IEE 2463
Programmable Electronic Systems

Peripherals Booster for ZYBO Z7

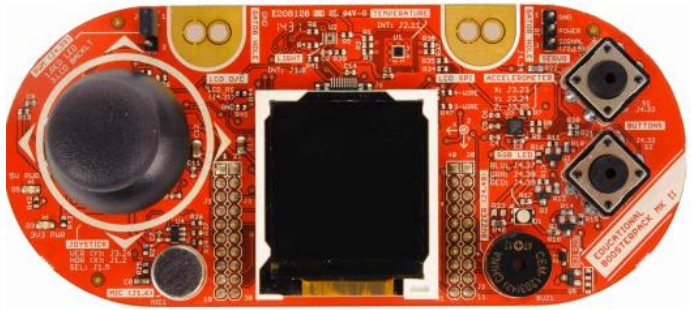
Electrical Engineering Department
Pontificia Universidad Católica de Chile
peclab.ing.uc.cl

Lecture Goals

- To understand the peripherals included in the booster Development kit
- To understand the purpose and schematic of the adapter board for this course.
- To understand how an Analog to Digital Converter works.

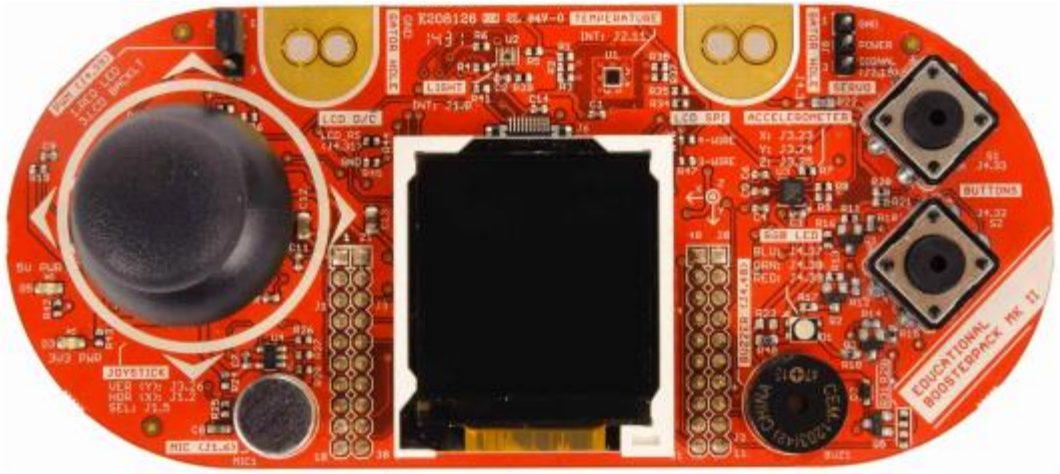
Introduction
Booster Development KI

This section provides a brief overview of BOOSTXL-EDUMKII Educational Booster Pack

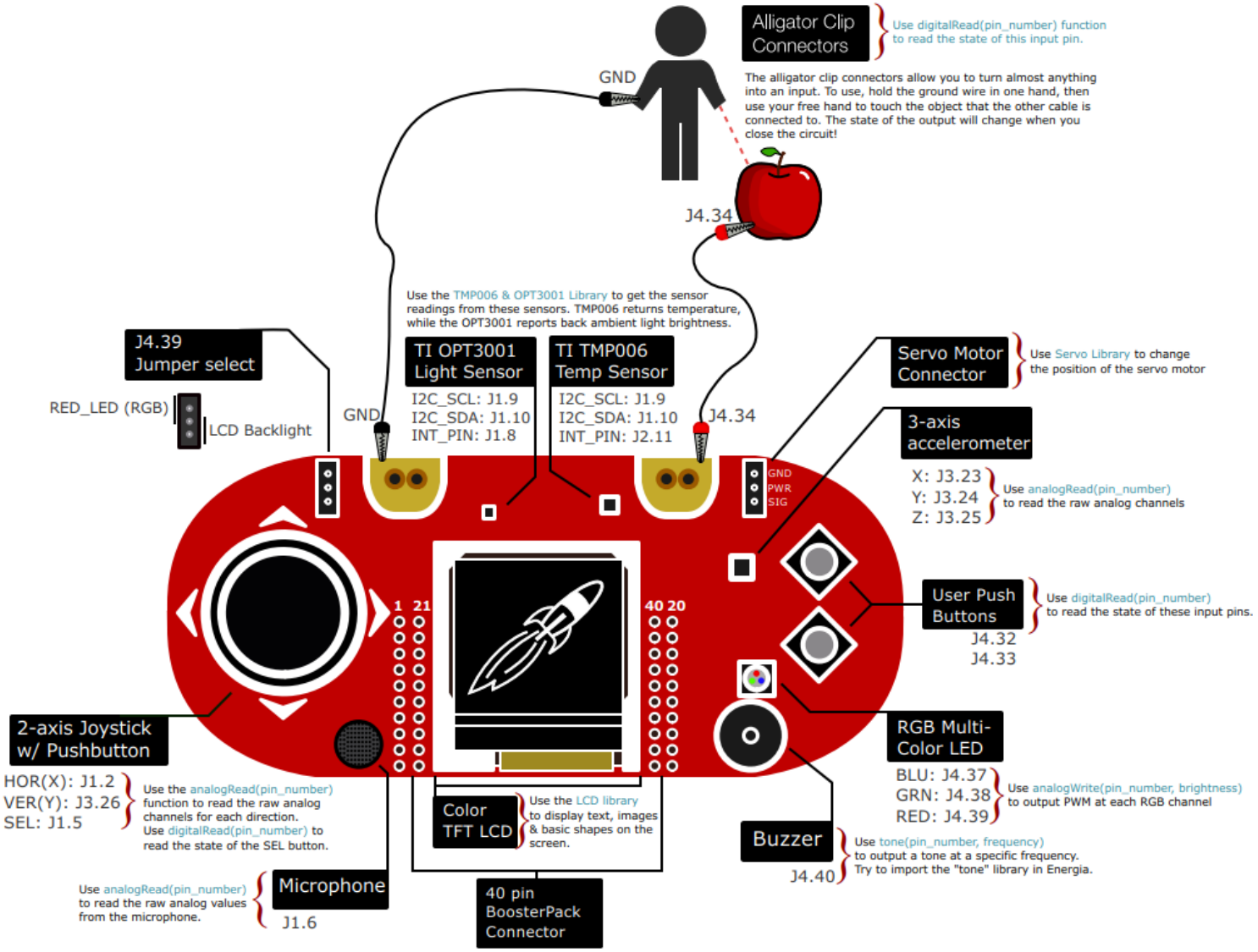


Booster Pack
Overview

- It is a educational Kit developed by Texas Instruments.
- TI OPT3001 light sensor
- TI TMP006 temperature sensor
- Servo motor connector
- 3-axis accelerometer
- RGB multicolor LED
- Piezo buzzer
- Color 128x128 TFT LCD display
- Microphone
- 2-axis joystick with pushbutton
- User push buttons
- 40-pin BoosterPack plug-in module standard for use with any LaunchPad development kit



Booster Pack
Overview



Booster Pack

Pinout Diagram

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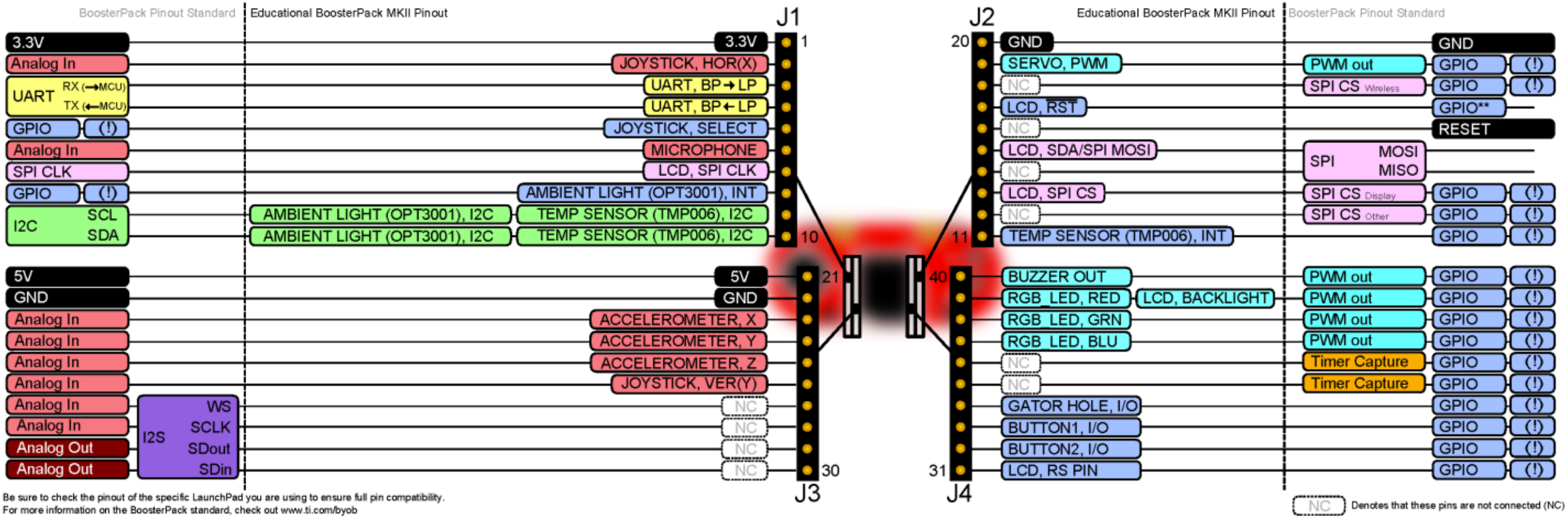
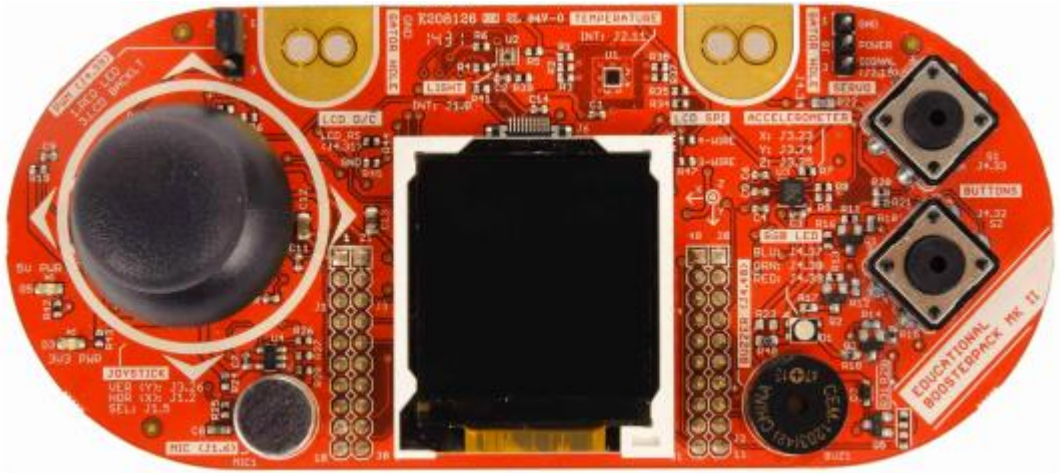
Pinout Diagram for your BoosterPack



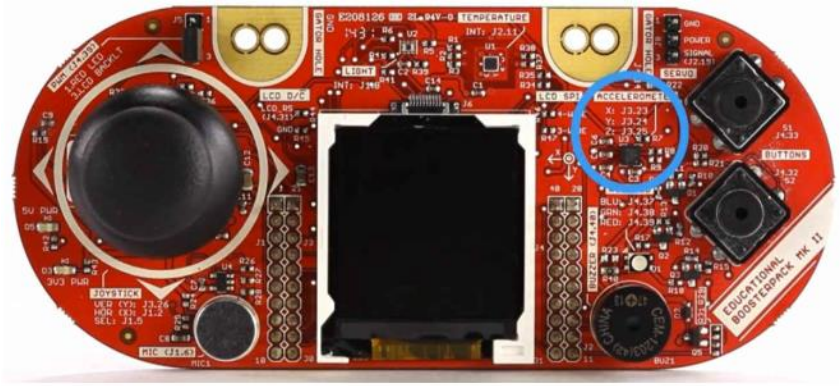
Be sure to check the pinout of the specific LaunchPad you are using to ensure full pin compatibility.
For more information on the BoosterPack standard, check out www.ti.com/byob

PERIPHERALS CONNECTED THROUGH ANALOG SIGNALS



Booster Pack
Accelerometer

- The Kionix KXTC9-2050 is a 3-axis analog accelerometer that measures g-forces.
- **Three analog outputs,** filtered by C4,C5 and C6.
- Moving the board along the axes will change the analog signal generated by the accelerometer.
- Output range of +/-2g (19.6 m/s/s)



Position into the Booster

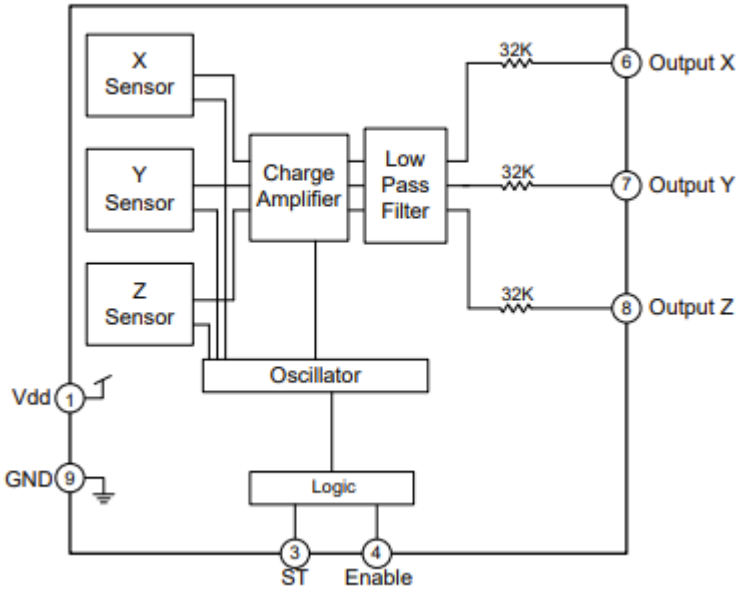
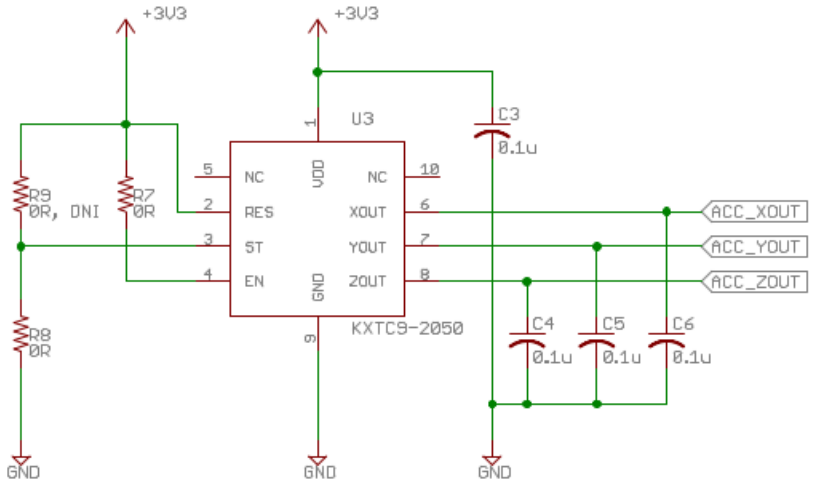


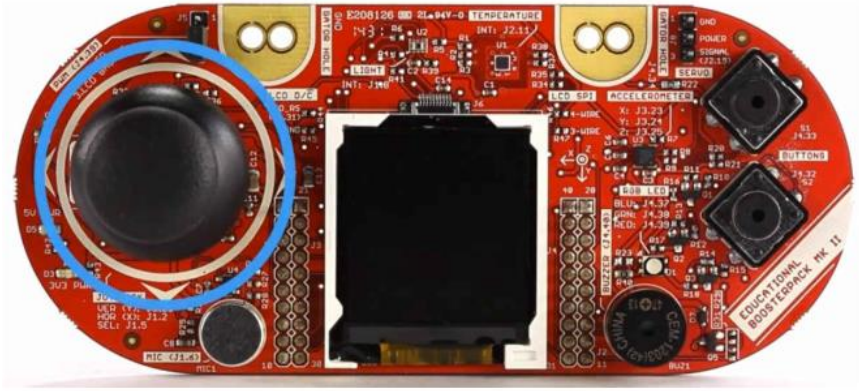
Diagram of Accelerometer



Booster Pack

Joystick

- The IM130330001 Joystick posses 2 axis 10kOhm potentiometer and one button.
- JOY_Y/1 and JOY_X/1 are **the analog output** voltages of the Joystick
- JOY_SEL/1 represents the Joystick button.
- Capacitors C9,C10 and C11 are filters for avoiding noise.
- The R19 is a pull-up resistor for the button.
- The potentiometers are also connected to the 3.3V.
- V+, V- and V stands for the three terminals of the vertical potentiometer. Same for H.



Position into the Booster

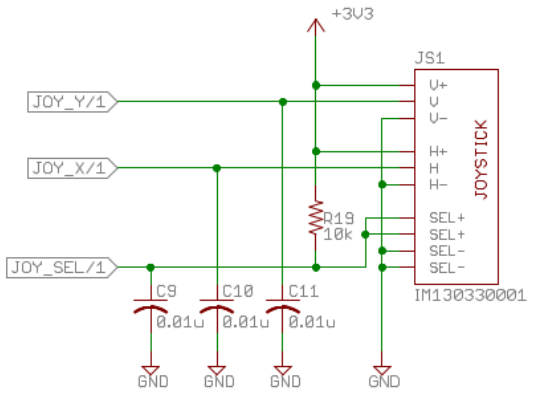
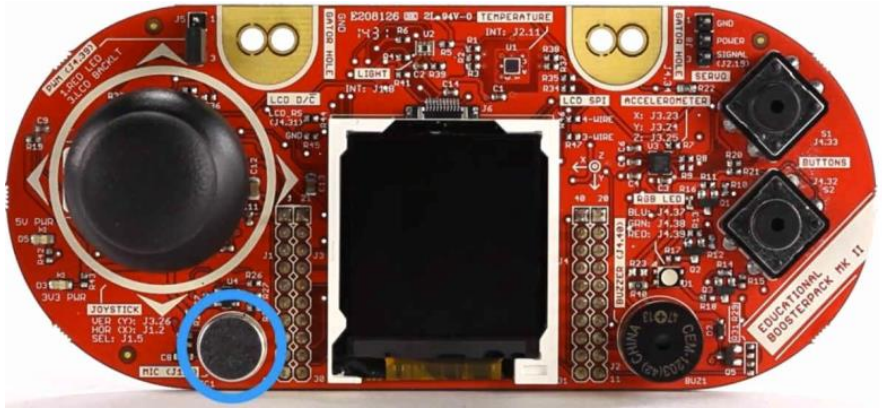


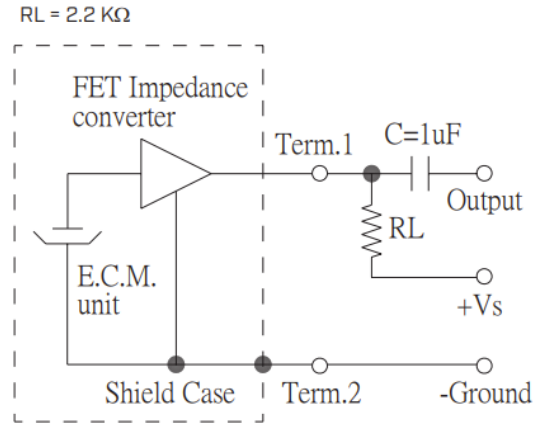
Diagram of Joystick

Booster Pack
Microphone

- The CUI CMA-4544PF-W electret microphone uses an OPA344 operational amplifier to boost the output of the microphone.
- It works in human spectrum range, i.e. 20Hz to 20kHz.
- It has one **analog output.**

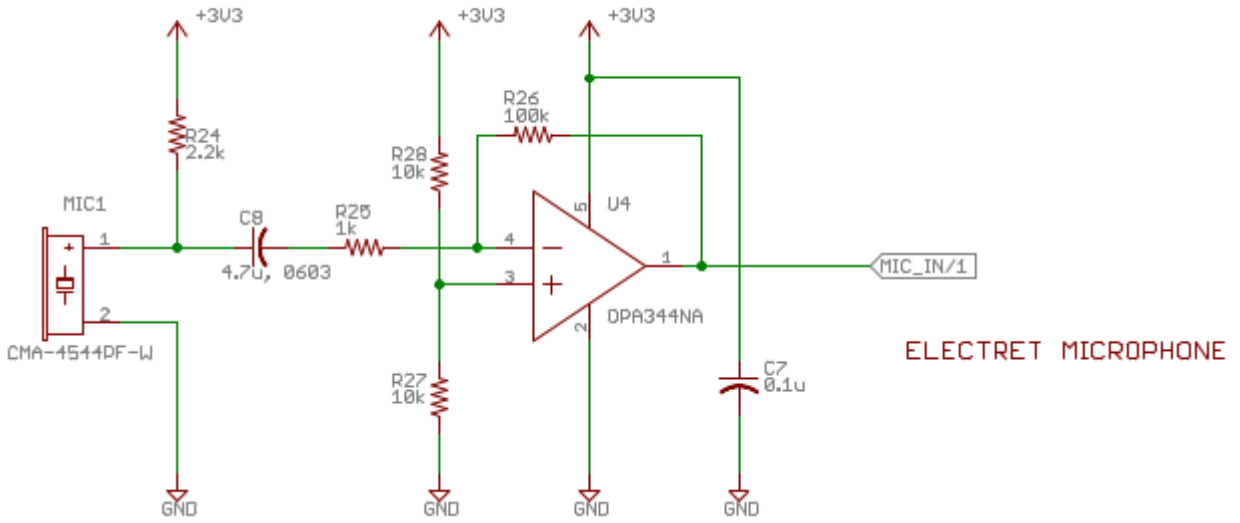


Position into the Booster

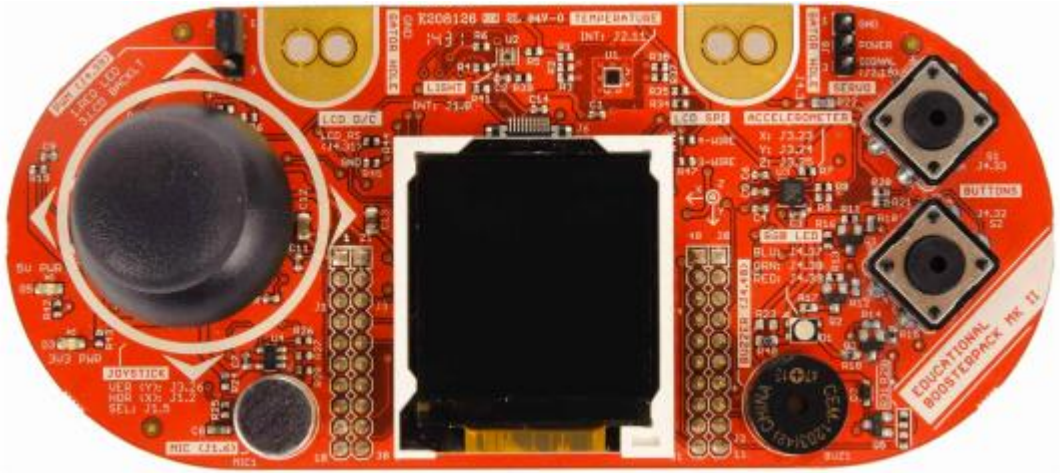


Schematic Diagram

Diagram of Microphone

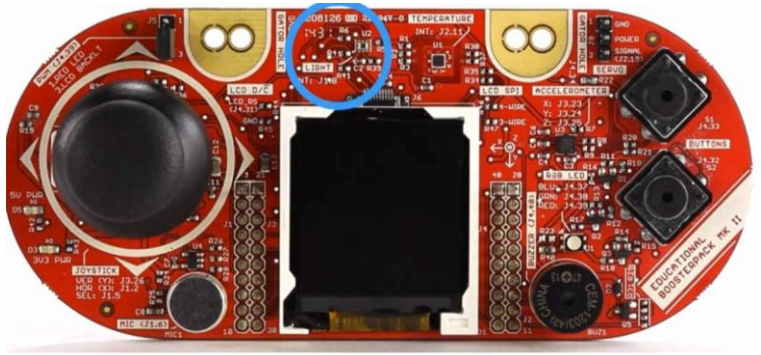


PERIPHERALS CONNECTED THROUGH I2C protocol

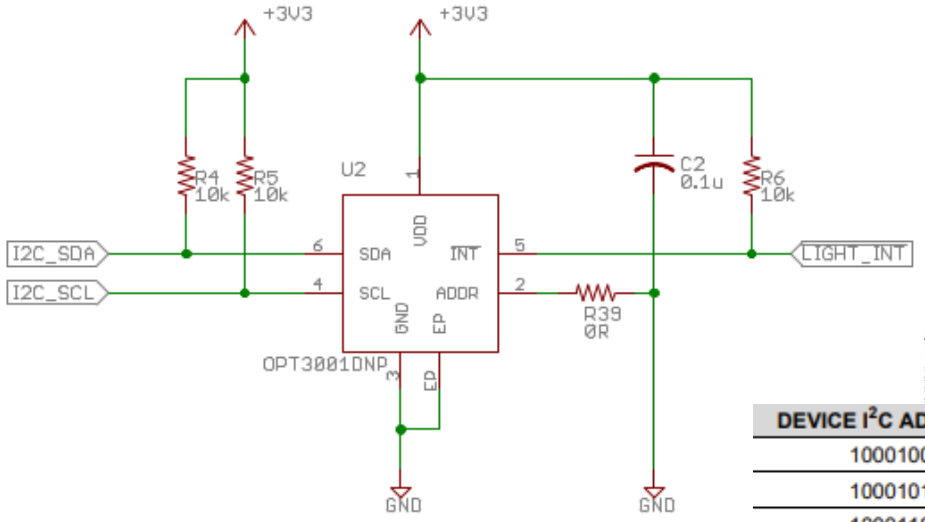


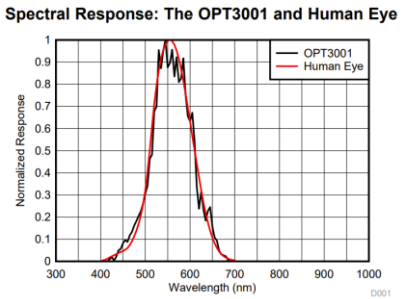
Booster Pack
Light Sensor

- The OPT3001 is a digital ambient light sensor (ALS) that measures the intensity of light as visible by the human eye.
- Its communication is through **I2C protocol**.
- The ADDR pin allow to change the address of the device.
- The device has an interrupt indicates whether the light is above or below levels of interest.



Position into the Booster





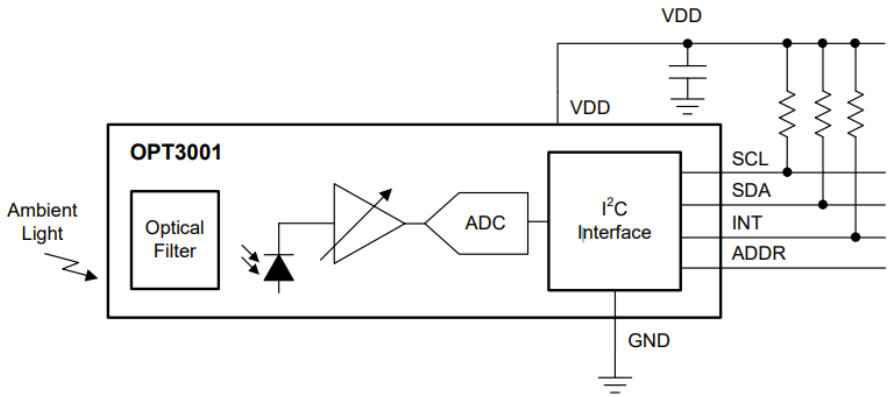


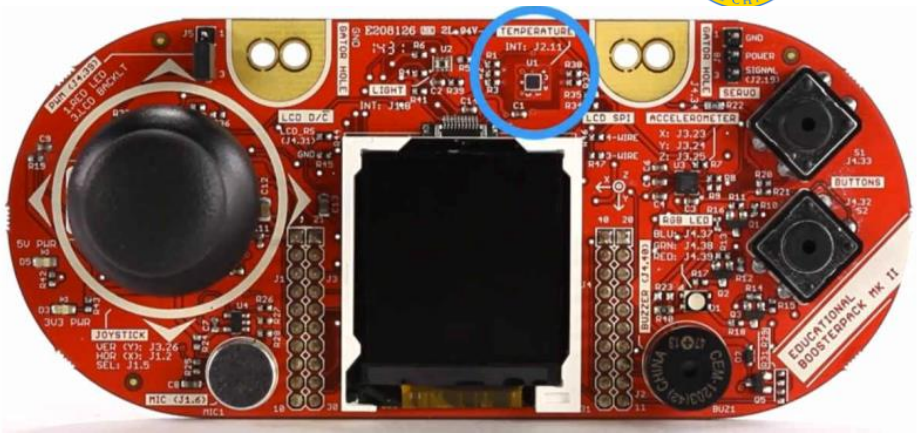
Diagram of Light Sensor

DEVICE I²C ADDRESS	ADDR PIN
1000100	GND
1000101	VDD
1000110	SDA
1000111	SCL

Booster Pack

Temperature Sensor

- The TMP006 is a digital infrared (IR) thermopile contactless temperature sensor (**without being in direct contact)**.
- Based on thermopile sensor. (convert thermal energy in voltage)
- It internally transform the analog voltage (7uV/°C) to a digital value sent by **I2C protocol.**
- Measurable temperature can go between 125°C to -40°C.
- It contain registers for holding configuration information, temperature measurement results, and sensor voltage measurement.



Position into the Booster

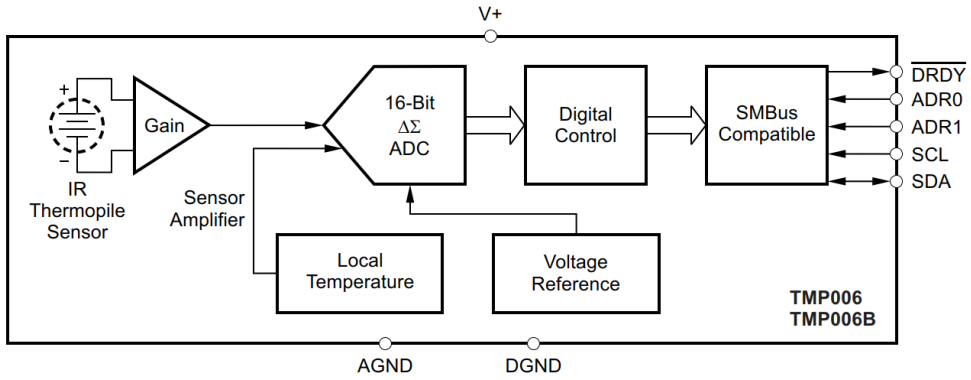
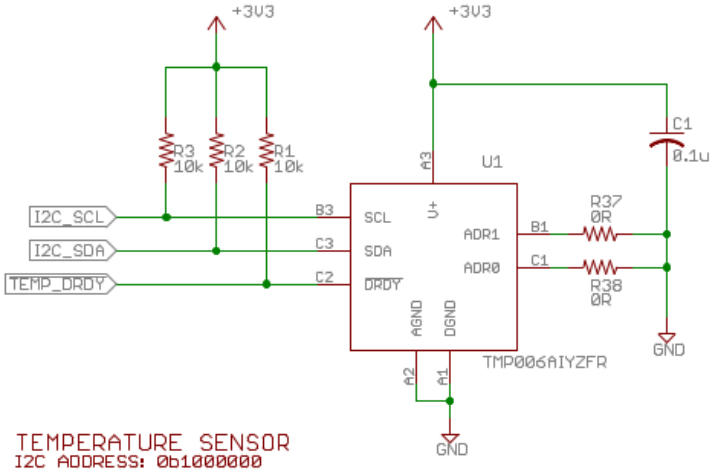


Diagram of Temperature Sensor



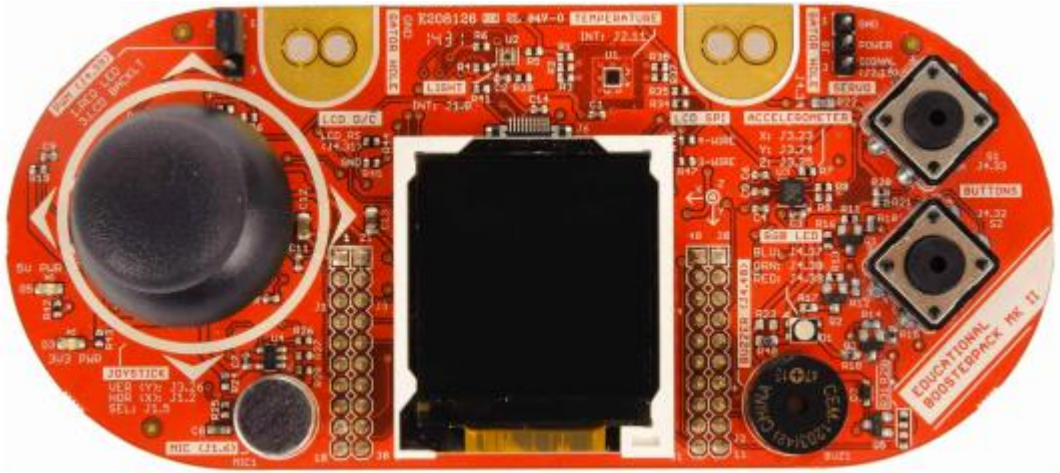
ADDR0,1: Allow select address od device.
DRDY: Data ready, active low, open-drain; requires a pull-up resistor to V+

Table 5. Input Signal versus Ideal Output Code(1)

SENSOR SIGNAL	OUTPUT CODE
FS (2^{15} – 1)/2^{15} (5.12 mV)	7FFFh
+FS/2^{15} (156.25 nV)	0001h
0	0
–FS/2^{15} (–156.25 nV)	FFFFh
–FS (–5.12 mV)	8000h

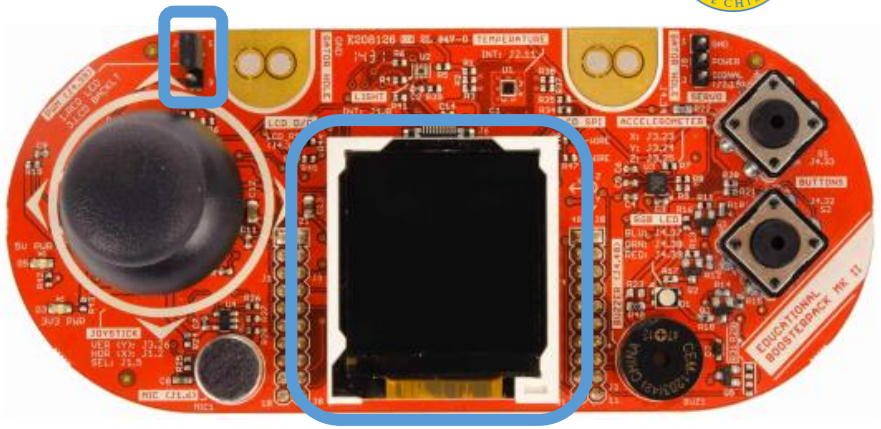
(1) FS = Full-scale value.

PERIPHERALS CONNECTED THROUGH SPI protocol

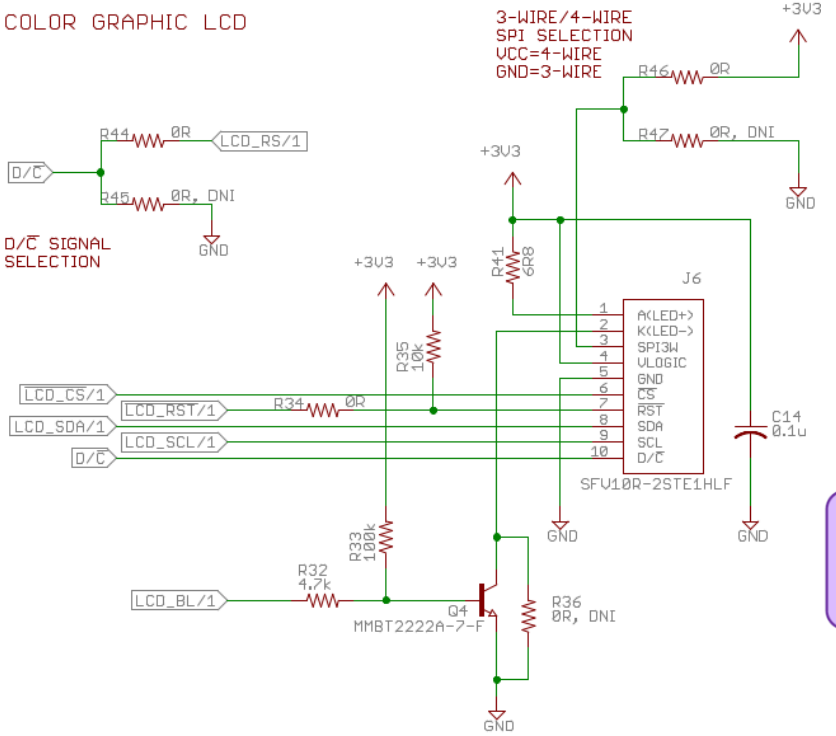


Booster Pack
LCD Display

- The Crystalfontz CFAF128128B-0145T color 128x128-pixel TFT LCD supports display updates up to 20 frames per second (FPS).
- It is controlled the **SPI interface.**
- LCD_BL/1 Controls the brightness of display. This wire has to be selected in Jumper J5.
- LCD_CS, LCD_SDA (MOSI), LCD_RST, LCD_SCL are the **SPI lines** for controlling the screen. No need of MISO.
- Examples here!. Display has its own library which can be used for easy implementation.



Position into the Booster



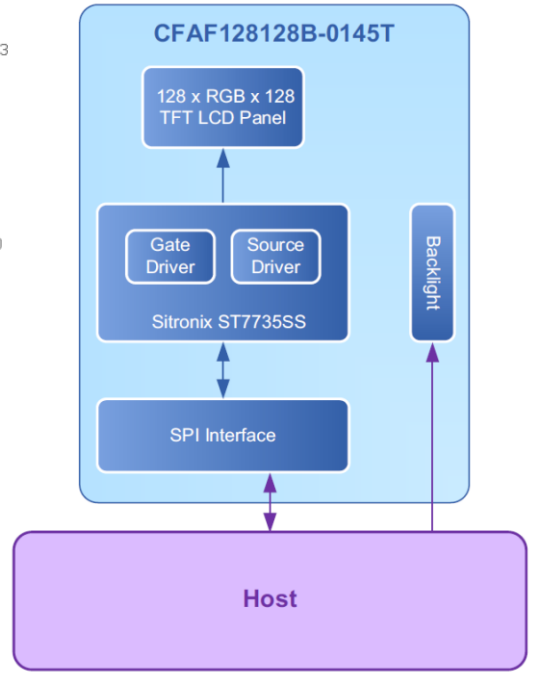
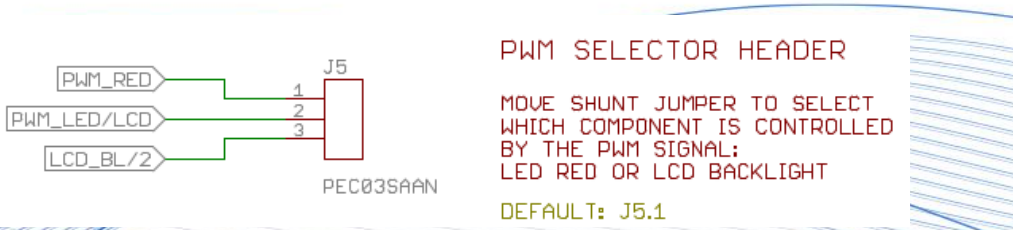
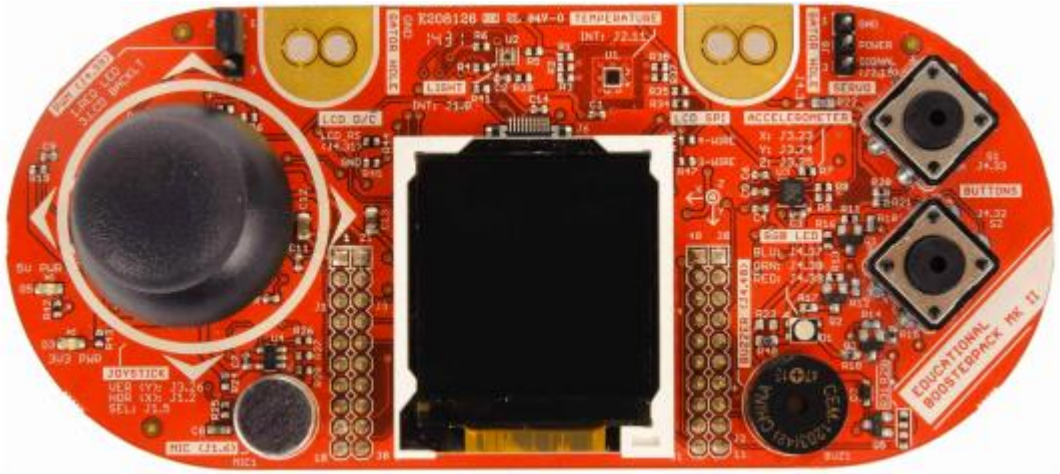


Diagram of TFT Display

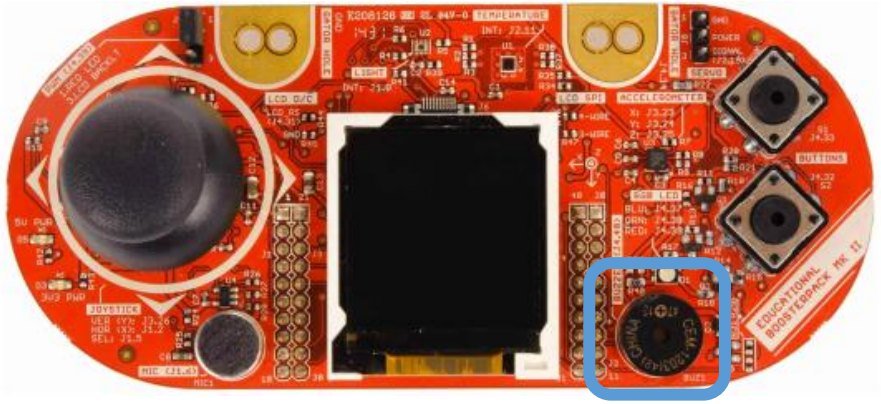


PERIPHERALS DIRECTLY CONNECTED THROUGH
Digital Signals

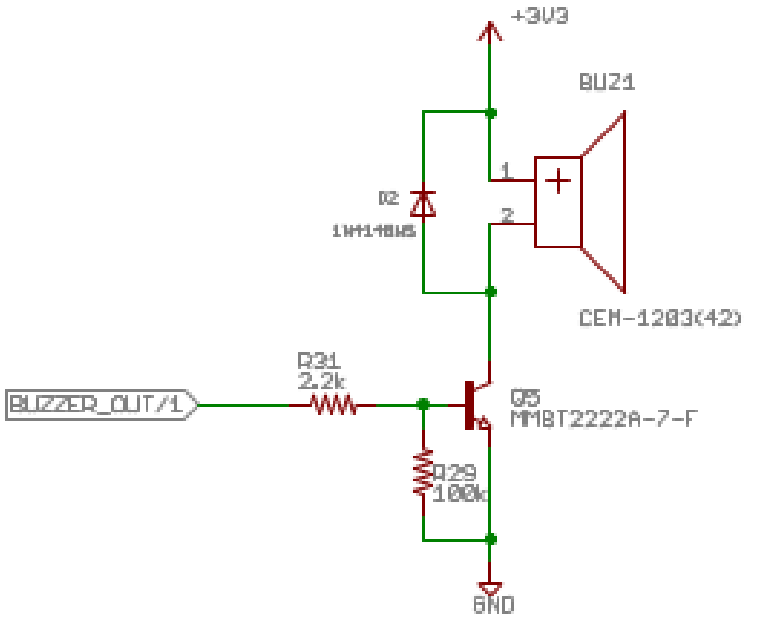


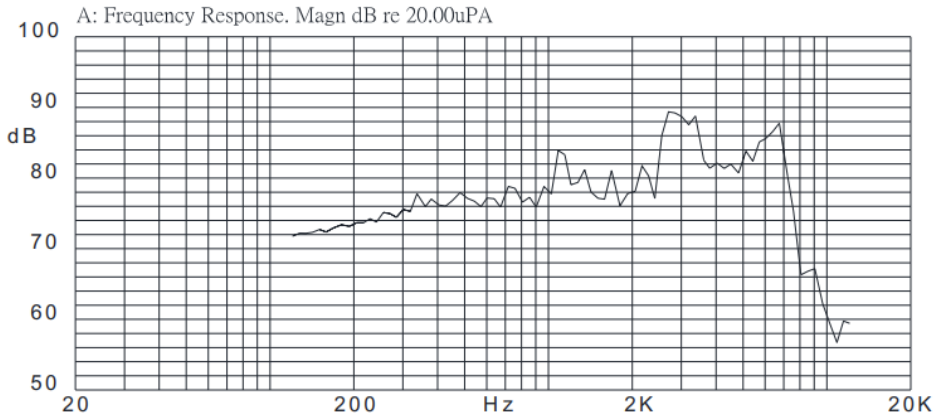
Booster Pack
Piezo Buzzer

- The CUI CEM-1203(42) piezo buzzer can play various frequencies based on the user-provided PWM signal.
- It is controlled by a simple PWM signal.
- It has an operation range in audible bandwidth.
- When transistor is opened, speaker current flows through diode. This avoid that speaker current goes suddenly to zero causing over voltage.



Position into the Booster





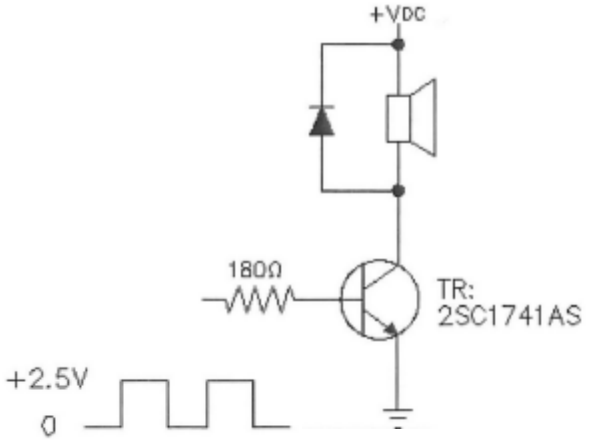
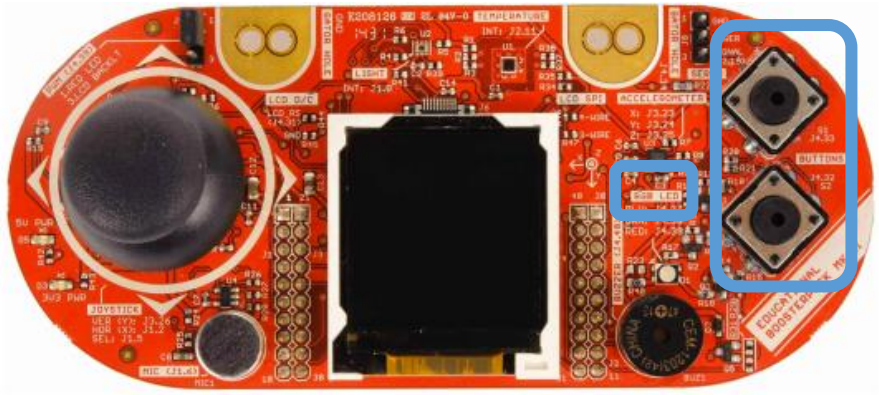


Diagram of Buzzer

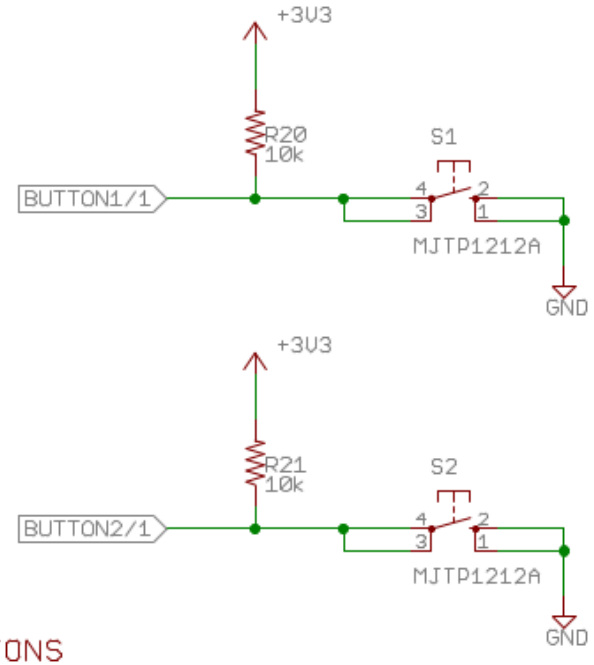
Booster Pack

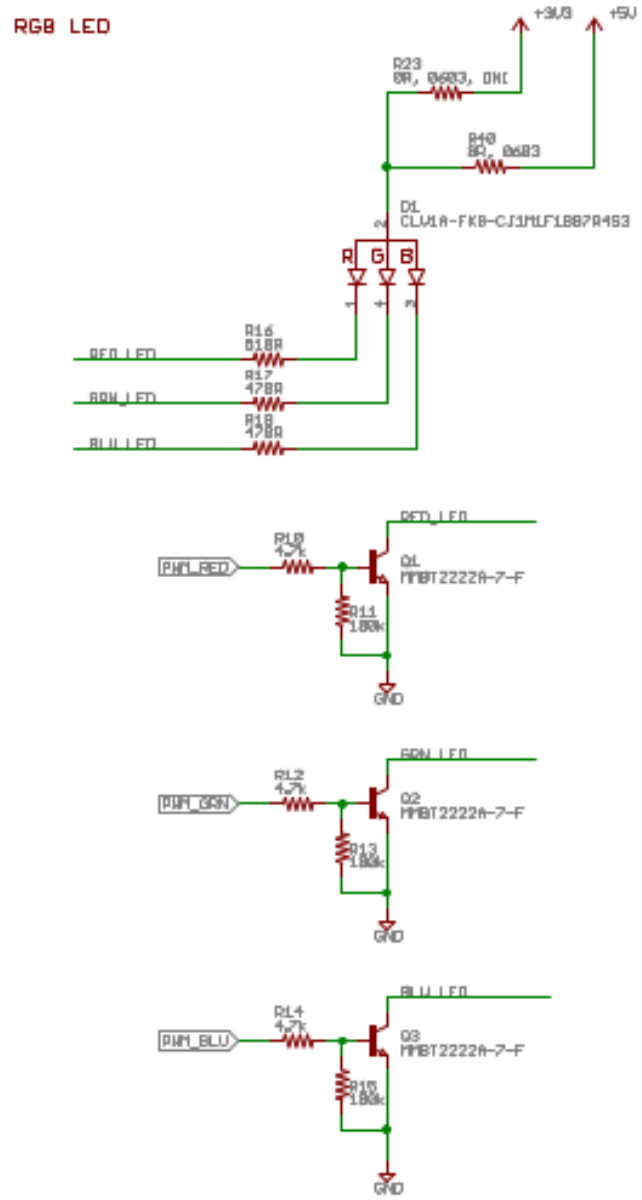
Buttons and RGB Leds

- There are two general purpose buttons and one RGB LED.
- Buttons are connected to 3.3V and pull-up resistors
- RGB Led is controlled by three PWM signals.



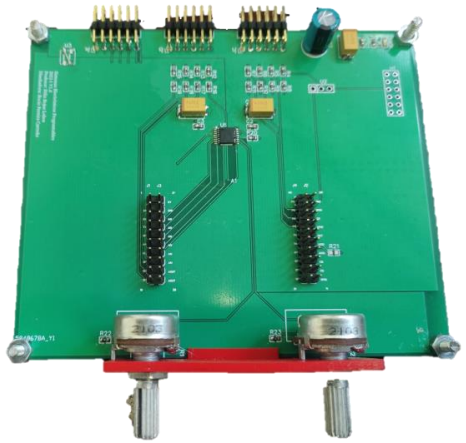
Position into the Booster





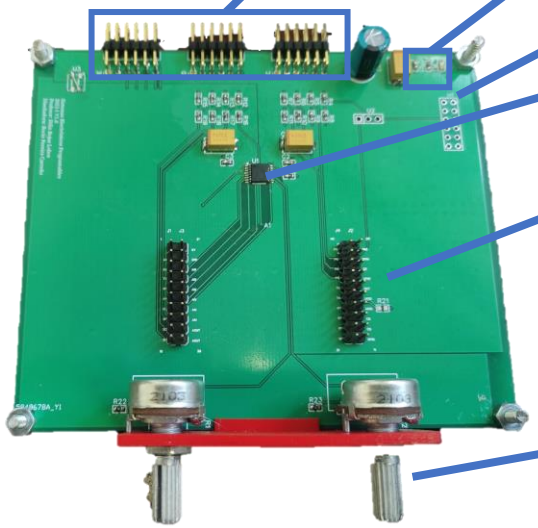
Introduction
Adapter Board

This section provides a brief introduction to the adapter board used to connect Booster to Zybo-Z7



Adapter Board

Schematic



A: Pins to connect the Zybo Z7 to connectors JD, JD, JE

E: Power LED

F: Extra connector for output PWM (not used)

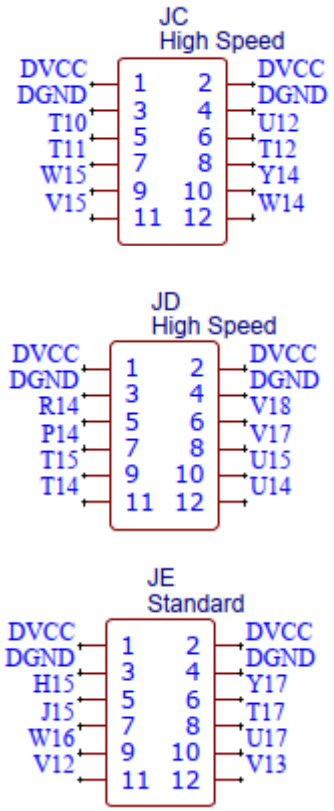
B: Analog to Digital Converter

D: Pins for connecting the Booster Development Board

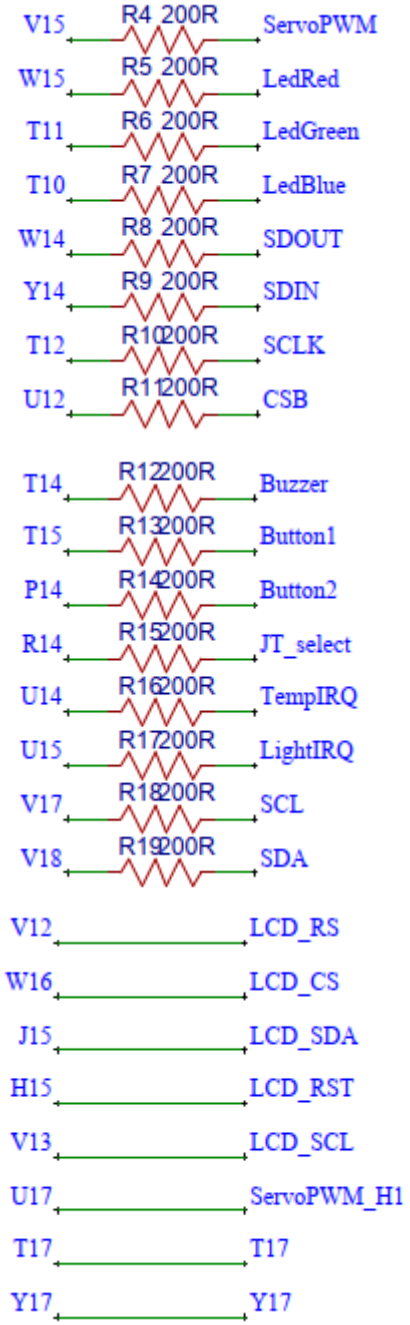
C: Two general purpose Potentiometer.

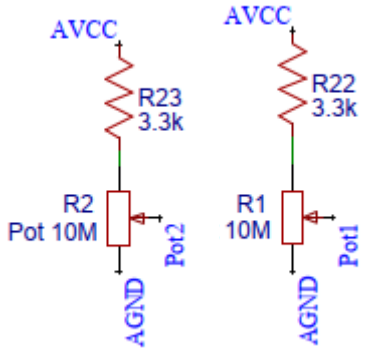
Adapter Board

Schematic

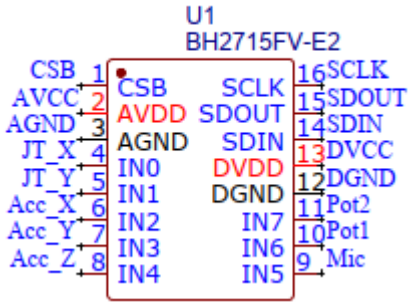


A: Pins to connect the Zybo Z7 to connectors JD, JD, JE

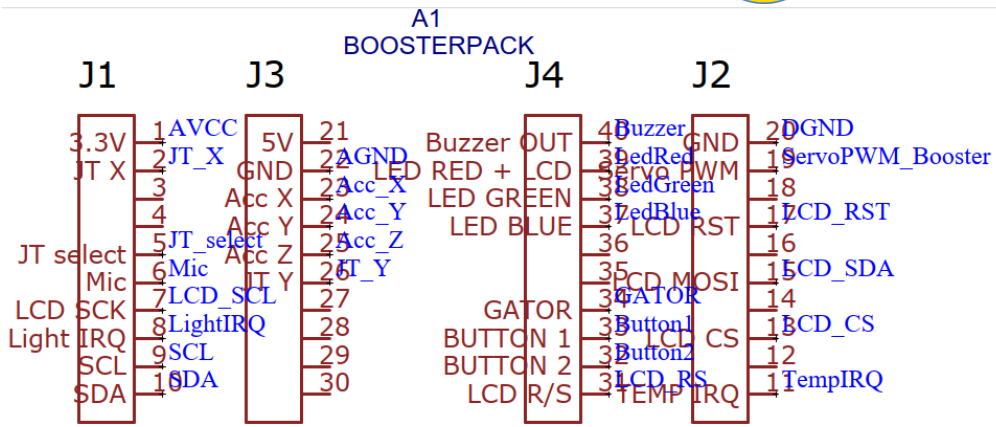




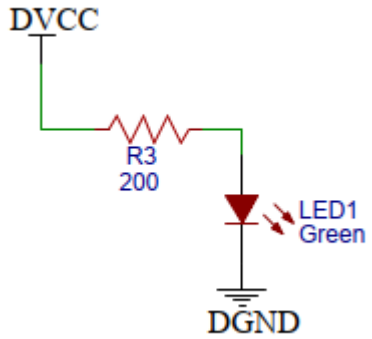
C: Two general purpose Potentiometer.



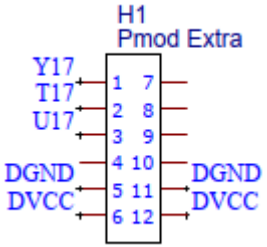
B: Analog to Digital Converter



D: Pins for connecting the Booster Development Board



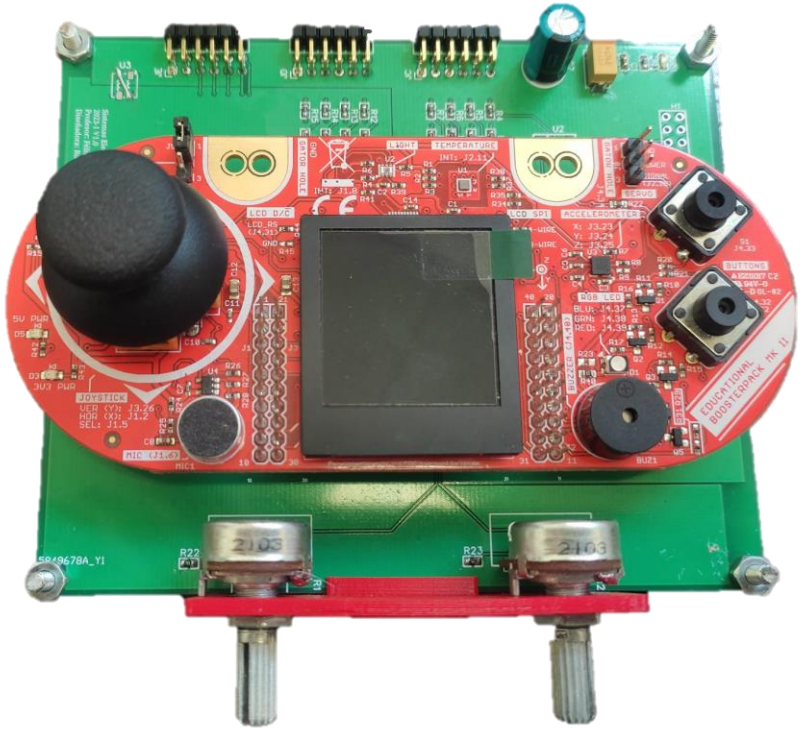
E: Power LED



F: Extra connector for output PWM (not used)

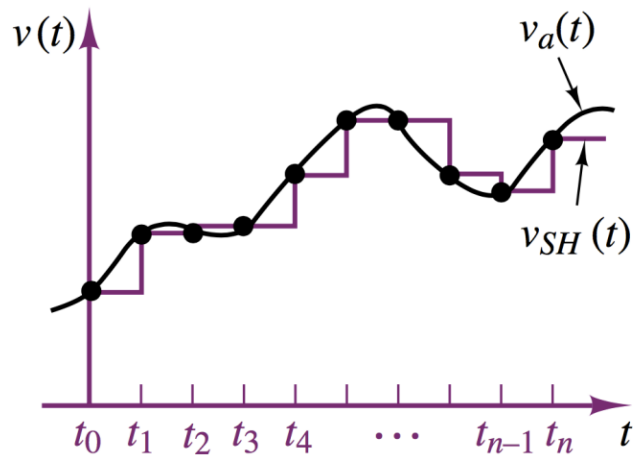
Adapter Board

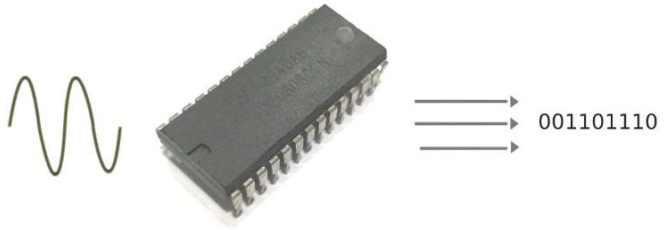
Mounted Booster into Adapter Board



Introduction
Analog to Digital converter (ADC)

Overview about Analog to Digital Conversion

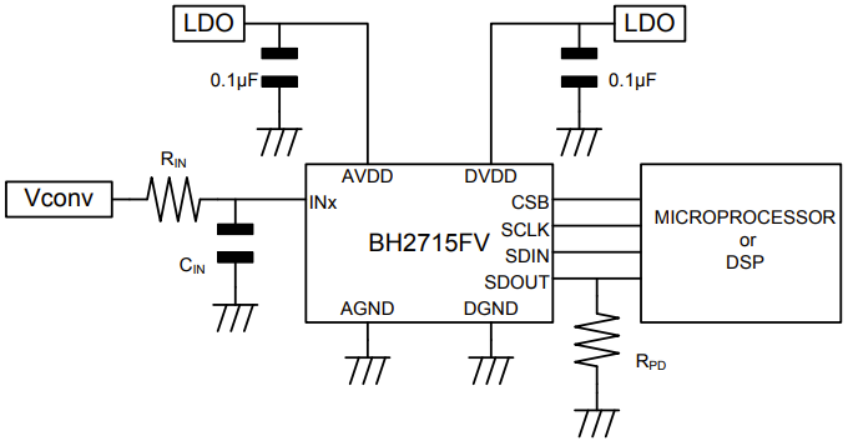




Analog to Digital Converter

Digitalization Process

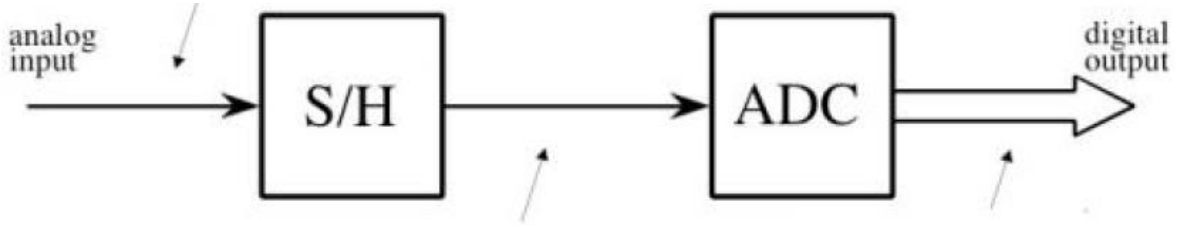
- An ADC converts an analog signal into a digital value which can be used by the processor.
- To main process are involved: Sampling and quantization.
- An ADC is characterized by:
  - Its number of bits used for digitalization. (resolution)
  - Speed of taking samples (samplings per second (Msps))
  - Voltage range of the analog input voltage.
  - Type of Conversion:
    - Flash ADC
    - Successive Approximation ADC
    - Ladder ADC
    - Integrating ADC

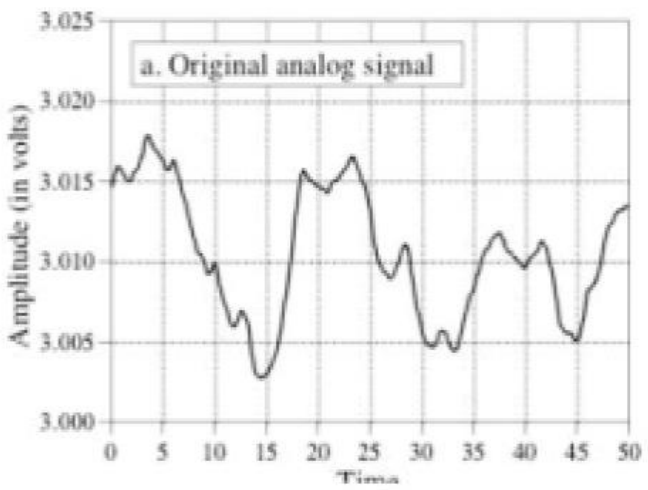


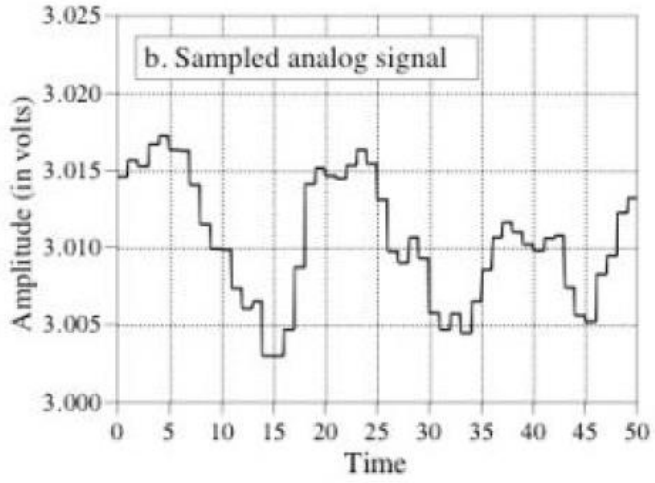
Analog to Digital Converter

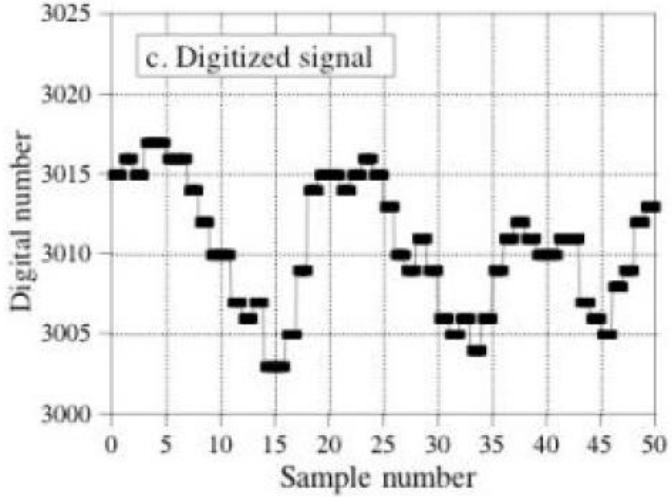
Digitalization Process

- An ADC Sample and Hold circuit ensures that the voltage is stable for the conversion.





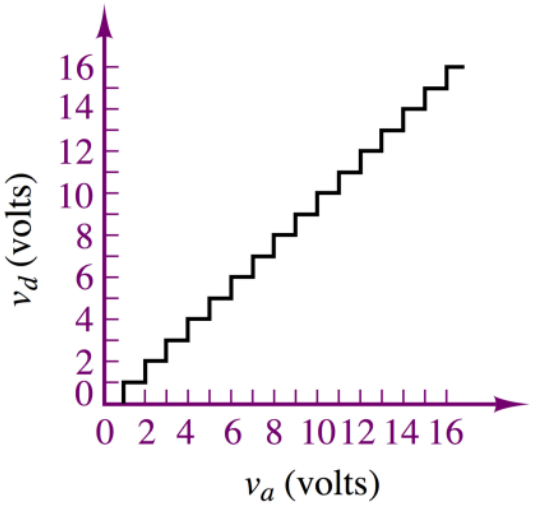




Analog to Digital Converter

Quantization

- It is the conversion of an analog signal into a set of finite numbers of values.
- The output of a ADC is a quantized signal.
- Va represents an analog voltage
- Vd: is the output digital/quantized voltage.

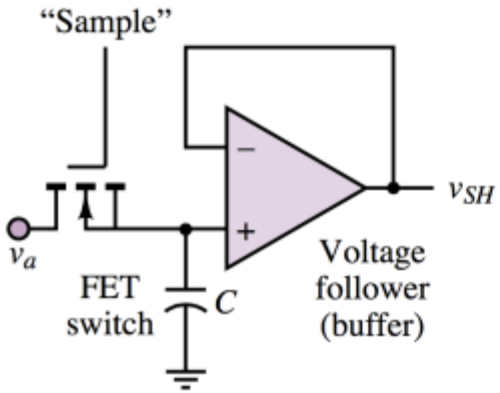


Quantized voltage	Binary representation			
v_d	b_3	b_2	b_1	b_0
0	0	0	0	0
1	0	0	0	1
2	0	0	1	0
3	0	0	1	1
4	0	1	0	0
⋮		⋮		
14	1	1	1	0
15	1	1	1	1

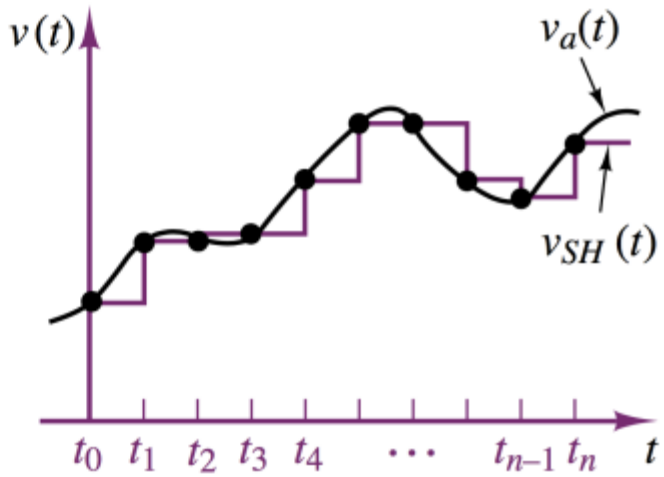
Analog to Digital Converter

Sample and Hold

- A MOSFET is used as a switch to fill the capacitor. After a small time, it is open and the capacitor voltage keep constant, ready for being transformed into a digital value (quantized).
- Choice of C is a compromise between:
  - a) voltage stability, i.e. precision (large C- immune to leakage current)
  - b) fast sampling, i.e. acquisition time(small C).
- The MOSFET should not distort the measurement. (no leakage current while it is open)
- Most of ADC comprise a sampling and hold stage.



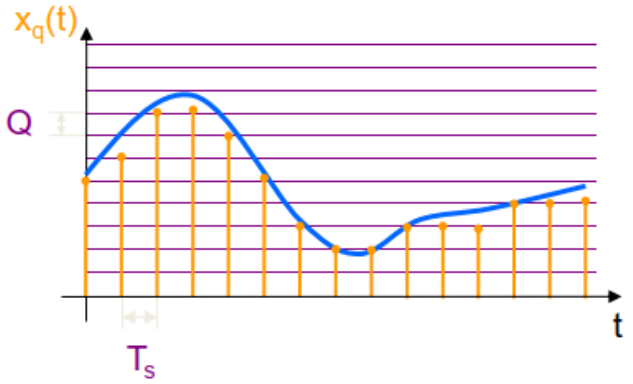
Sample-and-hold amplifier



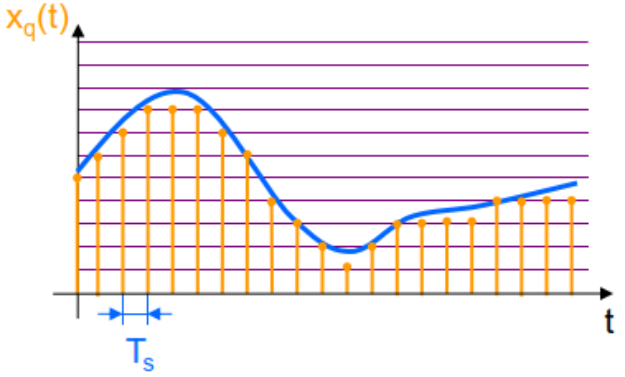
Analog to Digital Converter

Accuracy

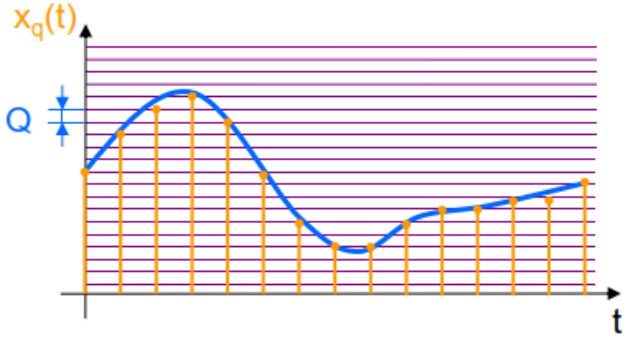
- If your ADC converts with 10bits, and the input can be between 0-5V, then there are 2^10 values to represent the analog signal.
  - Resolution=5/2^{10}



Higher Sampling Rate



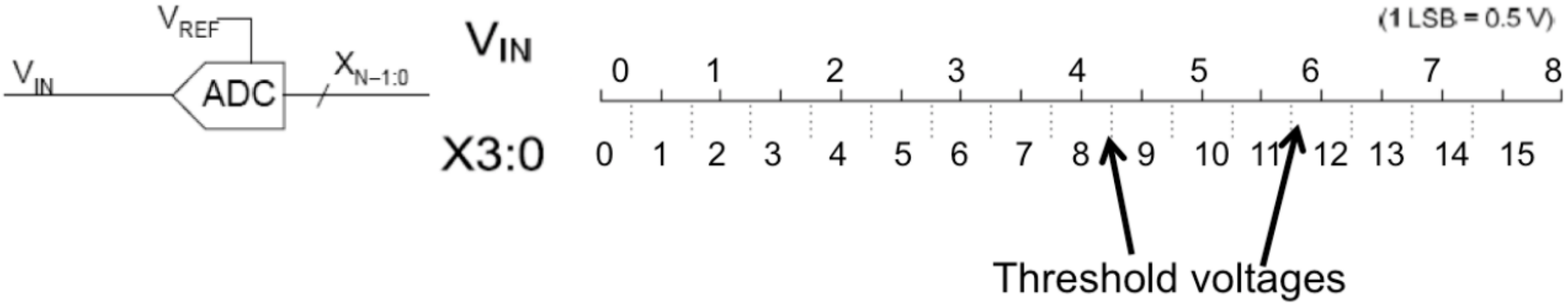
Higher Resolution



Analog to Digital Converter

Threshold Voltage

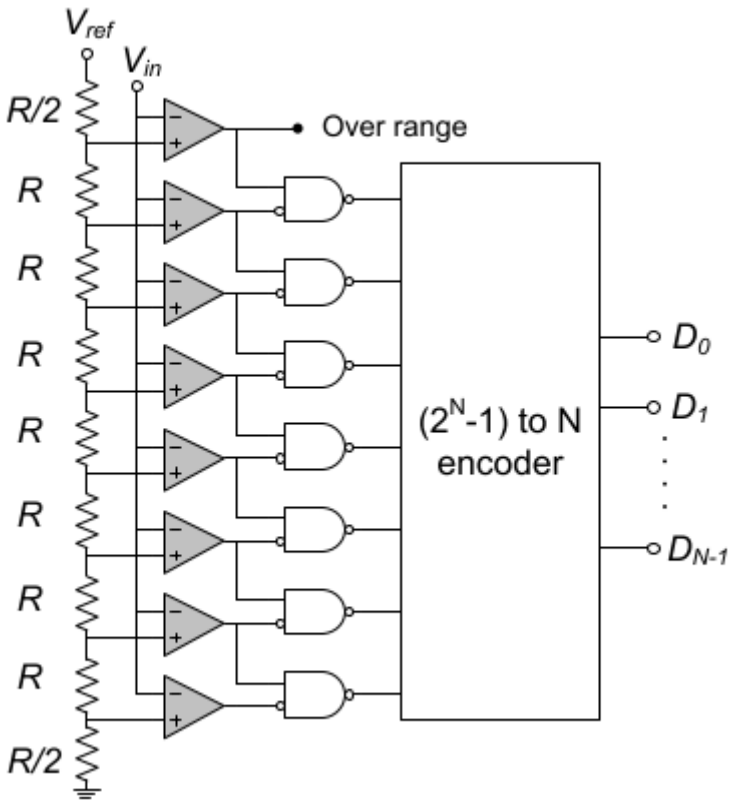
- Suppose you have an input range of 8V and your ADC is 4bits.
- Then you can represent 0-8V with 2^4=16 values. This gives a resolution of 8/16=0.5V.
- The resolution is equal to 1LSB.
- The voltages where Vin changes from one number to the other is called threshold level.



Analog to Digital Converter

Types of ADC: Flash ADC

- Vin is connected with 2^N parallel comparators
- The Vref voltage is the range of the ADC and is connected to a series of resistors.
- Each comparator will be set to 1 or 0, if the Vin is greater than the voltage connected to voltage at its positive pin.
- Simplest ADC.
- The speed is limited only by the propagation delays of the comparator and the priority encoder. (very fast!) However, accuracy is moderate.
- A 12-bit converter needs 4095 comparators on a single chip! That can be a lot.

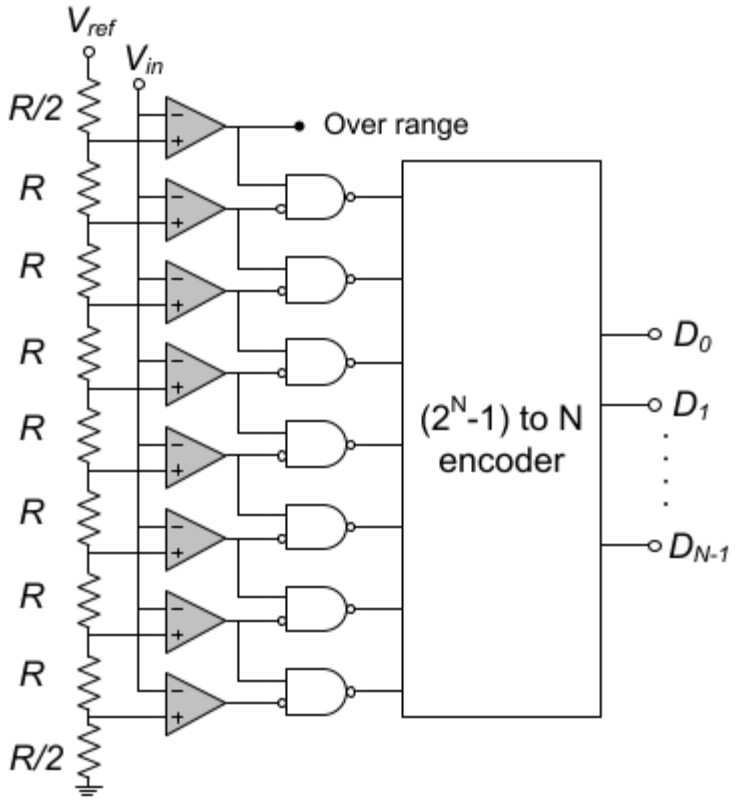


Analog to Digital Converter

Types of ADC: Flash ADC

- If we use 7 comparators we couls possible have 2^7 values. However, only 8 values can occurs.
- This 8 values can be represented with only 3bits (no need of 7 bits).
- Ths conversion from 7 to two wires is made by a Priority Encoder.

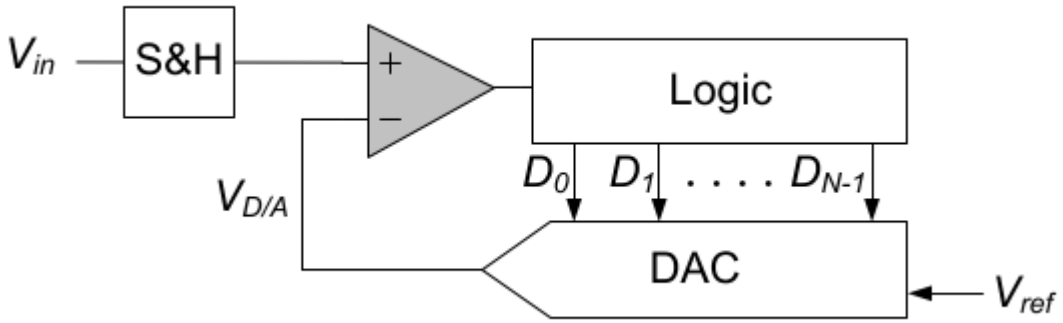
G7:1	X2:0
1111111	111 = 7
0111111	110 = 6
0011111	101 = 5
0001111	100 = 4
0000111	011 = 3
0000011	010 = 2
0000001	001 = 1
0000000	000 = 0

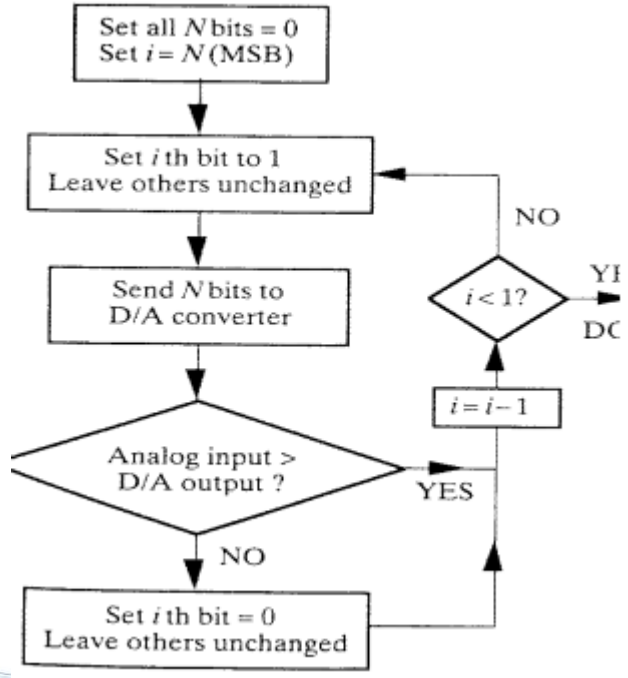


Analog to Digital Converter

Types of ADC: Successive Approximation ADC

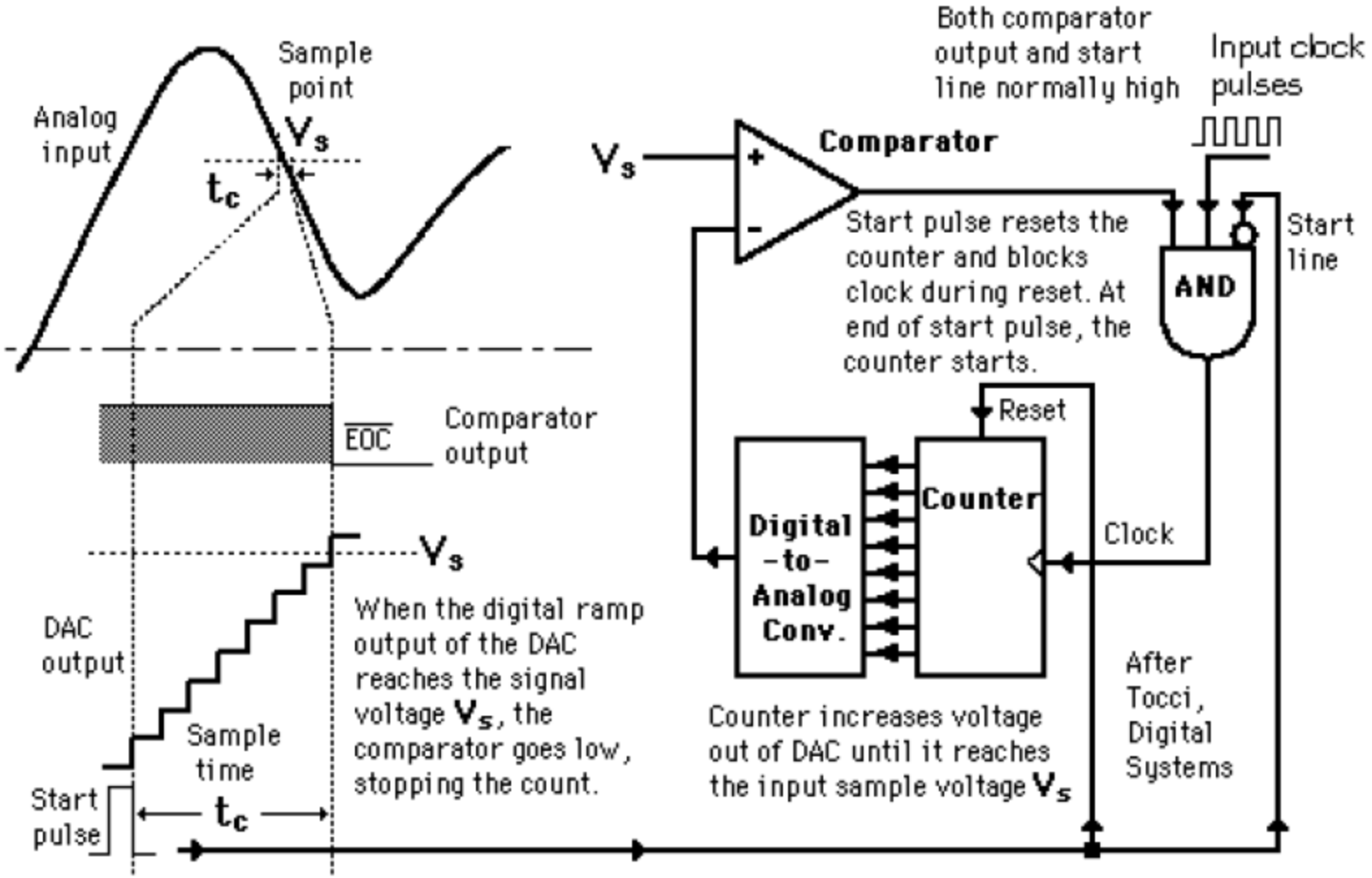
- Generate an internal analog signal VD/A
- The generated value is compared to eh input sampled voltage.
- The digital output D0-DN-1 is modified until is the closest value to Vin.
- This ADC is one of the most commonly used where accuracy is needed and speed is not too much of a limitation, for example in microcontrollers. SA type ADCs can easily achieve conversion times of a few microseconds.



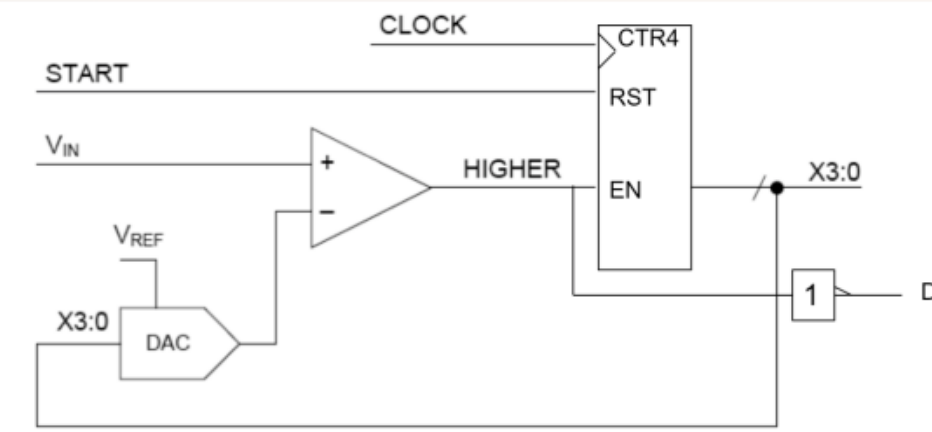


Analog to Digital Converter

Types of ADC: Ladder ADC



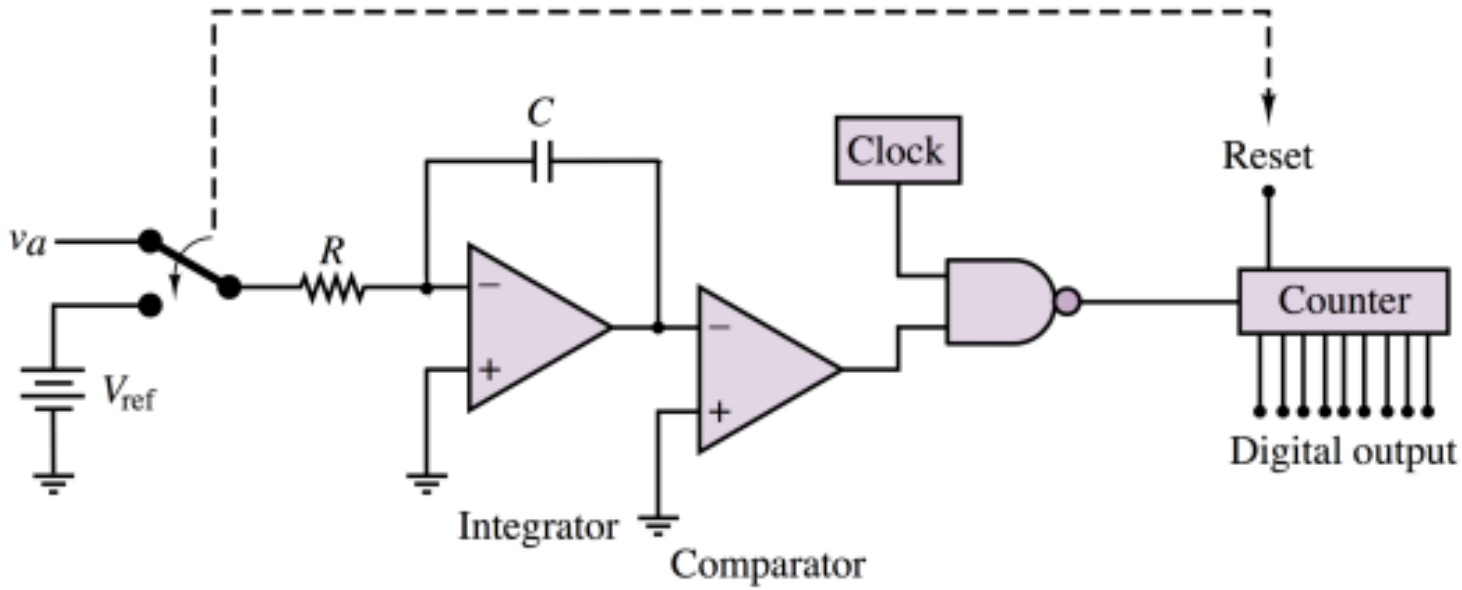
- A ramp is compared to the analog input.
- The maximum time conversion depends on the clock and number of bits of the counter .
- Tconv=nc/fc
- nc: Number of bits of the counter
- fc: frequency of the counter.



Analog to Digital Converter

Types of ADC: Integrating ADC

- Close the switch and start counting.
- Charge the capacitor for a fixed period of time
- Then measure the time to discharge the capacitor.
- When capacitor discharge to 0V , comparator will stop the counter.
- Very slow method, but cheap.



Electrical Engineering Department
Pontificia Universidad Católica de Chile
peclab.ing.uc.cl