Transparent Standby for Low-Power, Resource-Constrained Embedded Systems

A Programming Language-Based Approach

www.ceu-lang.org

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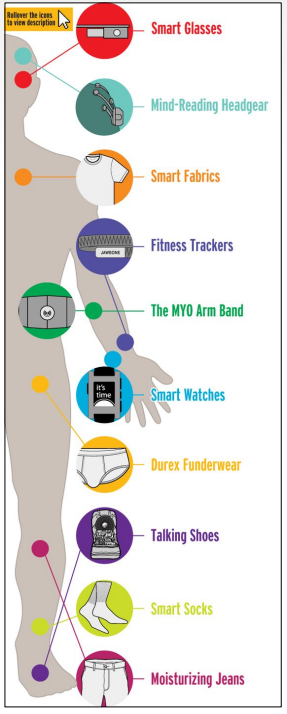

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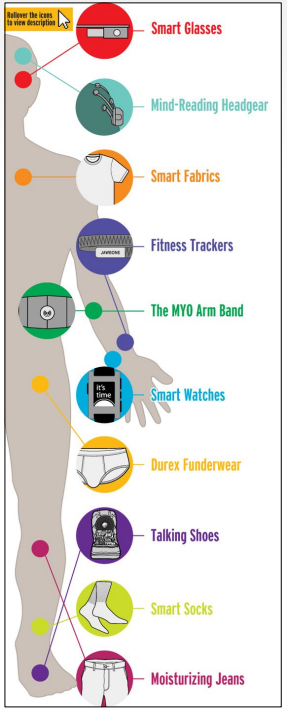

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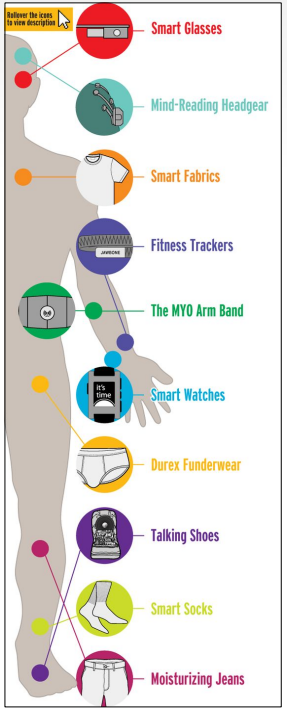

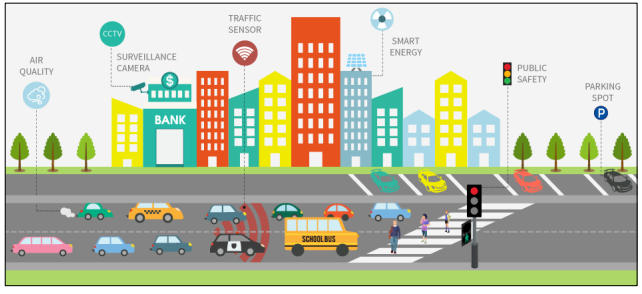

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30-50% economy with existing technologies

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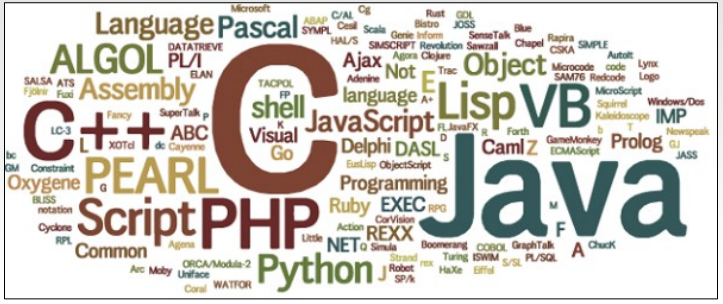

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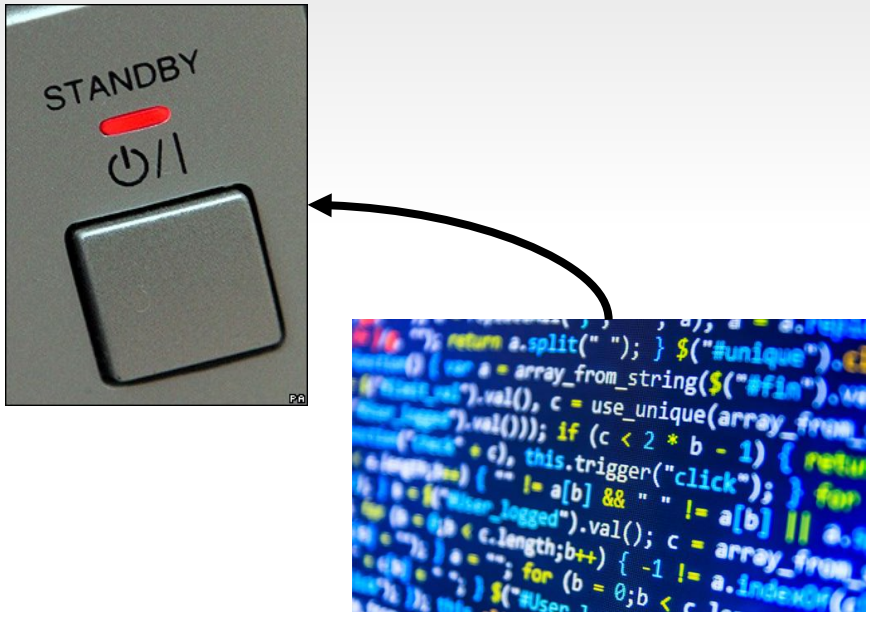

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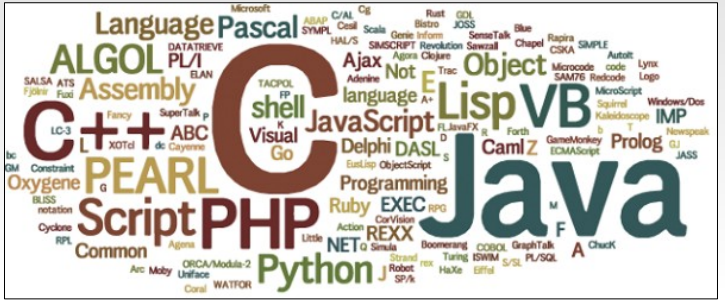

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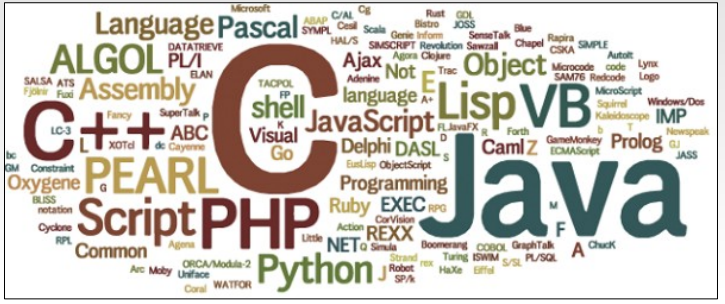

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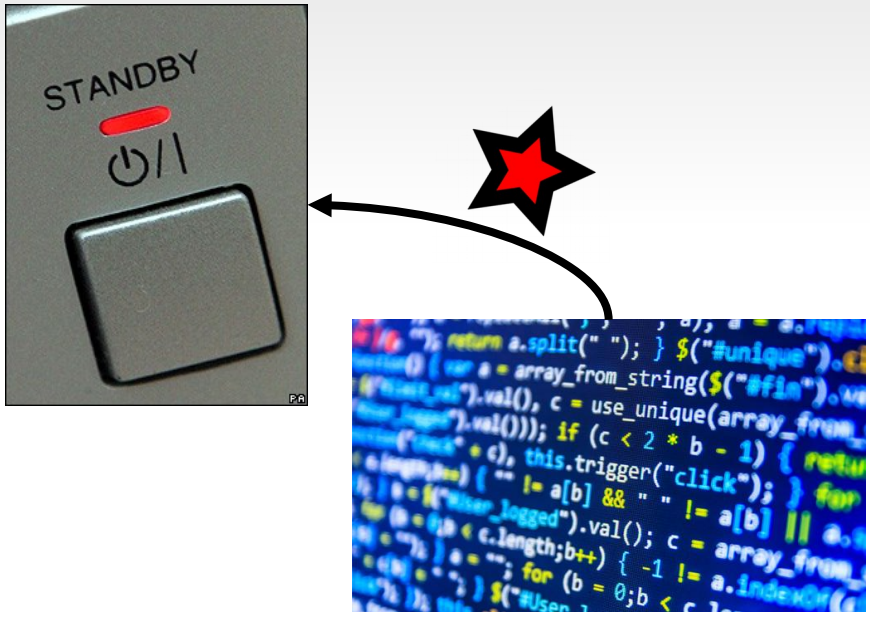

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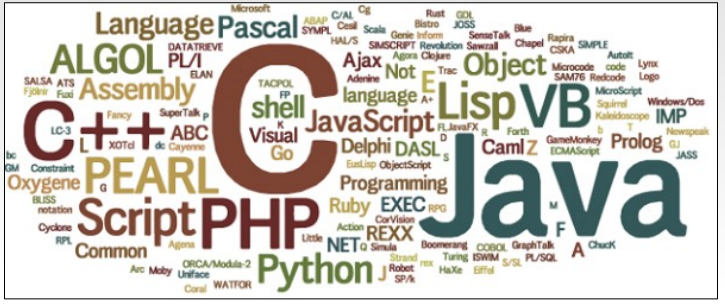

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4. Support **transparent**/non-intrusive standby mechanisms that reduce barriers of adoption.

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  - ***Not constrained embedded platforms (goal 2)***

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- Put device to sleep
- Only awake from interrupts

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- Deterministic
  - always yields the same outcome for a given timeline

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  emit ADC_REQUEST;
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code AnalogRead (void) -> int do
  PM_SET(PM_ADC, 1);
  do finalize with
    PM_SET(PM_ADC, 0);
  end
  emit ADC_REQUEST;
  int value = await ADC_DONE;
  escape value;
end
```

```
par/or do
  await RadioAvail();
with
  loop do
    await 1s;
    int v = await AnalogRead();
    await RadioWrite(v);
  end
end
```

```
output void ADC_REQUEST do
   ADMUX = 0x40|(A0&0x07);
   bitSet(ADCSRA, ADIE);
   bitSet(ADCSRA, ADSC);
end
```

```
code AnalogRead (void) -> int do
  PM_SET(PM_ADC, 1);
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   ADMUX = 0x40|(A0&0x07);
   bitSet(ADCSRA, ADIE);
   bitSet(ADCSRA, ADSC);
end
```

```
input ADC_vect_num do
  bitClear(ADCSRA, ADIE);
  emit ADC_DONE(ADC);
end
```

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code AnalogRead (void) -> int do
  PM_SET(PM_ADC, 1);
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    PM_SET(PM_ADC, 0);
  end
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```
void pm_sleep (void) {
  if (PM_GET(PM_TIMER1)) {
      sleep_1(<...>)
    } else if (PM_GET(PM_ADC)) {
      sleep_2(<...>);
    } else {
      sleep_3(<...>);
    }
  }
}
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output void ADC_REQUEST do
   ADMUX = 0x40|(A0&0x07);
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(Consumption in mA)

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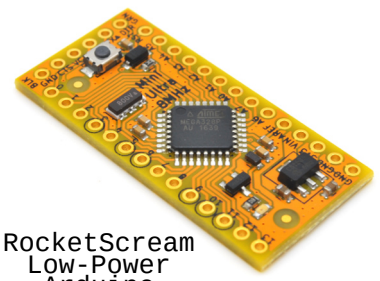

RocketScream
Low-Power
Arduino

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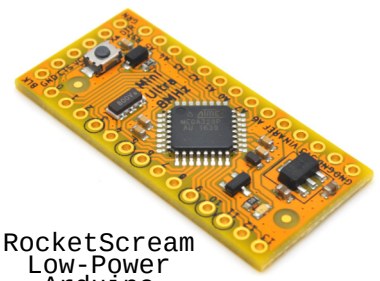

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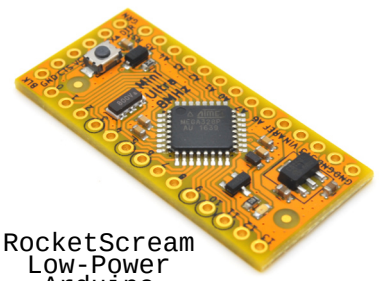

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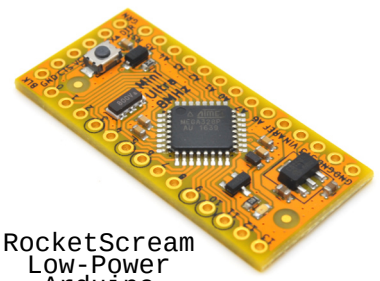

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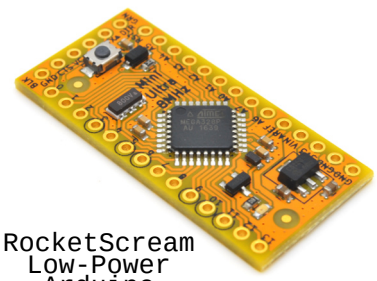

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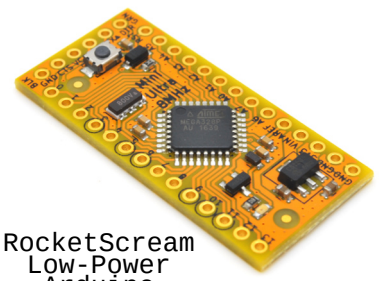

RocketScream
Low-Power
Arduino

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loop do
   emit PIN(13,high);
   await 1s;
   emit PIN(13,low);
   await 1s;
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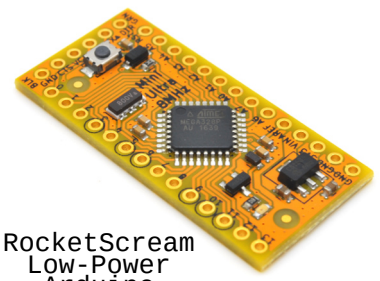

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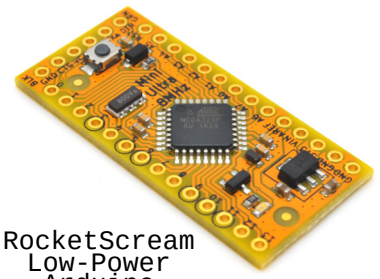

RocketScream
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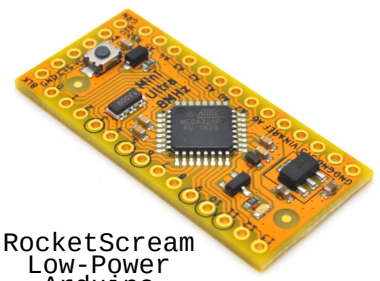

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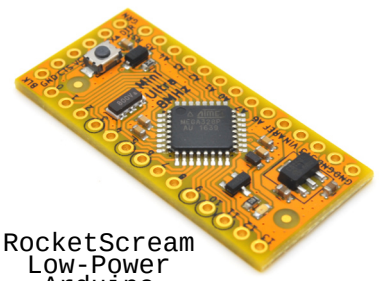
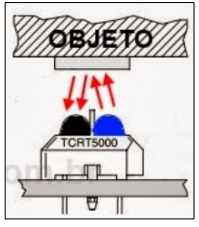


RocketScream
Low-Power
Arduino



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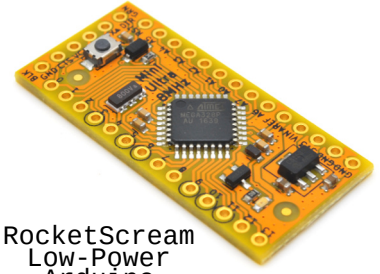

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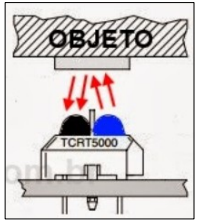


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loop do
   emit PIN(13,high);
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   await 1s;
end
```

```
emit PIN(13, _digitalRead(2));
loop do
   var bool v = await Pin(2);
   emit PIN(13, v);
end
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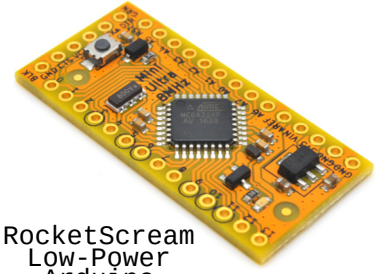

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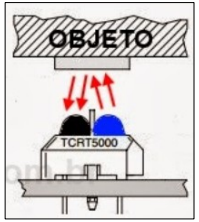


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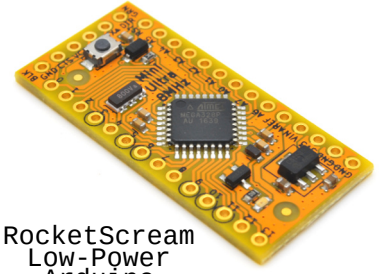

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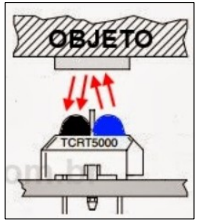


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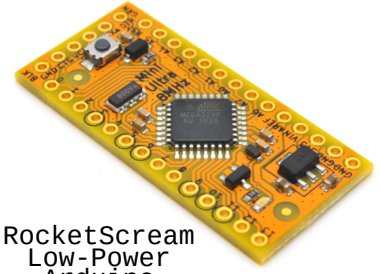

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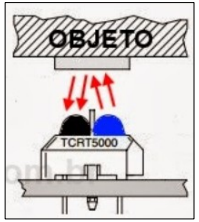


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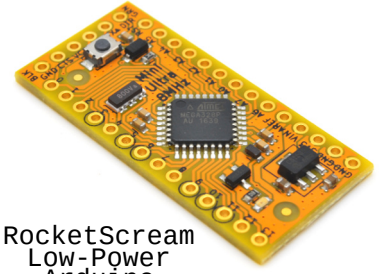

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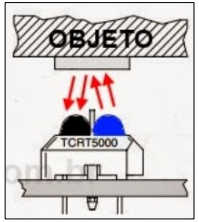


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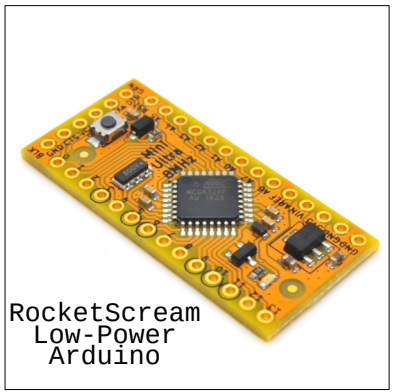
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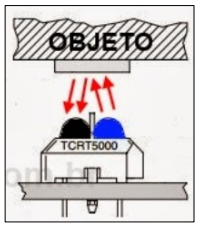

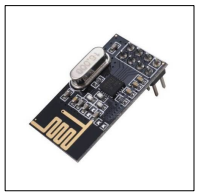

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loop do
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emit PIN(13, _digitalRead(2));
loop do
   var bool v = await Pin(2);
   emit PIN(13, v);
end
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Initial Results

	Arduino	Céu		OBS
		M1	M2	
Empty	3.7	0.002		No activity.
Blink	6.0	3.1		Least efficient mode b/c of TIMER1.
Sensor	11.4	7.7		Most efficient mode b/c of INT2.
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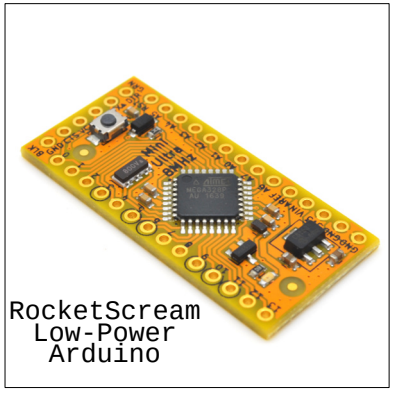
(Consumption in mA)


RocketScream
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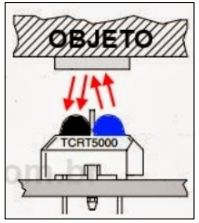

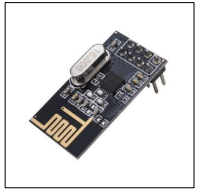

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loop do
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   <...>
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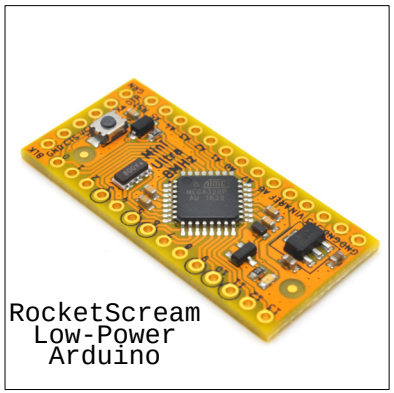
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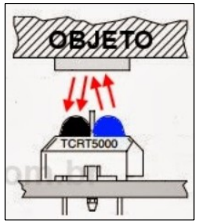

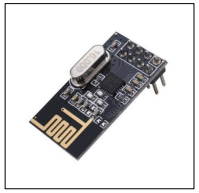

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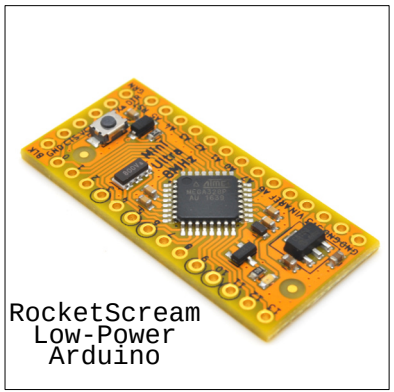
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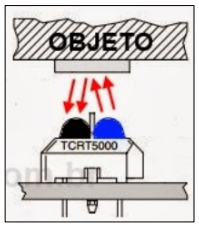

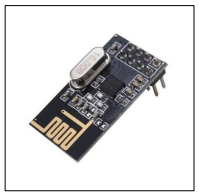

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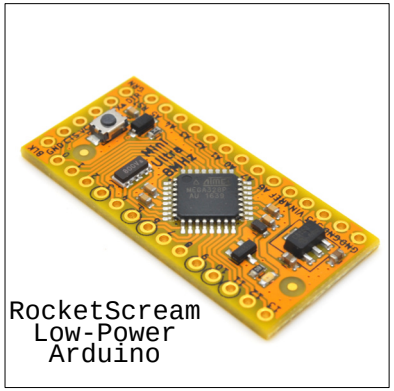

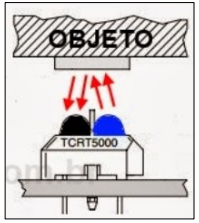

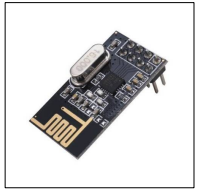

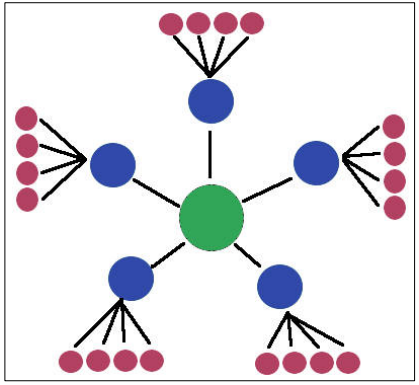

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General Approach

(standby, constrained, programming language, transparent)

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par/or do
  await RadioAvail();
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(standby, constrained, programming language, transparent)

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Transparent Standby for Low-Power, Resource-Constrained Embedded Systems

A Programming Language-Based Approach

www.ceu-lang.org

Francisco Sant'Anna

francisco@ime.uerj.br

@_fsantanna

Standby Efficiency for IoT

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Related Publications

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