KYAMBOGO UNIVERSITY

Tet la'ngech

Embedded Systems Technology

TETE 3102 MICROCONTROLLERS AND APPLICATIONS

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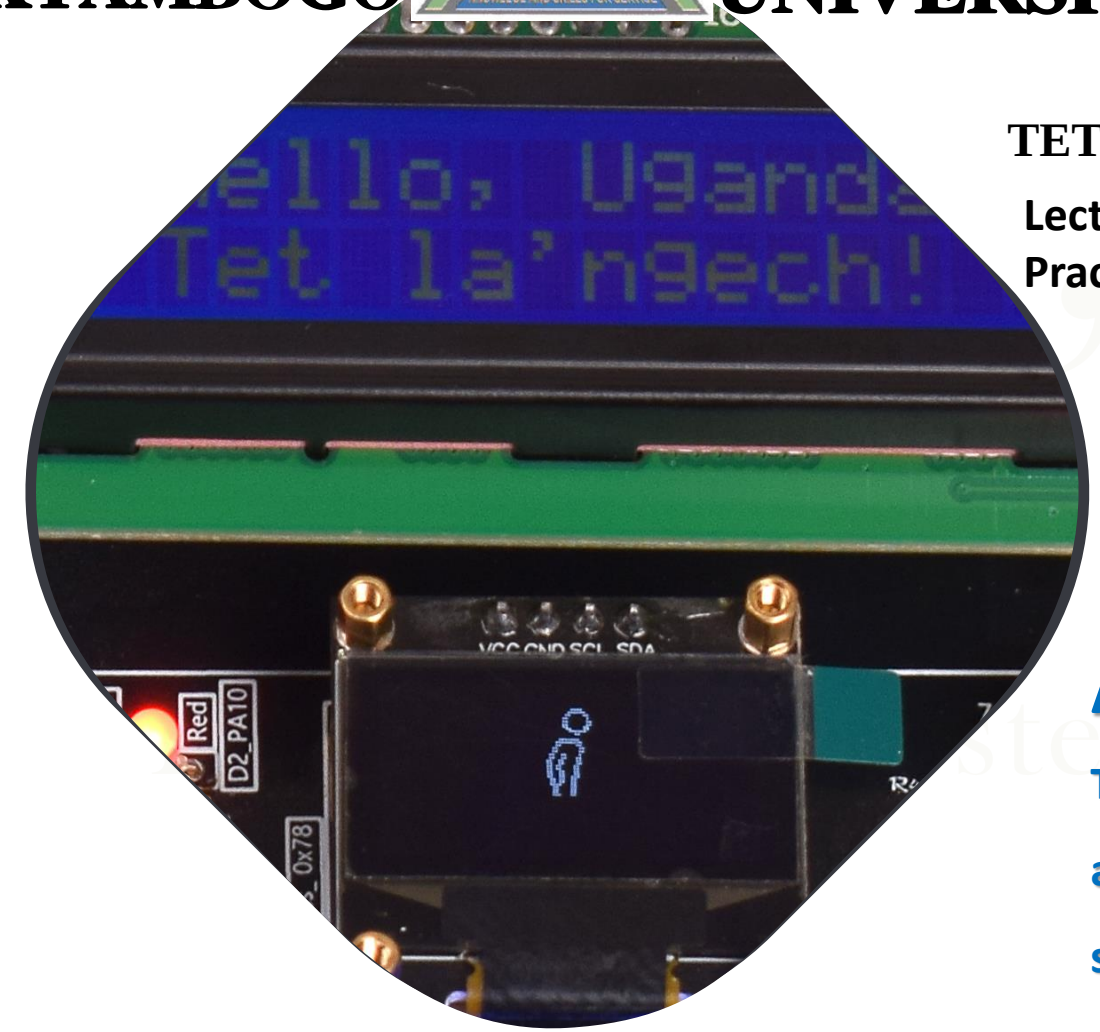
Prac session: Mr. Matovu Paul

Department of Electrical and Electronics Engineering



Embedded Systems

ADC – Analog to Digital Converter

The analog-to-digital converters inside STM32 MCUs allow the microcontroller to accept an analog values like a sensor output and convert the signal into the digital domain.

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Analog vs Digital signals

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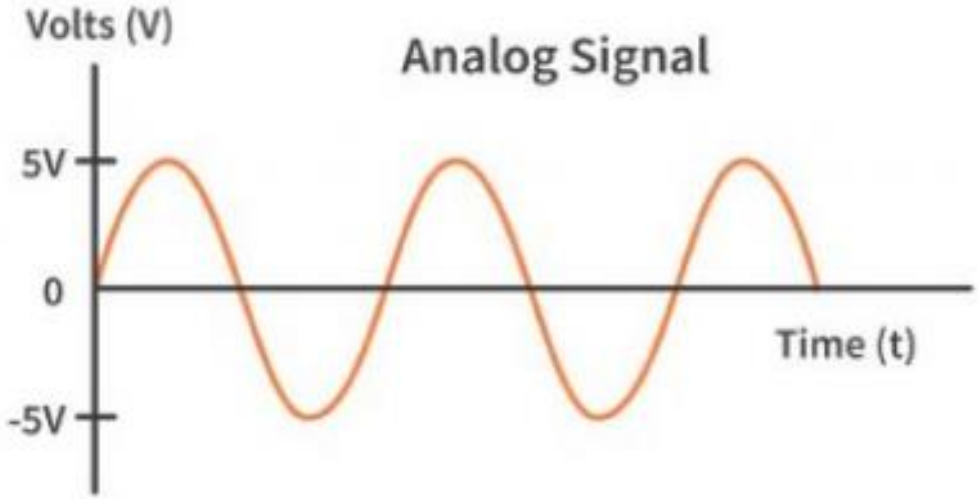
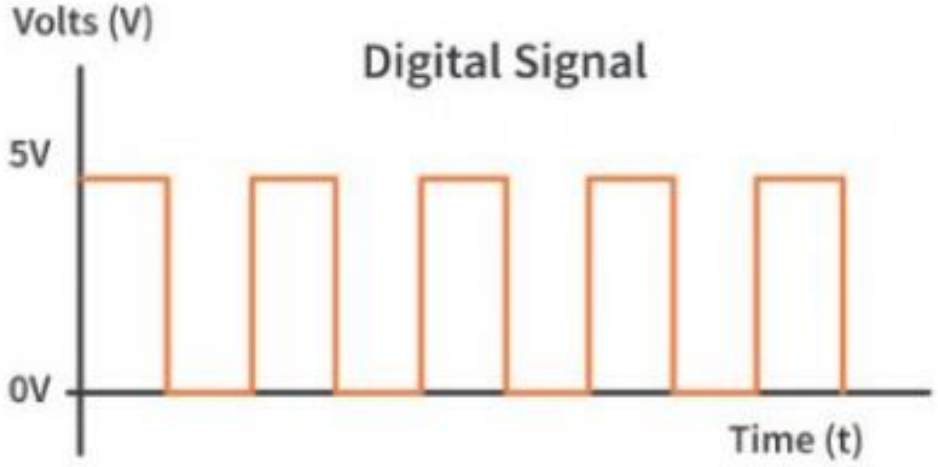
Analog Signals

- Continuous wave: keeps changing over time.
- Representation: sine waves; real-world quantities



Digital Signals

- Discrete: discrete in both value and time.
- Representation: binary numbers (0s and 1s); data representation in digital systems.



https://www.tutoroot.com/blog/what-are-analog-and-digital-signals-definition-difference-examples/

Light sensor

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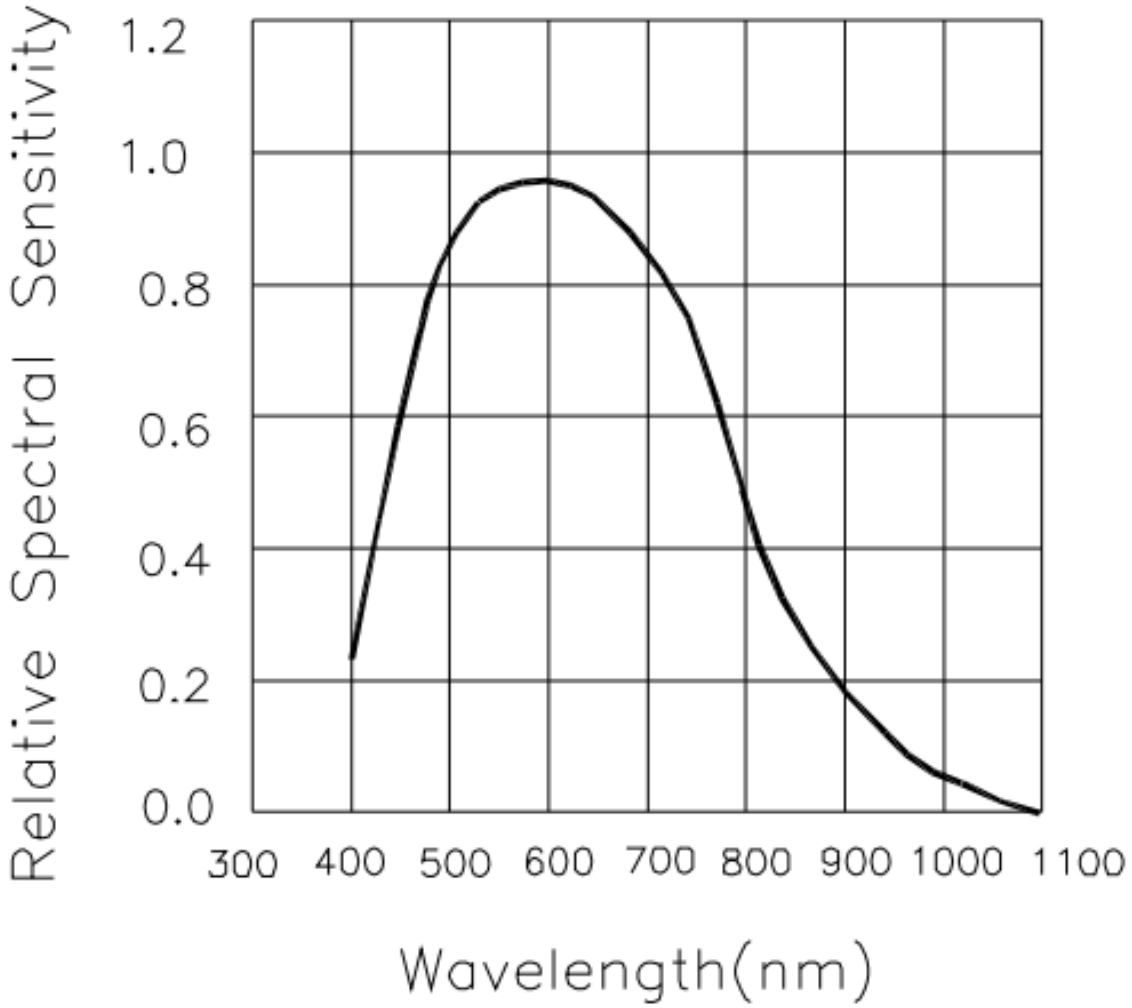
- Light sensor detects the amount of light energy
- Ambient light photo sensor on sipi
- Sensitive to the visible spectrum



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Light sensor

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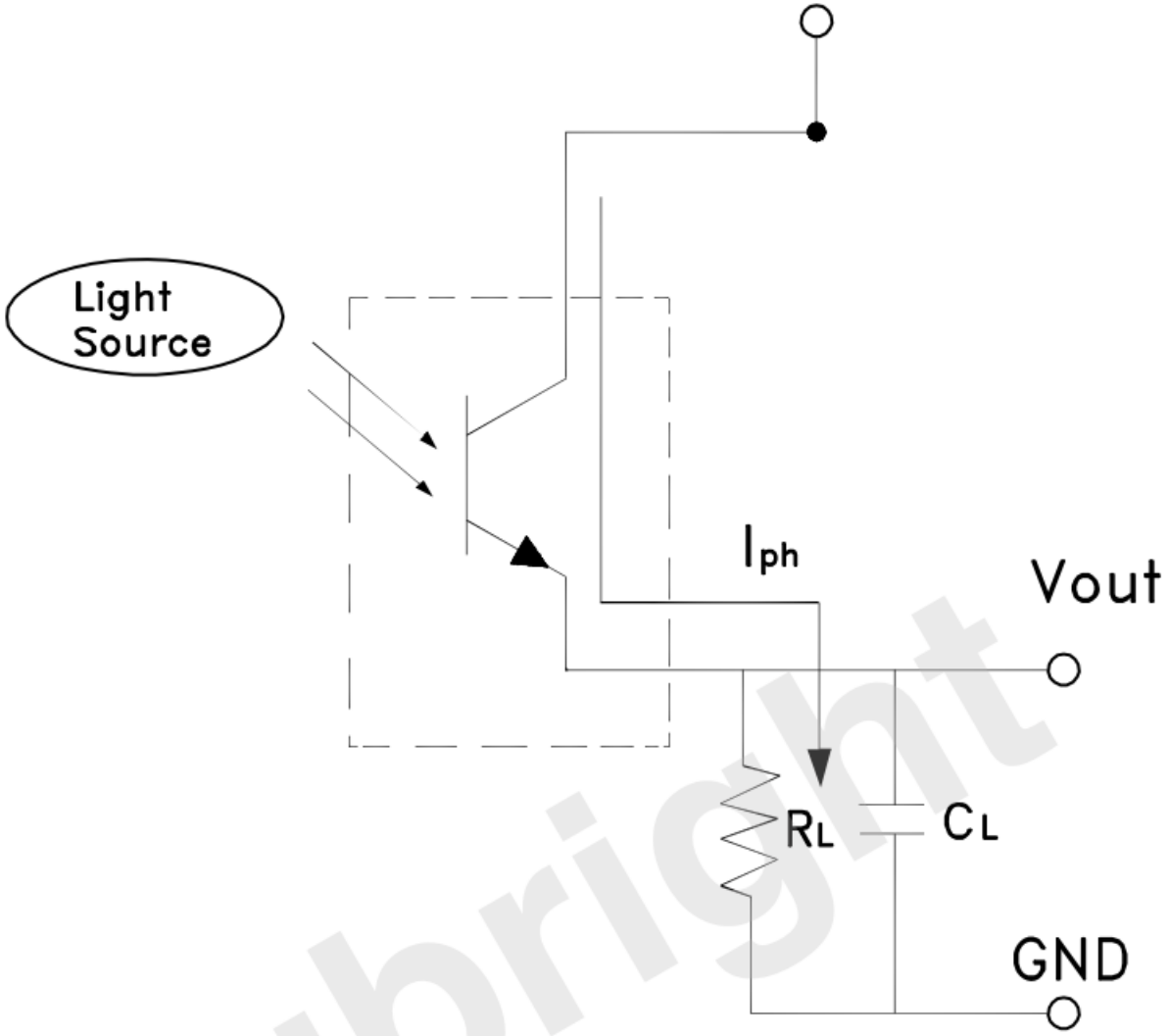

- Photons of light converted into electrical signal (voltage)

Converting photocurrent to voltage

- Output voltage is product of photocurrent (IPH) and loading resistor (RL)

$$V_{out} = I_{ph} \times R_L$$

Light sensor: Real world applications

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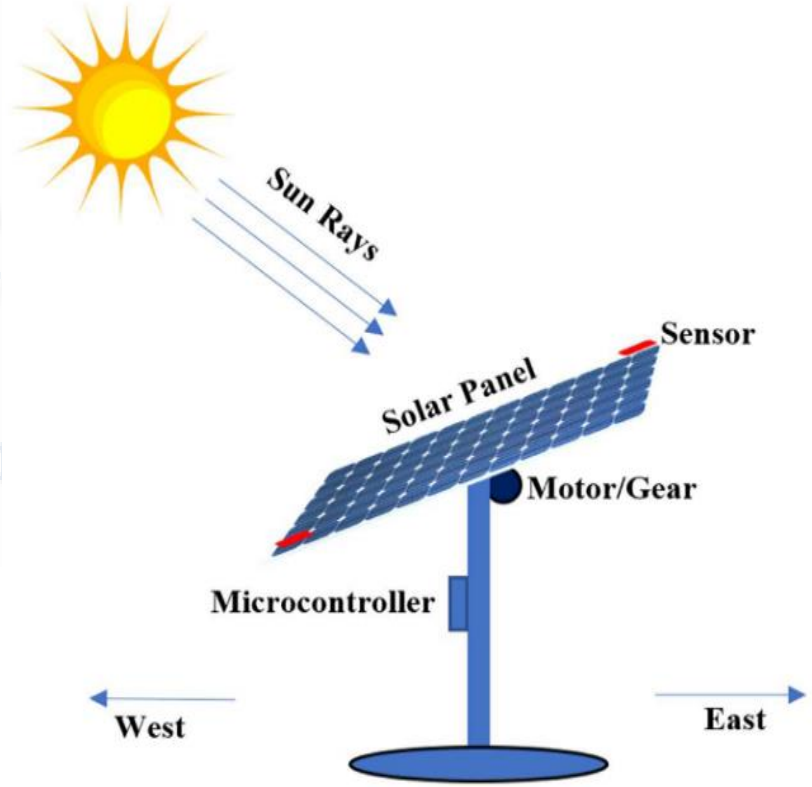
- Street lighting systems
- Solar tracking systems
- Mobile phones
- Note books (laptops)
- Video cameras
- Etc.



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Analog-to-digital converter (ADC) in STM32

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- ADC reads analog voltage from analog sensors
- Resolutions; 12-bit (0-4095), 10-bit (0-1023), 8-bit (0-255), 6-bit (0-63), etc.
- 12-bit maps analog voltages between 0 & 3.3 volts into integer values between 0 & 4095.

Analog voltage at known ADC value e.g 20

- 12 bit ADC = max value is 4095
- For voltage between 0-3.3 V, Max reference voltage is 3.3 V

$$4095\ \text{ADC value} = 3.3\ \text{V}$$

$$20\ \text{ADC value} = \left(\frac{(20 \times 3.3)}{4095}\right)\text{V}$$

$$\text{Voltage}_{\text{ADC value}} = \left(\frac{\text{ADC value} \times \text{Max reference voltage}}{\text{Max ADC value}}\right)\text{V}$$

$$\text{Voltage}_{\text{ADC value}} = \left(\frac{\text{ADC value}}{\text{Max ADC value}}\right) \times \text{Max reference voltage}$$

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ADC Conversion Modes in STM32

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- **Single conversion mode:** ADC does one conversion, then stops
- **Continuous conversion mode:** ADC starts a new conversion as soon as it finishes one
- **Discontinuous mode**: ADC converts only a single channel at each trigger signal from the list of pre-defined programmed input channels.
- **Scan mode:** Used to scan a group of analog channels

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ADC Conversion Modes in STM32

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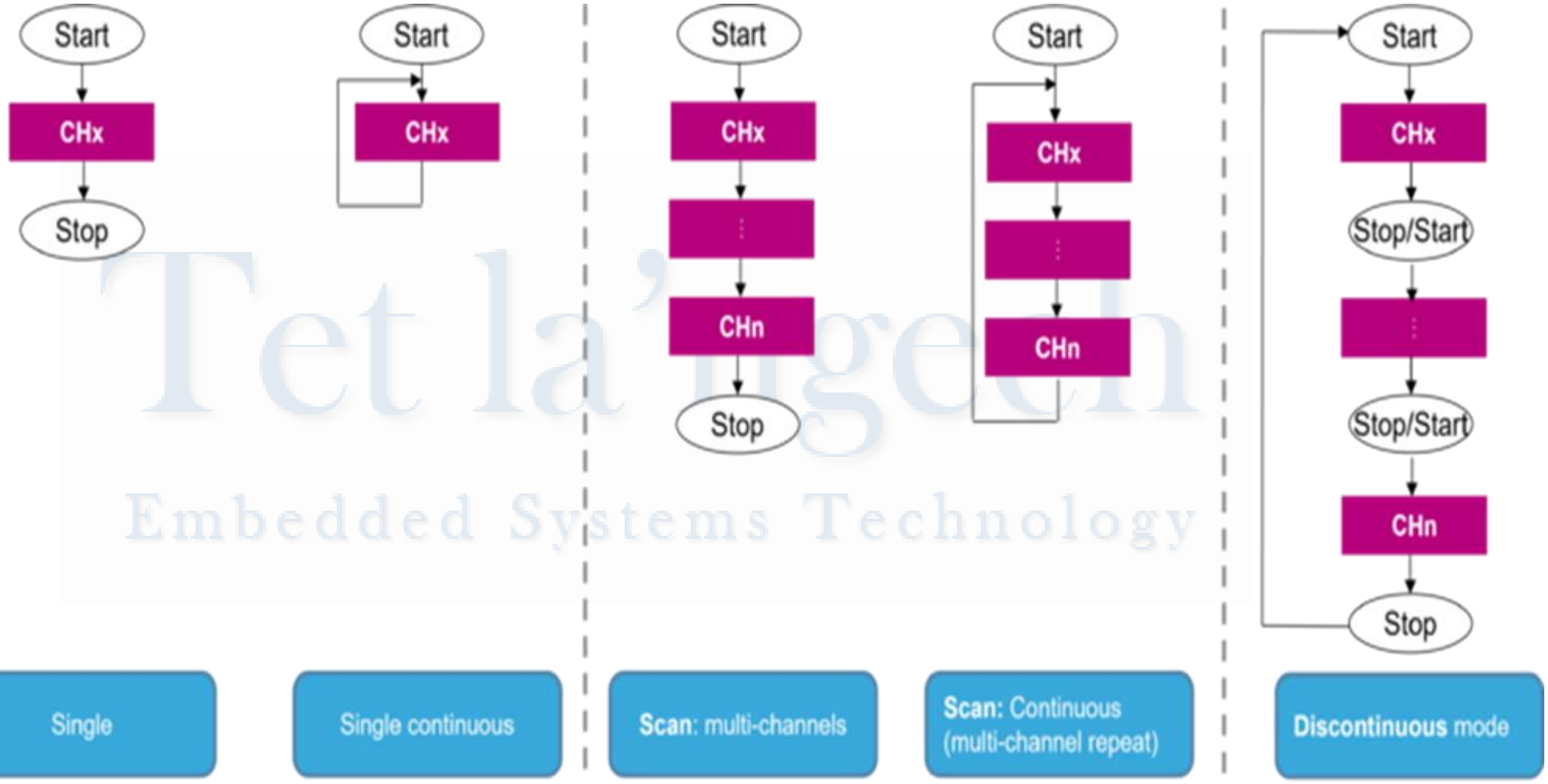

Analog-to-digital converter (ADC) in STM32

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ADC Conversion Time

- Depends on [Reference manual] of MCU (STM32F411RE)
- ADC samples voltage
- Cycles depends on ADC resolution
- ADC clock, ADCCLK derived from APB2
- Use prescalar to further control ADC clock
- Temperature sensor internally connected to ADC1
- For STM32F411RE, internal temp sensor requires a minimum of 10 µs to work; $T_{conv} \geq 10\ \mu s$.

$$T_{conv} = \frac{\text{sampling time + cycles}}{\text{ADC Clock}}$$ [Reference manual]

Resolution	Normal conversion mode	Fast conversion mode
12 bit	12 cycles	15 cycles
10 bit	10 cycles	13 cycles
8 bit	8 cycles	11 cycles
6 bit	6 cycles	9 cycles

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Analog-to-digital converter (ADC) in STM32

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ADC Conversion Time (STM32F411RE)

- 12-bit ADC resolution (15 cycles – fast mode)
- $T_{conv} \geq 10$ µs eg 12 µs.
- Adjust sampling time, ADC clock values to obtain the target of T_{conv}
- APB2 at 84MHz

$$\text{ADC clock} = \frac{84}{8} = 10.5\ \text{MHz}$$

- Prescaler of 8

$$T_{conv} = \frac{\text{sampling time + cycles}}{\text{ADC Clock}}$$

[Reference manual]

$$\text{sampling time} = (T_{conv} \times \text{ADC Clock}) - \text{cycles}$$

$$\text{sampling time} = (12 \times 10.5) - 15$$

$$\text{sampling time} = 111\ \text{cycles}$$

Programming Light sensor

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Single channel

- ❑ **Single conversion mode**
- ❑ **PollForConversion (Blocking mode)**

Task:

- ❑ **Read ADC values from light sensor**
- ❑ **Visualize light sensor ADC values using**

  a serial terminal e.g. Docklight

```
// start the adc
HAL_ADC_Start(&hadc1);

// poll for conversion
HAL_ADC_PollForConversion(&hadc1, 100);

// get the adc value
LightSensor_val = HAL_ADC_GetValue(&hadc1);

// stop adc
HAL_ADC_Stop(&hadc1);
```

Programming Light sensor

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Task:

- ❑ Read ADC values from light sensor
- ❑ Visualize light sensor ADC values using a serial terminal
- ❑ Low light intensity: turn on blue LED
- ❑ High light intensity: turn on red LED

Single channel

- ❑ Continuous conversion mode
- ❑ Interrupts

```
//Start ADC with interrupt
HAL_ADC_Start_IT (&hadc1);
```

```
/* INTERRUPT callback function */
void HAL_ADC_ConvCpltCallback(ADC_HandleTypeDef* hadc)
{
        //get the adc value
        LightSensor_val = HAL_ADC_GetValue(&hadc1);
}
```

Get In Touch With Us

Contact Us

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