHighThld(ADC12_0_INST, HIGHMARGIN);
    DL_ADC12_configWinCompLowThld(ADC12_0_INST, LOWMARGIN);
```

Faster development time | Save on software resources

MSPM0 MCU subsystem availability

General functionality

Subsystem	M0G	M0L	M0C
Digital mux	✓	✓	✓
Task scheduler	✓	✓	✓
Diode matrix	✓	✓	✓
Power sequencer	✓	✓	✓
LED driver with PWM	✓	✓	✓
FIR (digital filters)	✓		
IIR (digital filters)	✓		
RTC scheduler	✓	✓	✓
Interfacing with 5V	✓	✓	✓

Communication bridges

Subsystem	M0G	M0L	M0C
UART to I2C	✓	✓	✓
CAN to UART	✓		
CAN to SPI	✓		
CAN to I2C	✓		
I2C to UART	✓	✓	✓
UART to SPI	✓	✓	✓

Analog functions

Subsystem	M0G	M0L	M0C
ADC to PWM	✓	✓	✓
PWM DAC	✓	✓	✓
ADC with DMA ping pong	✓	✓	
ADC with SPI interface	✓	✓	✓
ADC with I2C interface	✓	✓	✓
ADC with UART	✓	✓	✓
Data sensor aggregator	✓	✓	✓
PGA	✓	✓	
Transimpedance amplifier	✓	✓	

LED Drivers with PWM

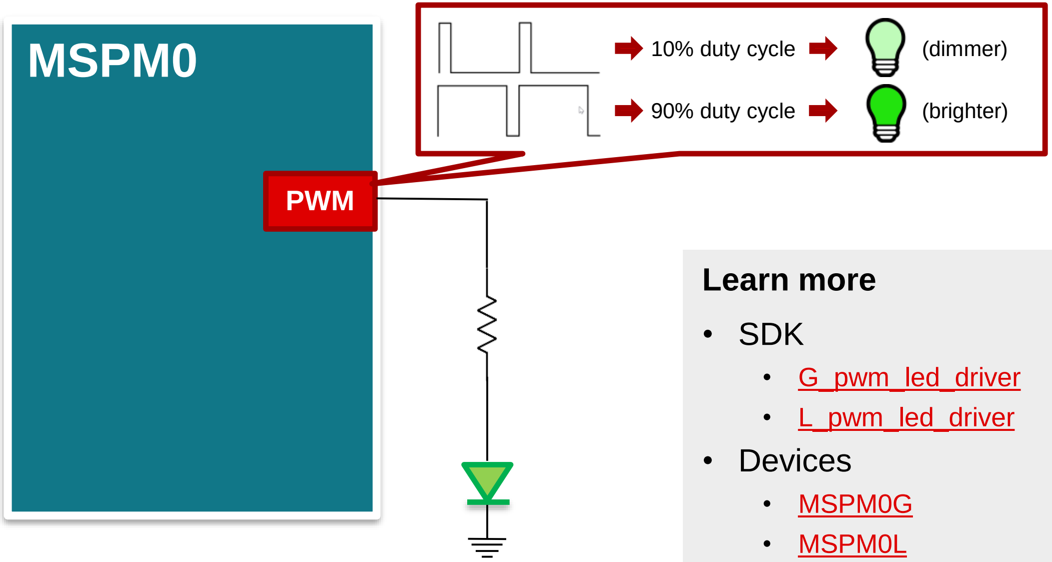
Using MSPM0 to drive LEDs

Functions

- Drive LEDs on M0 devices using PWMs
- Control rate of dimming using general purpose timer

Advantages

- Four general purpose timers with two capture compare registers each → 8 total PWM channels to drive LEDs (drive multiple LEDs with one timer)
- Can drive up to 20 mA on both M0G and M0L devices
- Pipelined compare feature that allows you to hold the update timer counter values until a certain event
- 5V tolerant open-drain IOs
- HD IOs available on M0G device

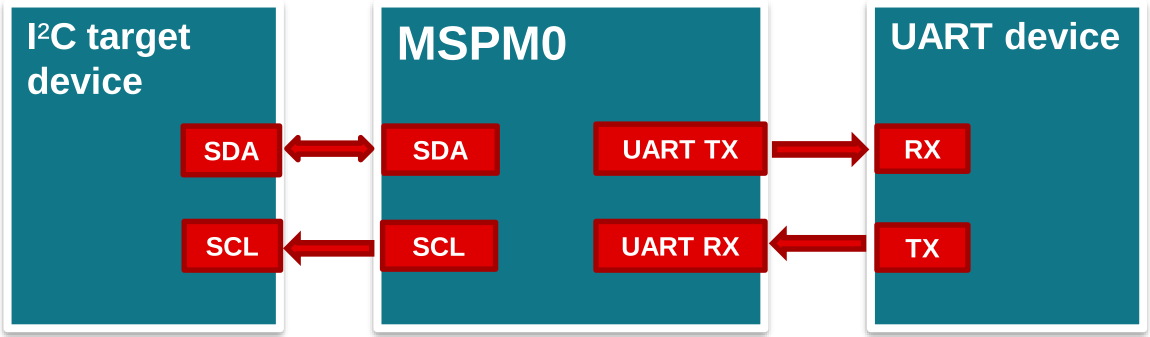


Learn more

- SDK
  - G_pwm_led_driver
  - L_pwm_led_driver
- Devices
  - MSPM0G
  - MSPM0L
  - MSPM0C

UART-to-I2C Bridge

Using low cost MSPM0



Functions

- Write UART input data to target device via I2C communication
- Read data from I2C target device to controller and output on UART

Advantages

- Support for both UART and I2C on one device
- Easily convert between UART to I2C protocols
- Send packet of UART data to multiple peripheral devices via I2C
- Allow hardware devices that only support UART to access I2C protocol for data transmission and exchange

Learn more

- M0 MySecure repository
  - Request access to mysecure
- Devices
  - MSPM0G
  - MSPM0L

Key questions

- Do you need to communicate UART data to multiple peripheral devices or read from multiple peripheral devices and output via UART?
- Does your system only support UART?

Low cost ADC to SPI, I2C, UART

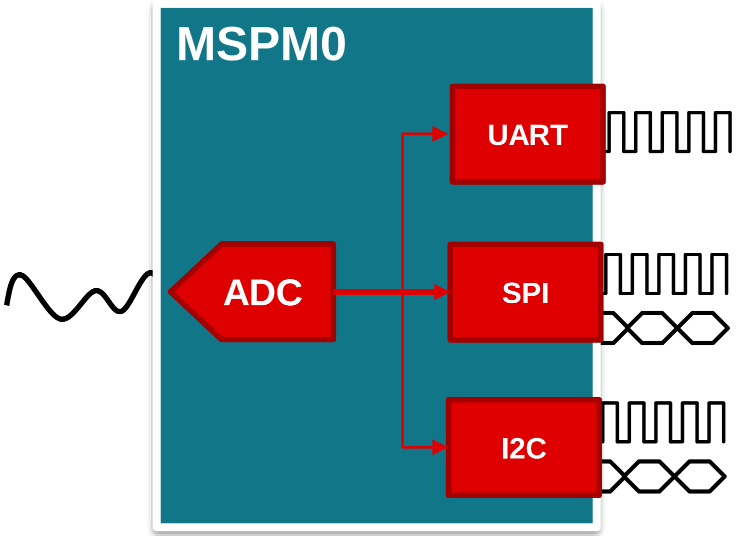
Using low cost MSPM0

Functions

- Samples analog signals with ADC
- Sends ADC result through desired communication interface (SPI, I2C, UART)

Advantages

- Reduce size of your PCB by using the MSPM0's internal ADC and send through SPI, I2C and/or UART.
- Can pre-process the ADC data before sending to another device.
- Can send through any included communication interface for flexibility



Key questions

- Does your system need an analog signal read?
- Does your system require SPI, I2C, or UART communication?
- Do you have limited PCB space?

Learn more

- SDK
  - G_adc_to_uart
  - G_adc_to_i2c_target
  - G_adc_to_spi_peripheral
  - L_adc_to_uart
  - L_adc_to_i2c_target
  - L_adc_to_spi_peripheral
- Devices
  - MSPM0G
  - MSPM0L
  - MSPM0C

Dynamic Programmable Gain Amplifier

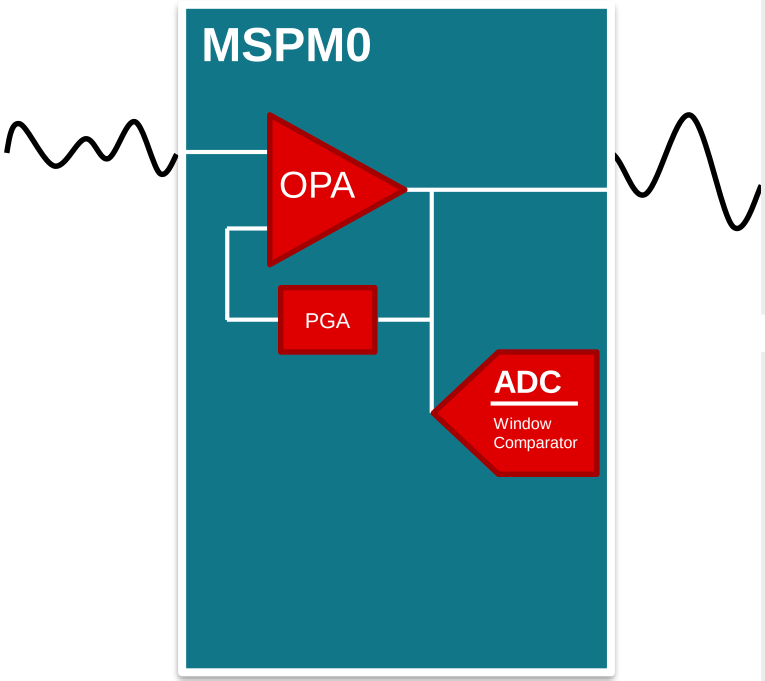
Using low cost MSPM0

Functions

- Automatically adjust signal gain to keep output at defined voltage ranges
- Optionally output signal or sample with ADC

Advantages

- OPA Gain adjusts without signal interruption
- Increases signal acquisition dynamic range
- Reduce hardware components and board space
- Shutdown Amp capability to save power



Key questions

- Do you need to a high dynamic range of signal acquisition?
- Does your system have multiple gain stages for the same signal for different situations?
- Do you need Shutdown Amp capabilities?

Learn more

- SDK
  - L_programmable_gain_amplifier_1
  - L_programmable_gain_amplifier_2
- Devices
  - MSPM0G
  - MSPM0L
  - MSPM0C

Getting started

Arm Cortex –M0+ MCU subsystems page

Subsystem categories

TI has divided its MSPM0 subsystems into the categories below. Each subsystem contains a subsystem design and software example.

Expand all

Analog and sensing

Communication bridges

CAN to I2C Bridge	Software
I2C to UART	Software
CAN to SPI bridge	Software
CAN to UART bridge	Software
UART to I2C	Software

Miscellaneous MCU functionality

Timing and control

MSPM0 SDK

https://www.ti.com/tool/MSPM0-SDK

MSPM0C Launchpad

https://www.ti.com/tool/LP-MSPM0C1104

MSPM0L Launchpad

https://www.ti.com/tool/LP-MSPM0L1306

MSPM0G Launchpad

https://www.ti.com/tool/LP-MSPM0G3507

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265