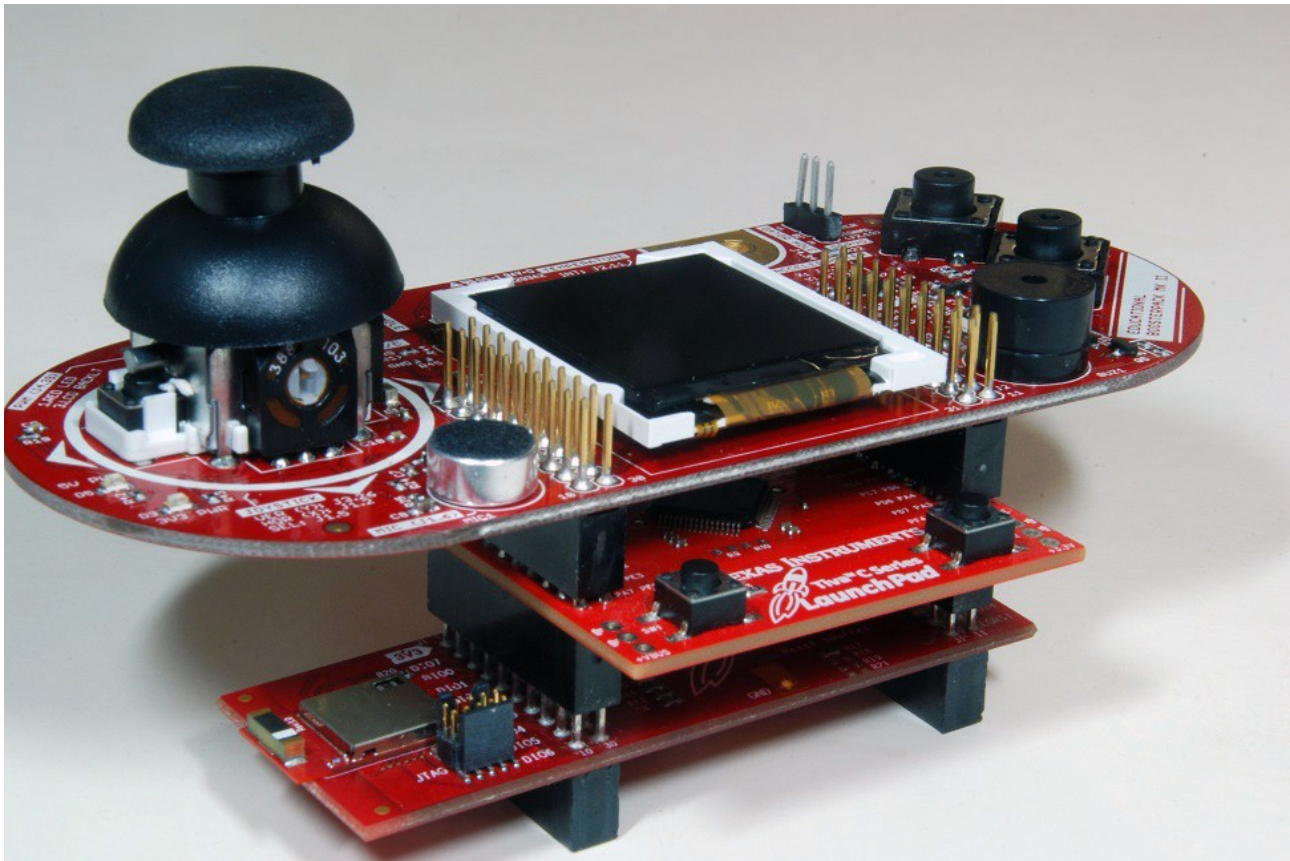




## UTAustinX: UT.RTBN.12.01x Realtime Bluetooth Networks

### LabKit:

1. LaunchPad: **EK-TM4C123GXL** or **MSP-EXP432P401R**
2. MK-II I/O booster: **BOOSTXL-EDUMKII**
3. CC2650 Bluetooth module: **BOOSTXL-CC2650MA** or **LAUNCHXL-CC2650**



### Лабораторные работы:

1. Introduction to I/O using the BSP and debugging,
  - Learn about Keil compiler and debugger
  - Understand what the MK-II boosterpack measures
  - Learn how to perform timing profiles of the software system
2. Thread management for a personal fitness device
  - Multiple threads
  - Real-time periodic threads
  - Spinlock semaphores
  - Round robin scheduler
3. Thread synchronization and scheduling for a personal fitness device

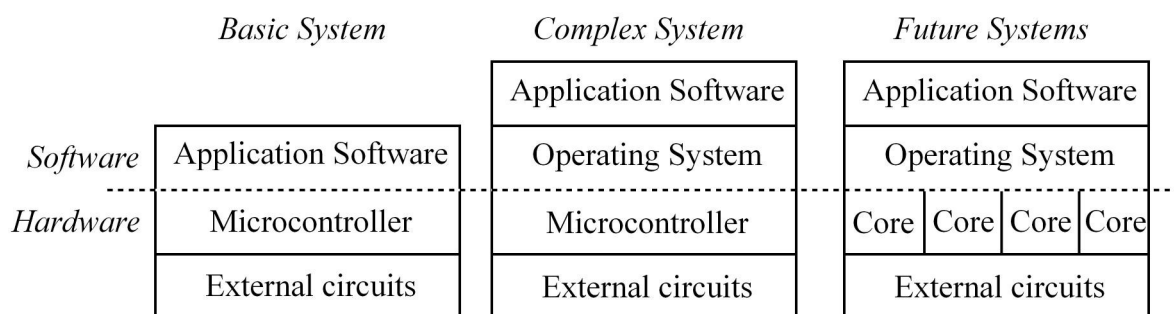
- Timer-based real-time threads
  - Thread sleeping
  - Blocking semaphores with first come first serve scheduler
4. Real-time operating system for a hand-held video game
- Edge triggered interrupts
  - Blocking semaphores with priority scheduler
5. File system using the flash ROM of the microcontroller
- Logging data onto flash/playback of data
6. Bluetooth personal area network.
- Interacting with the device from a smart phone

## Базовые понятия

**Дональд Гиллес:** системой реального времени является такая система, корректность функционирования которой определяется не только корректностью выполнения вычислений, но и **временем**, в которое получен требуемый результат. Если требования по времени не выполняются, то считается, что произошел **отказ** системы.

**Стандарт POSIX 1003.1:** система реального времени — система, которая способна обеспечить **требуемый уровень сервиса** в **заданный промежуток времени**.

Операционная система реального времени (ОСРВ) - операционную систему, с помощью которой можно построить систему **жесткого реального времени** (в смысле определения Д. Гиллеса).



## Сравнение традиционных ОС и ОСРВ:

Regular OS	Real-time OS
Complex	Simple
Best effort	Guaranteed response
Fairness	Strict timing constraints
Average bandwidth	Minimum and maximum limits
Unknown components	Known components
Unpredictable behavior	Predictable behavior
Plug and play	Upgradable

**Встраиваемая система:** вычислительная компьютерная система как часть большей инженерной системы — встраиваемая система.

Типы задач встраиваемых систем:

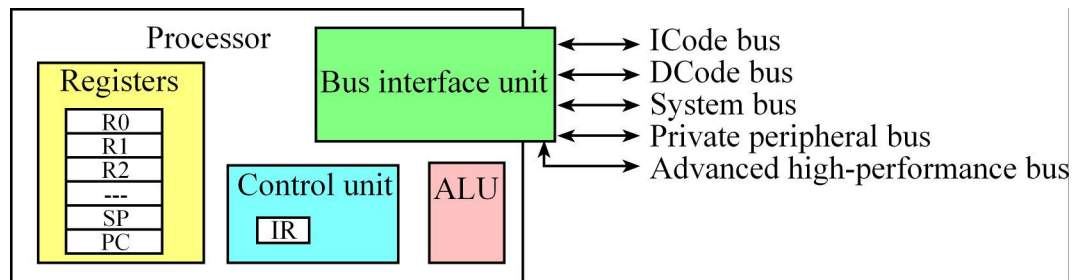
- математические вычисления, анализ, обработка данных;
- управление временем в явном виде: обработка входных сигналов и выдача выходных сигналов с определенной частотой;
- системы управления;
- системы DSP;
- сеть и коммуникация.

Ограничения встраиваемых систем (как правило):

- маленький размер;
- небольшой вес;
- небольшое энергопотребление;

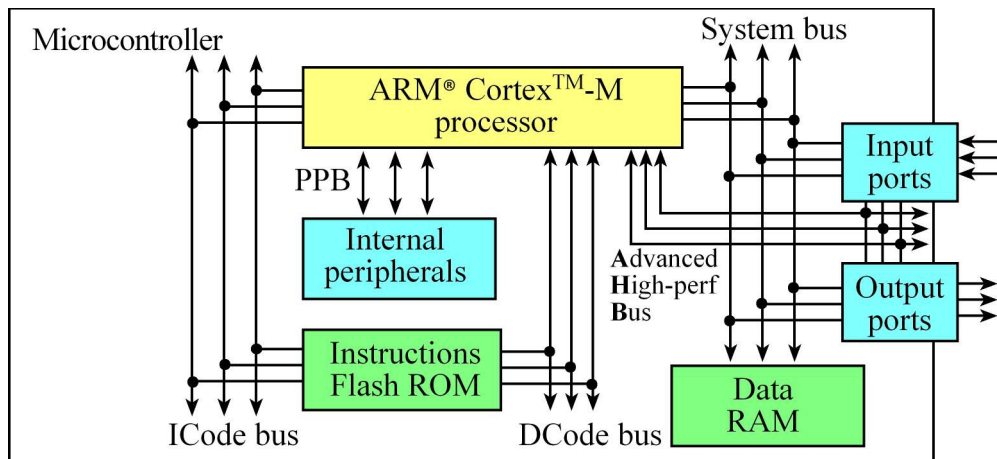
- работа в сложных условиях (высокая температура, давление...);
- критичные системы (safety critical);
- цена-выгода.

## Архитектура ARM



- There are bus interface units (**BIU**) that read data from the bus during a read cycle and write data onto the bus during a write cycle. The BIU always drives the address bus and the control signals of the bus.
- The effective address register (**EAR**) contains the memory address used to fetch the data needed for the current instruction.
- Cortex-M microcontrollers execute **Thumb** instructions extended with **Thumb-2** technology.
- The control unit (**CU**) orchestrates the sequence of operations in the processor. The CU issues commands to the other three components.
- The instruction register (**IR**) contains the operation code (or op code) for the current instruction. When extended with Thumb-2 technology, op codes are either 16 or 32 bits wide.
- The **arithmetic logic unit (ALU)** performs arithmetic and logic operations.

**Микроконтроллер** (англ. Micro Controller Unit, MCU) — микросхема, предназначенная для управления электронными устройствами. Типичный микроконтроллер сочетает на одном кристалле функции процессора и периферийных устройств, содержит ОЗУ или ПЗУ. По сути, это однокристальный компьютер, способный выполнять простые задачи.

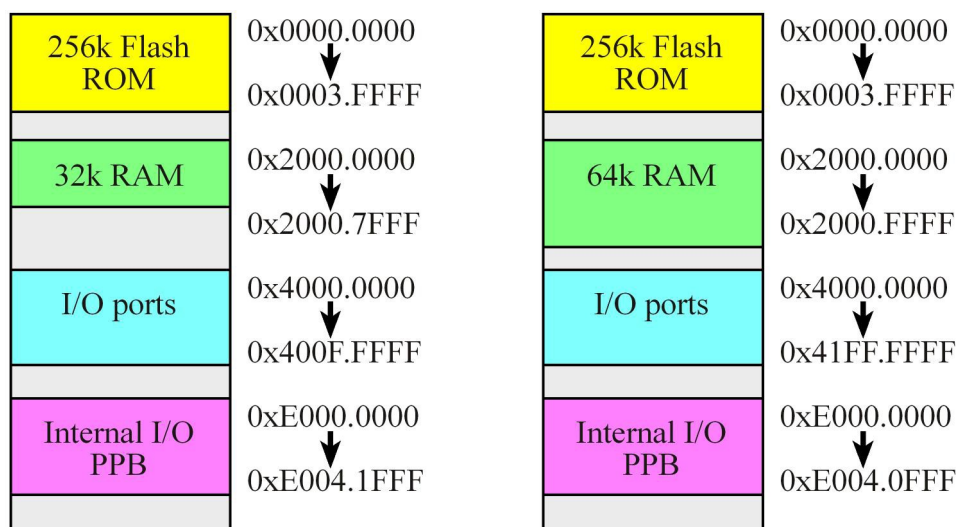


- ICode bus Fetch opcode from ROM
- DCode bus Read constant data from ROM
- System bus Read/write data from RAM or I/O, fetch opcode from RAM
- PPB Read/write data from internal peripherals like the NVIC
- AHPB Read/write data from internal peripherals like the USB

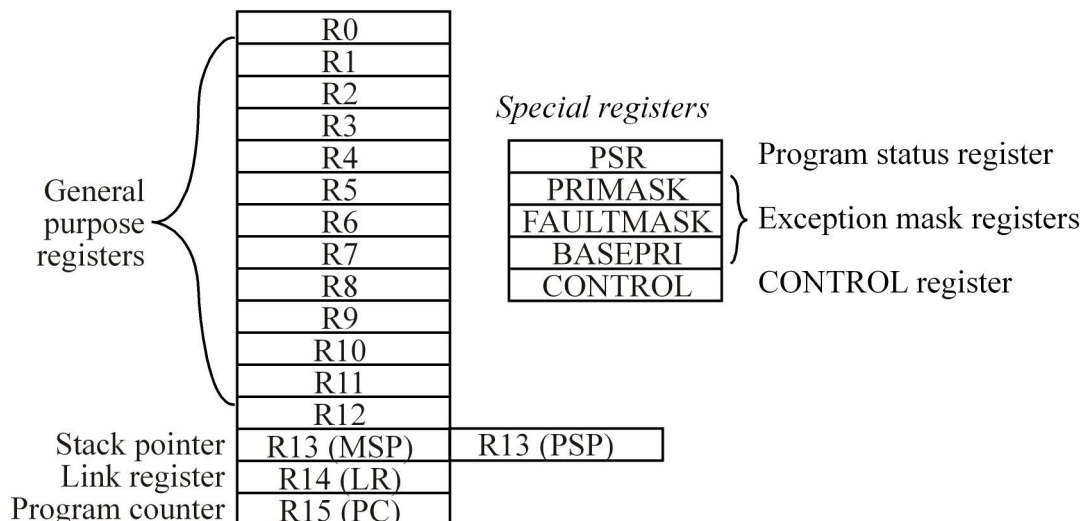
Сравнение различных моделей микроконтроллеров:

Part number	RAM	Flash	I/O	I/O modules
MSP432P401 RIPZ	64	256	84	floating point, DMA
LM4F120H5 QR	32	256	43	floating point, CAN, DMA, USB
TM4C123GH 6PM	32	256	43	floating point, CAN, DMA, USB, PWM
STM32F051R 8T6	8	64	55	DAC, Touch sensor, DMA, I2S, HDMI, PWM
MKE02Z64V QH2	4	64v	53	PWM
	KiB	KiB	pins	

Карта памяти для *TM4C123* и *MSP432*:



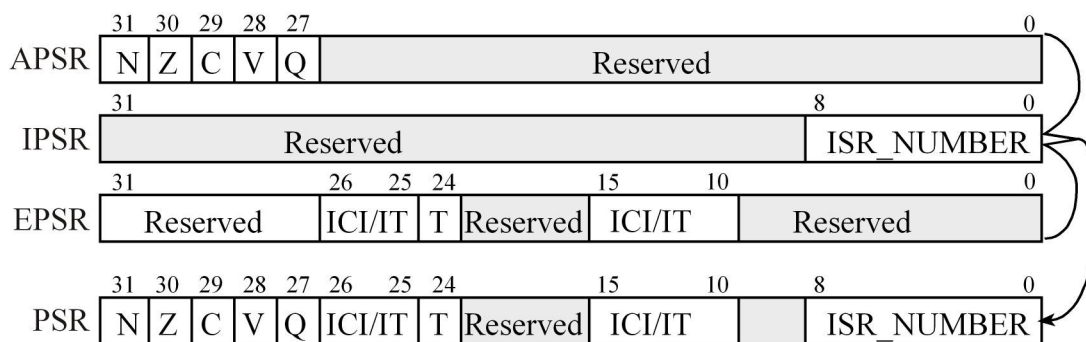
## Регистры ARM Cortex-M



- Actually, there are two stack pointers: the main stack pointer (**MSP**) and the process stack pointer (**PSP**). Only one stack pointer is active at a time. In a high-reliability operating system, we could activate the PSP for user software and the MSP for operating system software.
- Register R14 (also called the link register, **LR**) is used to store the return location for functions. The LR is also used in a special way during exceptions, such as interrupts.
- Register R15 (also called the program counter, **PC**) points to the next instruction to be fetched from memory. The processor fetches an instruction using the PC and then increments the PC by the length (in bytes) of the instruction fetched.

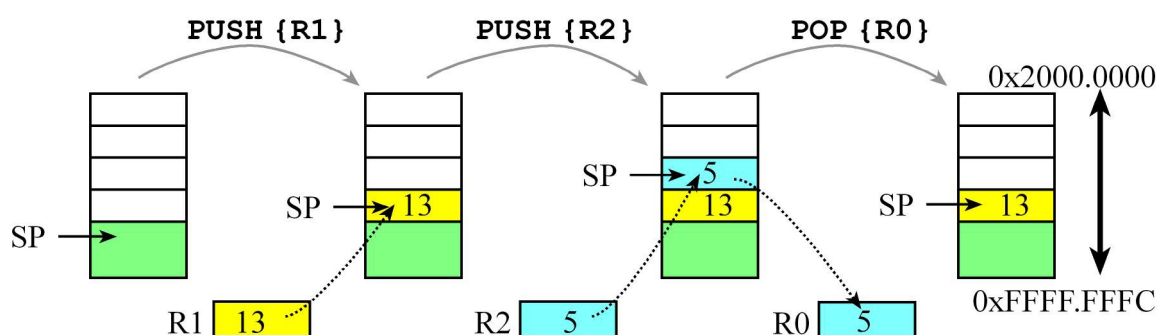
## Регистр статуса:

There are three status registers named Application Program Status Register (APSR), the Interrupt Program Status Register (IPSR), and the Execution Program Status Register (EPSR). These registers can be accessed individually or in combination as the Program Status Register (PSR).



The **T** bit will always be 1, indicating the ARM Cortex-M processor is executing Thumb instructions.

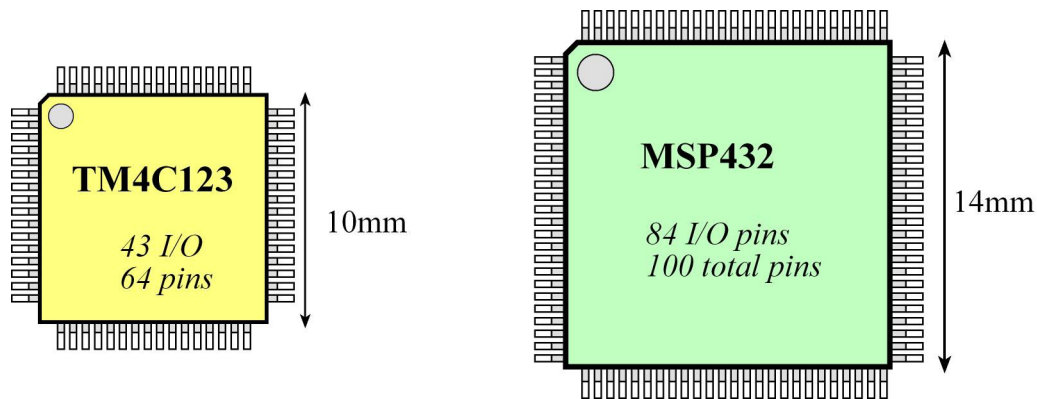
## Стек



## Reset

- The 32-bit value at flash ROM location 0 is loaded into the SP.
- A reset also loads the 32-bit value at location 4 into the PC. This value is called the reset vector. All instructions are halfword aligned. Thus, the least significant bit of PC must be 0. However, the assembler will set the least significant bit in the reset vector, so the processor will properly initialize the thumb bit (T) in the PSR. On the ARM Cortex-M, the T bit should always be set to 1.
- On reset, the processor initializes the LR to 0xFFFFFFFF.
- Bit 0 of the CONTROL register is the thread privilege level (TPL). If TPL is 1 the processor level is privileged. If the bit is 0, then processor level is unprivileged. Running at the unprivileged level prevents access to various features, including the system timer and the interrupt controller.
- Bit 1 of the CONTROL register is the active stack pointer selection (ASPSEL). If ASPSEL is 1, the processor uses the PSP for its stack pointer. If ASPSEL is 0, the MSP is used.

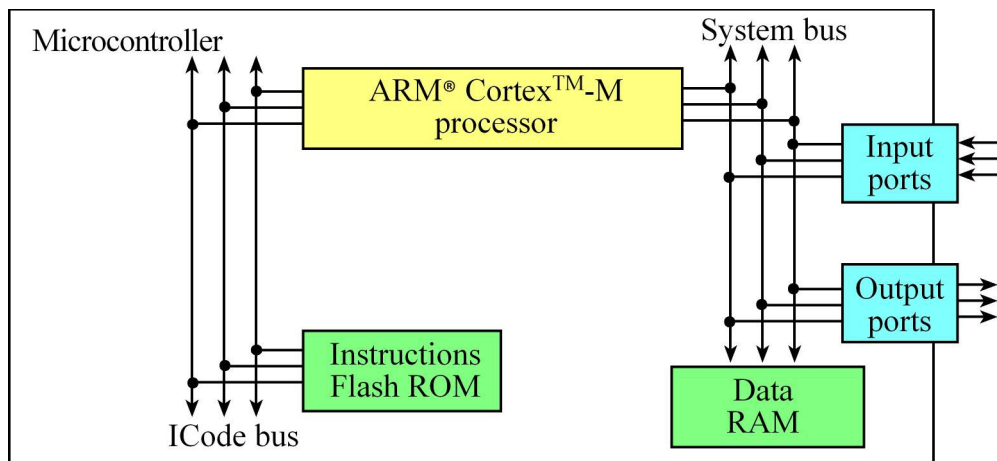
## I/O



Интерфейсы ввода/вывода:

- **Parallel/digital** - binary data are available simultaneously on a group of lines
- **Serial** - binary data are available one bit at a time on a single line
- **Analog** - data are encoded as an electrical voltage, current or power
- **Time** - data are encoded as a period, frequency, pulse width or phase shift

Порты отображаемые в память:

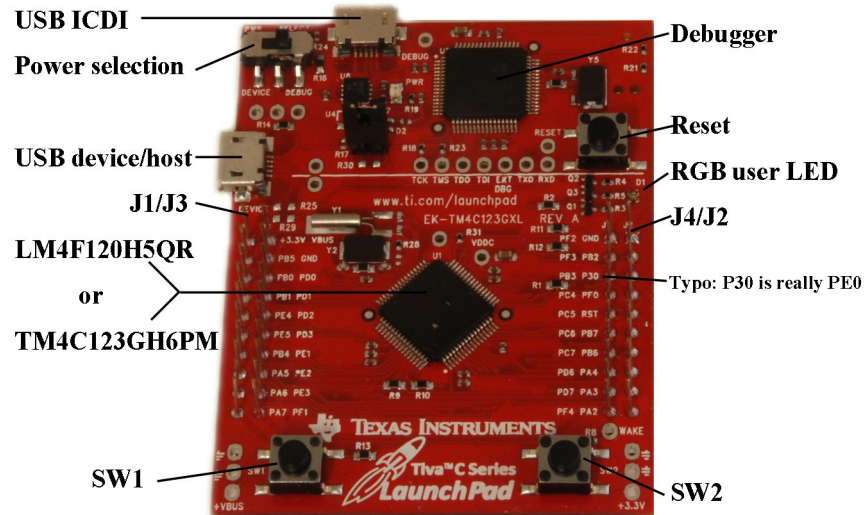


Most pins on Cortex M microcontrollers can be used for **general purpose I/O (GPIO)** called regular functions or for more complex functions called alternate functions.

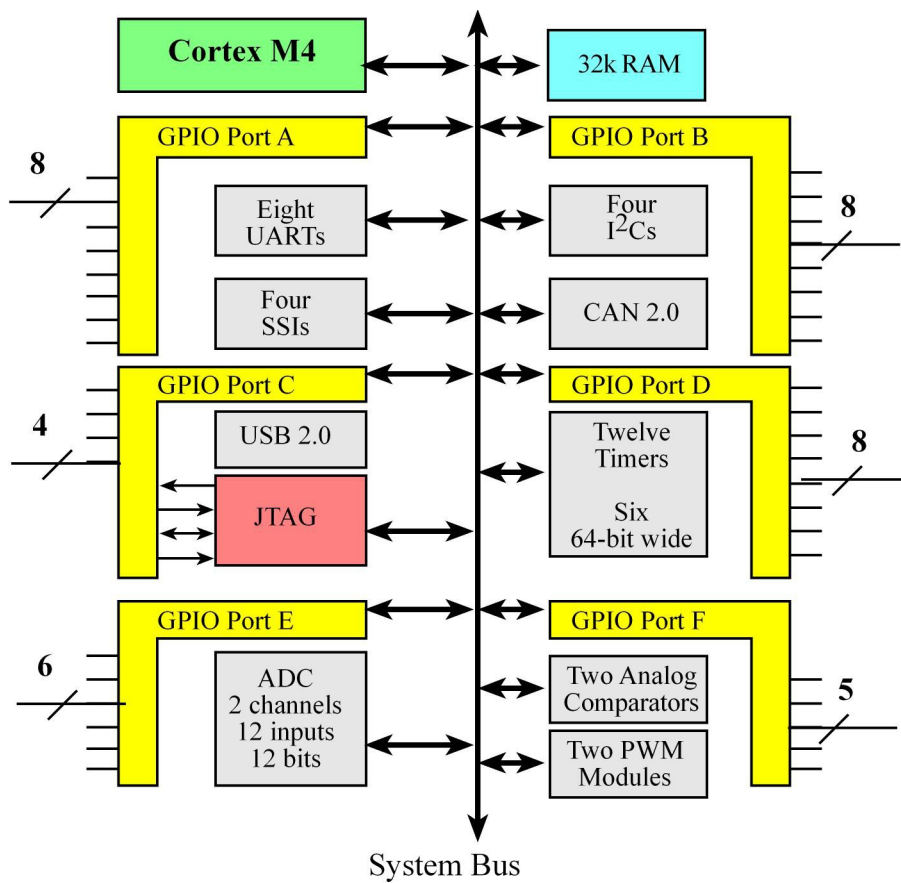
- **UART** Universal asynchronous receiver/transmitter
- **SSI** or **SPI** Synchronous serial interface or serial peripheral interface
- **I2C** Inter-integrated circuit
- **Timer** Periodic interrupts
- **PWM** Pulse width modulation
- **ADC** Analog to digital converter, measurement analog signals



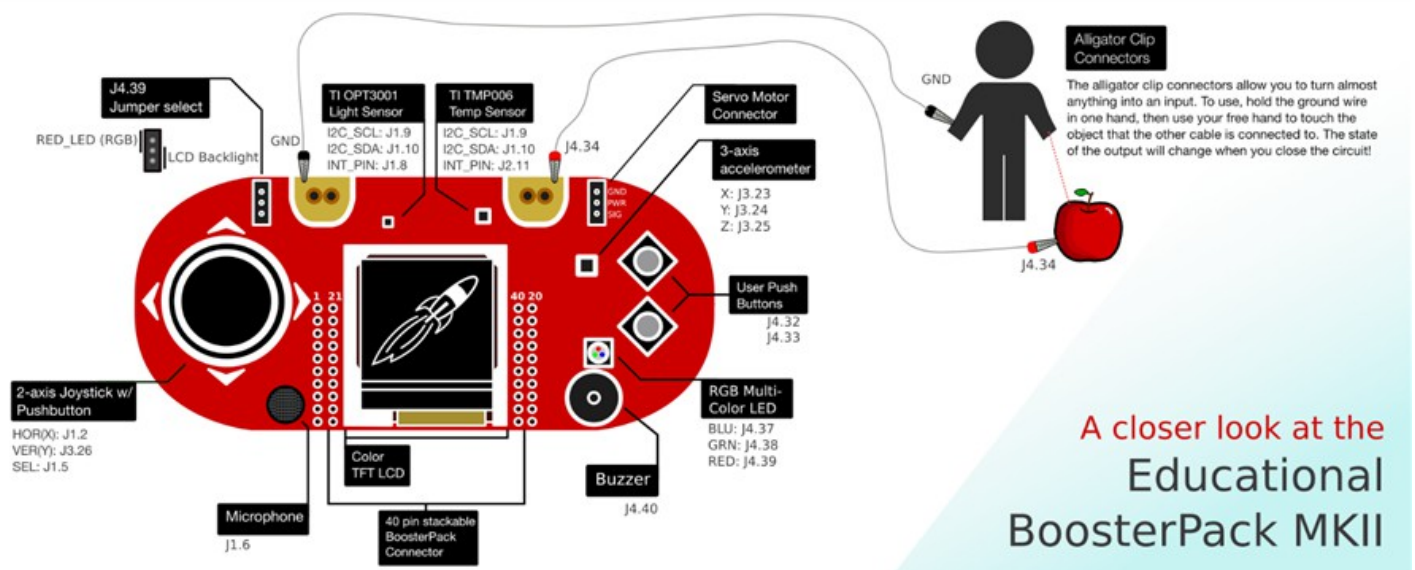
# TM4C123GH6PM



Порты:



# MKII BoosterPack



## Sensors

- TI [OPT3001](#) Light Sensor
- TI [TMP006](#) Temperature Sensor
- 3-Axis [Kionix Accelerometer](#)
- User Push Buttons
- [CREE RGB Multi-color](#) LED
- CUI [Microphone](#)

## Inputs

- [Itead IM130330001 2-Axis Joystick](#) with Pushbutton

## Outputs

- Servo Motor Connector
- [Crystalfontz 128×128 pixel 262K Color](#) TFT LCD Display
- CUI [Piezo Buzzer](#)

## Connectors

- 40-pin Stackable BoosterPack Connector