

Bionic Arm – LLC Team

Microcontroller Choice

This Document has multiple available choices of different microcontroller development boards describing their features and architectures. At first we discuss the basic needs of the bionic arm system with both its modular hand and elbow subsystems.

System Sensors and Actuators

<i>Category</i>	<i>Number of Units</i>	<i>Pins/Unit</i>	<i>Total MCU Requirements</i>
<i>Flex Sensor</i>	5	1 Analog Pin, Power	5 Analog Pins
<i>Force Sensors</i>	5	1 Analog Pin, Power	5 Analog Pins
<i>IMU</i>	2	1SDA, 1SCL, Power	2 SDA, 2 SCL Pins
<i>Rotary Position Sensors</i>	10	1 Analog Pin, Power	10 Analog Pins
<i>Infrared Temp Sensor</i>	1	1SDA, 1SCL, Power	1 SDA, 1SCL Pins
<i>Servos</i>	6	1 PWM, Power	6 PWM
<i>8 DC Motor Drivers</i>	8	1PWM, 2GPIO, Power	8 PWM, 16 GPIO
<i>Peltier</i>	1	1 PWM, 2GPIO, Power	1 PWM, 2 GPIO, Power
<i>Vibration Motor</i>	2	1 PWM, Power	2 PWM, Power

<i>MCU Specifications and Features</i>			
<i>Analog Input</i>	20 Pins	>Core m4 32bit	>80MHz
<i>PWM Output</i>	17 Pins	Dev board with Flasher and FPU	
<i>GPIO Output</i>	18-30	Easily Available in Egypt	
<i>I2C Modules</i>	3 Modules	Memory is not prioritized but higher is better	
<i>UART Modules</i>	2-3 Modules		

After analyzing the system requirements and features, we now search for MCUs with similar properties or provide solutions that satisfy the system requirements by a multiple of compact MCUs that communicate with each other through a shared protocol.

MCU Options and Features

1- BLUEPILL- Available in Egypt for 120LE

ARM STM32 Minimum System Development Board "STM32F103C8T6"

- Package Type: LQFP
- Number of pins: 48
- Kernel: Cortex-M3
- Operating frequency: 72MHz
- Storage resources: 64K Byte Flash, 20KByte SRAM
- Interface Resources: 2x SPI, 3x USART, 2x I2C, 1x CAN, 37x I / O ports,
- Analog-to-digital conversion: 2x ADC (12-bit / 16-channel)
- Timers: 3 general timers and 1 advanced timer
- Debug Download: Support JTAG / SWD debug interface to download, support for IAP.
- RT9193: 3.3V regulator chip, the maximum output of 300mA.

2-TIVA C: Available in Egypt for 610LE

EK-TM4C123GXL (ARM® Cortex®-M4F Based MCU TM4C123G LaunchPad™ Evaluation Kit)

- 80MHz 32-bit ARM Cortex-M4-based microcontrollers CPU
- 40 Pins on Dev Board
- 256KB Flash, 32KB SRAM, 2KB EEPROM
- Two Controller Area Network (CAN) modules
- USB 2.0 Host/Device/OTG + PHY
- Dual 12-bit 2MSPS ADCs, motion control PWMs
- 8 UART, 6 I2C, 4 SPI
- On-board In-Circuit Debug Interface (ICDI)

3- BlackPill – Not Available in Egypt ≈ 250LE

Available at AliExpress at:

https://www.aliexpress.com/item/4000389850380.html?spm=a2g0o.productlist.0.0.5a3d3112vo3KZj&algo_pvid=67c9036b-1667-4597-80fd-60c6eb866506&algo_expid=67c9036b-1667-4597-80fd-60c6eb866506-1&btsid=0bb0600116059188730495289e0075&ws_ab_test=searchweb0_0,searchweb201602_searchweb201603

- Package Type: LQFP
- Number of pins: 48
- Kernel: Cortex-M4
- Operating frequency: 100MHz
- Storage resources: 512K Byte Flash, 128KByte SRAM
- Interface Resources: 5x SPI, 3x USART, 3x I2C, 1x CAN, 37x I / O ports,
- Analog-to-digital conversion: 15pins
- FPU, CRC Available
- Timers: 10 general timers and 1 advanced timer
- Debug Download: Support JTAG / SWD debug interface to download, support for IAP.
- RT9193: 3.3V regulator chip, the maximum output of 300mA.

4-Nucleo 64 F446RE Available in Egypt Online for 600-750LE

Nucleo F446RE provides the following hardware components:

- STM32F446RET6 in LQFP64 package
- ARM® 32-bit Cortex®-M4 CPU with FPU
- Adaptive real-time accelerator (ART Accelerator)
- 180 MHz max CPU frequency
- VDD from 1.7 V to 3.6 V
- 512 KB Flash
- 128 KB SRAM
- 10 General purpose timers
- 2 Advanced control timers / 2 basic timers
- SPI(4)
- I2C(3)
- USART(4)
- UART(2)
- USB OTG Full Speed and High Speed
- CAN(2)
- SAI(2)
- SPDIF_Rx(1)
- HDMI_CEC(1)
- Quad SPI(1)
- Camera Interface
- GPIO(50) with external interrupt capability
- 12-bit ADC(3) with 16 channels
- 12-bit DAC with 2 channels

5-Nucleo 144 F446ZE Not Available in Egypt ≈700LE

https://www.aetronix-eg.com/pages/product/stm32/pv/9173778/pid?itemId=9173778&field-text=#specs_bookmark

- Core: Arm® 32-bit Cortex®-M4 CPU with FPU, Adaptive real-time accelerator (ART Accelerator) allowing 0-wait state execution from Flash memory, frequency up to 180 MHz, MPU, 225 DMIPS/1.25 DMIPS/MHz (Dhrystone 2.1), and DSP instructions
- 512 Kbytes of Flash memory
- 128 Kbytes of SRAM
- Dual mode QuadSPI interface
- LCD parallel interface, 8080/6800 modes
- Clock, reset and supply management
- 1.7 V to 3.6 V application supply and I/Os
- POR, PDR, PVD and BOR
- 4 to 26 MHz crystal oscillator
- Internal 16 MHz factory-trimmed RC (1% accuracy)
- 32 kHz oscillator for RTC with calibration
- Internal 32 kHz RC with calibration
- Low power
- Sleep, Stop and Standby modes
- VBAT supply for RTC, 20×32 bit backup registers plus optional 4 KB backup SRAM
- 3× 12-bit, 2.4 MSPS ADC: up to 24 channels and 7.2 MSPS in triple interleaved mode
- 2× 12-bit D/A converters
- General-purpose DMA: 16-stream DMA controller with FIFOs and burst support
- Up to 17 timers: 2x watchdog, 1x SysTick timer and up to twelve 16-bit and two 32-bit timers up to 180 MHz, each with up to four IC/OC/PWM or pulse counter
- Debug mode
- SWD and JTAG interfaces
- Cortex®-M4 Trace Macrocell™
- Up to 114 I/O ports with interrupt capability
- Up to 111 fast I/Os up to 90 MHz
- Up to 112 5 V-tolerant I/Os
- Up to 20 communication interfaces
- SPDIF-Rx
- Up to 4× I2C interfaces (SMBus/PMBus)
- Up to four USARTs and two UARTs (11.25 Mbit/s, ISO7816 interface, LIN, IrDA, modem control)
- Up to four SPIs (45 Mbits/s), three with muxed I2S for audio class accuracy via internal audio PLL or external clock
- 2x SAI (serial audio interface)
- 2× CAN (2.0B Active)
- SDIO interface

6- Infineon XMC4500 Evaluation Board KITXMC45RELAXLITEV1TOBO1

Not Available in Egypt ≈450LE

<https://www.aetronix-eg.com/pages/product/infineon/pv/1501738/pid?itemId=1501738&field-text=>

- 512 - 1024 KB Flash, 128-160 KB Ram
- Supply voltage range: 3.13 - 3.63V
- USIC 6ch [Quad SPI, SCI/UART, I²C, I²S, LIN]
- 2x PWM Timers (CCU8), 16-64Bit 8ch+ Dead-Time
- 3x CAN, 64 MO
- Peripherals Clock: 120 [MHZ]
- Core frequency: 120 [MHZ]
- 4x ΔΣ-Demodulator
- External Memory Interface (EBU)
- Package: LQFP144/LQFP100/LFBGA144
- Temperature range: -40°.....85°/125°
- 10/100 Ethernet MAC (/w IEEE 1588)
- Long-term availability with >15 years
- Free DAVE™ IDE and DAVE Apps

7- NUCLEO-G474RE ≈ 500LE

at <https://www.facebook.com/DevBoardsEgypt/>

Mainstream Arm Cortex-M4 core with DSP and FPU, 170MHz with 512 Kbytes of Flash memory, Math Accelerator, HR Timer, High Analog level integration.

- 7 x 12-bit DAC channels.
7 x ultra-fast rail-to-rail analog comparators.
6 x operational amplifiers that can be used in PGA mode, all terminals accessible.
- MCU Information : <https://www.st.com/.../microcontrollers-mic.../stm32g474re.html...>
Development Board : <https://www.st.com/en/evaluation-tools/nucleo-g474re.html>
- Price : 500 EGP.

8- ARM Adafruit Grand Central M4 Express featuring the SAMD51

Not Available in Egypt ≈800LE

At: <https://eu.mouser.com/new/adafruit/adafruit-grand-central-m4-express/>

- Cortex M4 core running at 120MHz
- Floating point support with Cortex M4 DSP instructions
- 1MB flash, 256KB RAM
- 32-bit, 3.3V logic, and power
- 70 GPIO pins in total
- Dual 1 MSPS DAC (A0 and A1)
- Dual 1 MSPS ADC (15 analog pins)
- 8 x hardware SERCOM (can be I2C, SPI or UART)
- 22 x PWM outputs
- Stereo I2S input/output with MCK pin
- 12-bit Parallel capture controller (for camera/video in)
- Built-in crypto engines with AES (256 bit), true RNG, Pubkey controller

9- ARM PJRC Teensy 4.1 Development Board Not Available in Egypt

≈ 800LE

At: <https://eu.mouser.com/ProductDetail/Adafruit/4622?qs=7MVldsJ5Uaxlly4FBCFg7w%3D%3D>

- 600 MHz Cortex-M7 processor (NXP iMXRT1062)
- PJRC notes that the processor can be overclocked beyond 600 MHz
- 32 general purpose DMA channels and FPU
- 35 PWM pins (c.f. 31 on Teensy 4.0)
- 40 digital pins, all interrupt capable
- 18 analog pins (c.f. 14 on Teensy 4.0), 2 ADCs on chip
- Peripherals for: USB, [SDIO](#), Serial, S/PDIF digital audio, [I2S](#) digital audio, [I2C](#), [SPI](#), cryptographic acceleration, RNG, [RTC](#), CAN (One bus with CAN FD)
- Power management support for peripherals
- 8192 kB flash memory (64 kB reserved for recovery & EEPROM emulation)
- 1024 kB RAM
- 6 pins available for 10/100 Mbit Ethernet and VBAT for RTC
- Micro SD Socket soldered onto board
- 42 breadboard-friendly [I/O](#) (c.f. 24 on Teensy 4.0)
- 2 USB ports (1 soldered)
- The Teensy 4.1 uses 5 pins with power management support
- Expansion ports for adding PSRAM or QSPI flash
- All pins are rated to 3.3 V

Choice of Microcontrollers:

Based on system I/O requirements and space availability in the design, the following microcontrollers are chosen to run the low level control of the system. (Motor control and Feedback).

Main Microcontroller→ **Nucleo 64 F446RE**

Hand-Sensors Microcontroller→ **BlackPill STM32F411**

MCU Peripherals Used:

MUST:

- | | |
|--|-------------|
| • RCC: For Clock speed selection | DONE |
| • GPIO: For connecting pins to MCU (INPUT/OUTPUT) | DONE |
| • NVIC/EXTI: For interrupt control | DONE |
| • STK: For internal timing | DONE |
| • ADC: For analog reads | DONE |
| • I2C: For communication with sensors | IN PROGRESS |
| • USART: For communication with other MCUs | IN PROGRESS |

EXTRA:

- | | |
|---|-------------|
| • DMA: For fast memory operation | IN PROGRESS |
| • FPU: For float point calculation | DELAYED |
| • Timers: For timing operations | IN PROGRESS |
| • Power Saving Mode: Sleep CPU when Idling | DELAYED |

Sensors and Motor Drivers:

- | | |
|--|-------------|
| • IMU: For wrist Feedback | |
| • Potentiometer: For Finger Position Feedback | |
| • FSR: For Force feedback to MCU + user | |
| • Temperature: For Temperature feedback for user | |
| • Encoder: For Elbow Motor Control | |
| • PWM GPIO: To Enable Variable speeds for motors | IN PROGRESS |
| • DC Motor Driver: To control DC Motor Direction, Speed | |
| • PID Controller: To Enable Error mitigation using PID controller | |
| • Servo Motor Driver: To control Closed Loop DC Motor (PID) | |