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

## *A Programming Language-Based Approach*


www.ceu-lang.org



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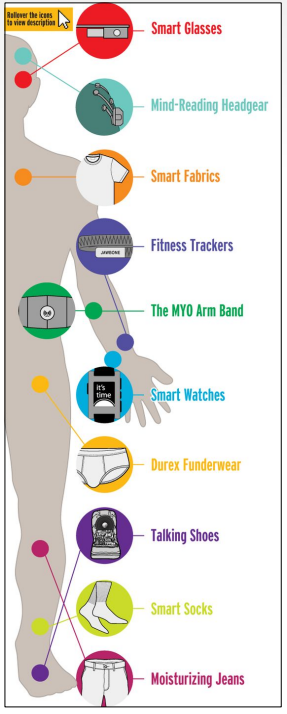

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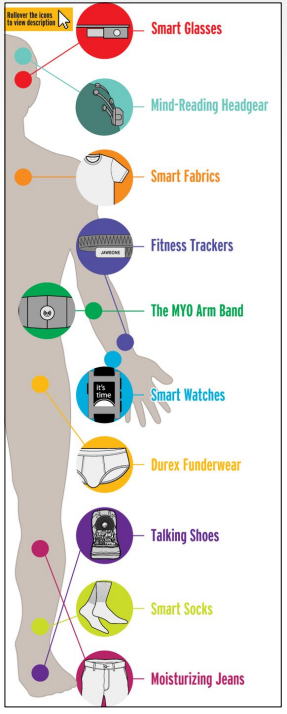


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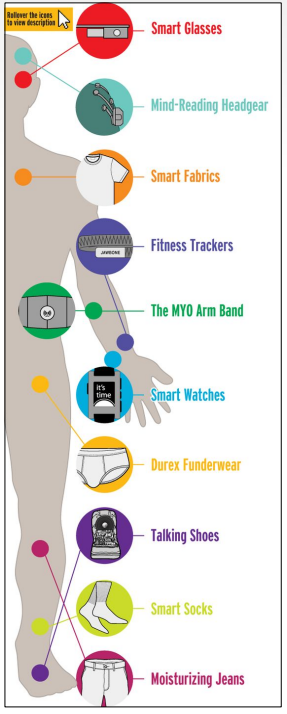



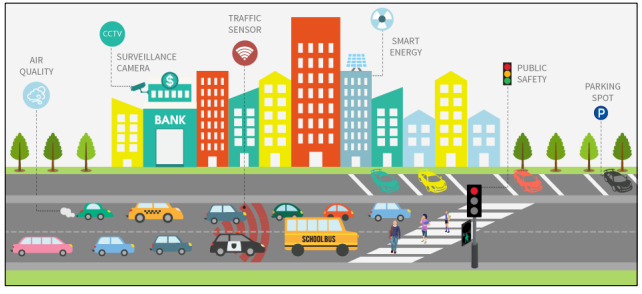

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**30-50% economy with existing technologies**

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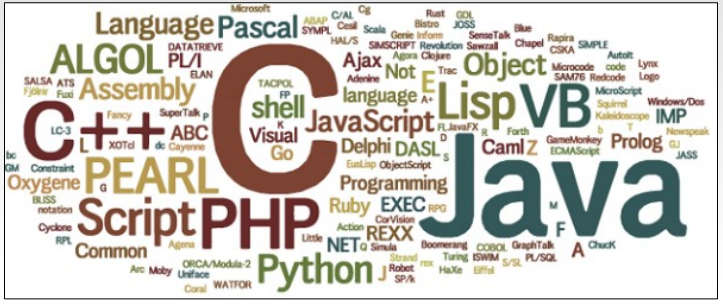

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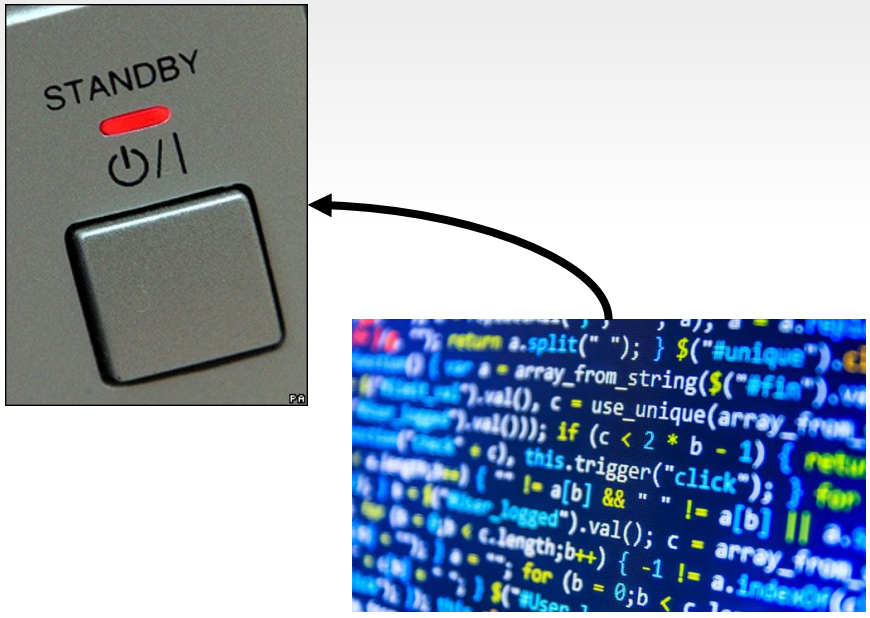


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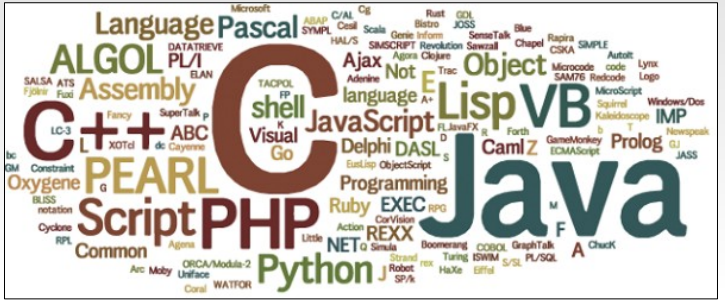


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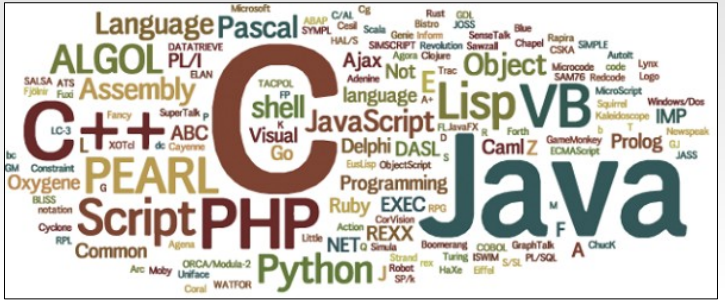


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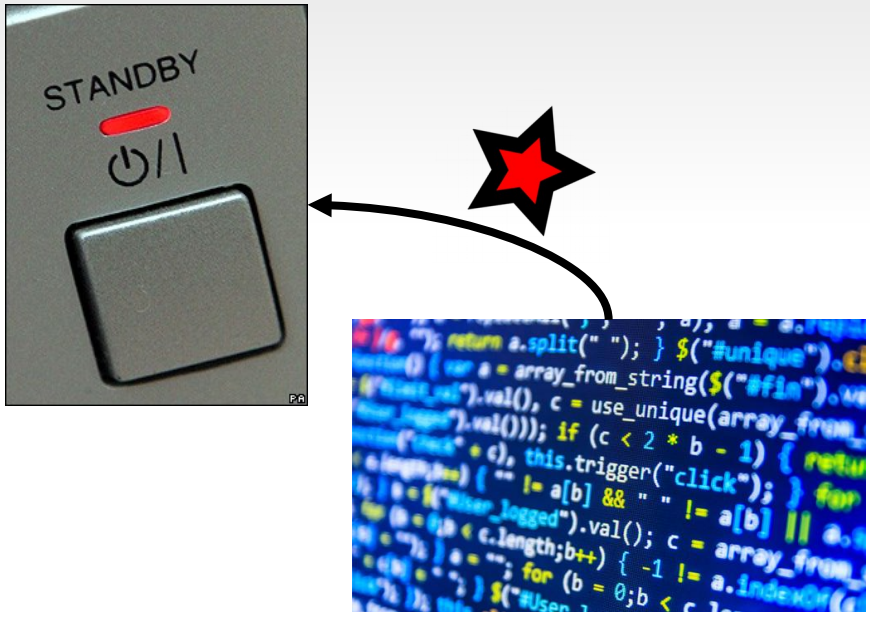


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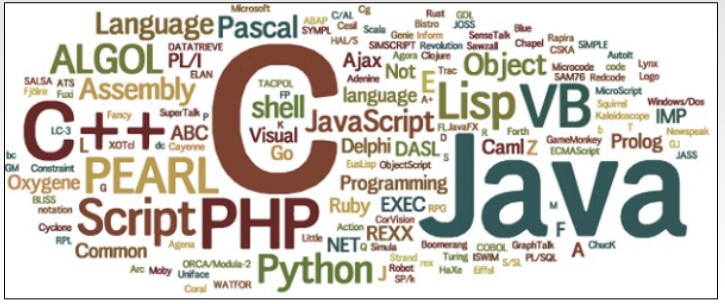


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4. Support **transparent**/non-intrusive standby mechanisms that reduce barriers of adoption.

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

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

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output void ADC_REQUEST do
   ADMUX = 0x40|(A0&0x07);
   bitSet(ADCSRA, ADIE);
   bitSet(ADCSRA, ADSC);
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  emit ADC_REQUEST;
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  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);
  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();
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output void ADC_REQUEST do
   ADMUX = 0x40|(A0&0x07);
   bitSet(ADCSRA, ADIE);
   bitSet(ADCSRA, ADSC);
end
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```
input ADC_vect_num do
  bitClear(ADCSRA, ADIE);
  emit ADC_DONE(ADC);
end
```

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

```
void pm_sleep (void) {
  if (PM_GET(PM_TIMER1)) {
      sleep_1(<...>)
    } else if (PM_GET(PM_ADC)) {
      sleep_2(<...>);
    } else {
      sleep_3(<...>);
    }
  }
}
```

```
output void ADC_REQUEST do
   ADMUX = 0x40|(A0&0x07);
   bitSet(ADCSRA, ADIE);
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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. |
| Radio | 19.5 | 15.8 | 3.0 | Alternates INT2 <-> TIMER1. |
| Protocol | 19.6 | 15.9 | | Consumption dominated by the Radio. |

*(Consumption in mA)*

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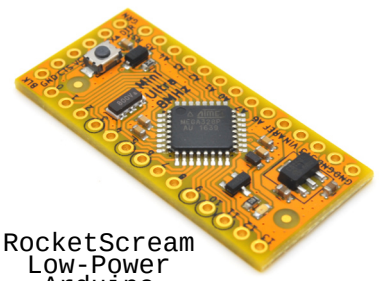

RocketScream
Low-Power
Arduino

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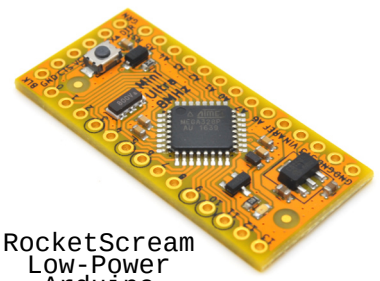

RocketScream
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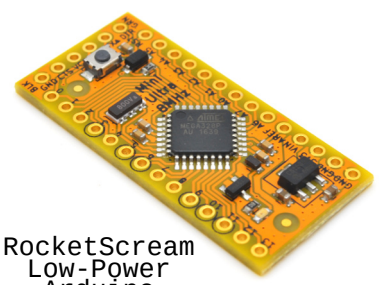

RocketScream
Low-Power
Arduino

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await FOREVER;
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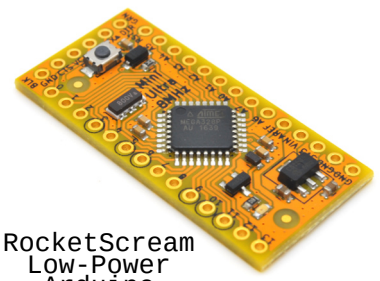

RocketScream
Low-Power
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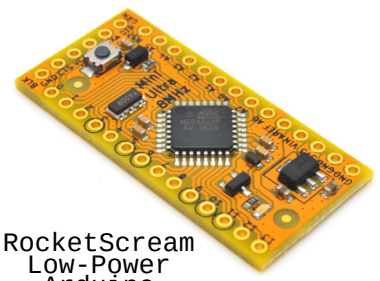

RocketScream
Low-Power
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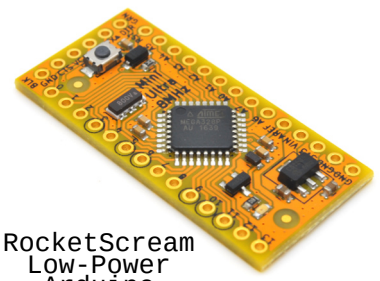

RocketScream
Low-Power
Arduino

```
await FOREVER;
```

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

# Initial Results

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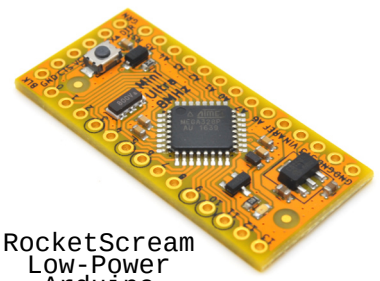


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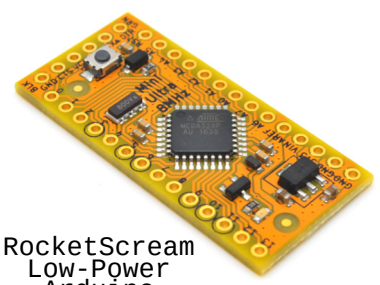

RocketScream
Low-Power
Arduino

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# Initial Results

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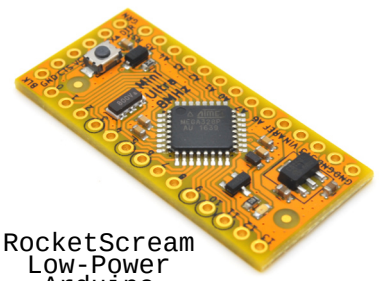

RocketScream
Low-Power
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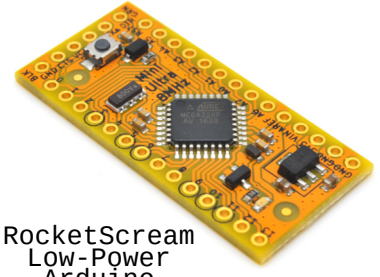
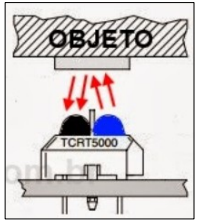


RocketScream
Low-Power
Arduino

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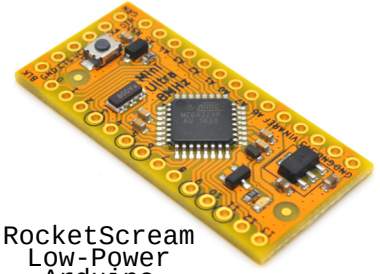

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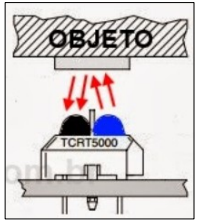


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```
loop do
   emit PIN(13,high);
   await 1s;
   emit PIN(13,low);
   await 1s;
end
```

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

# Initial Results

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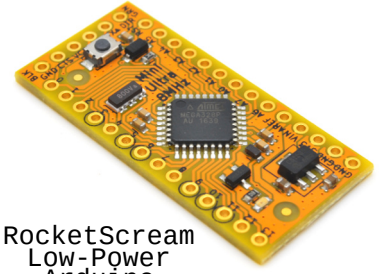

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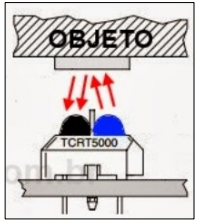


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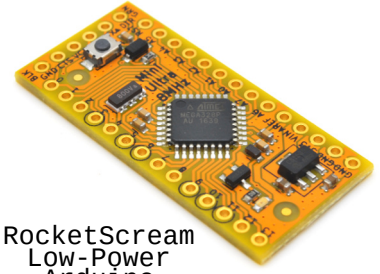

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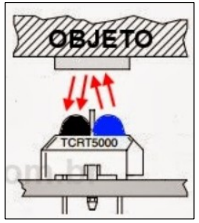


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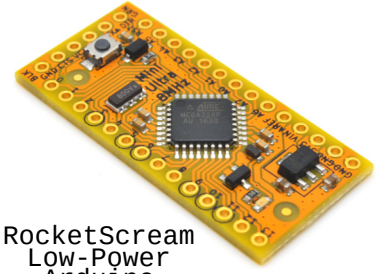

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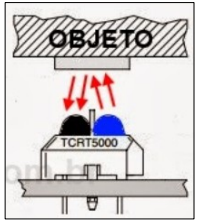


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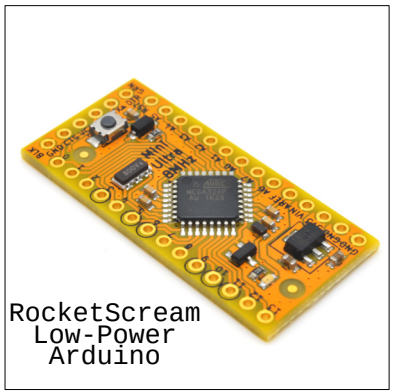


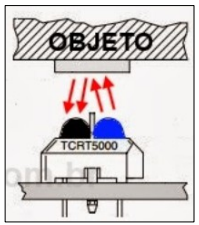


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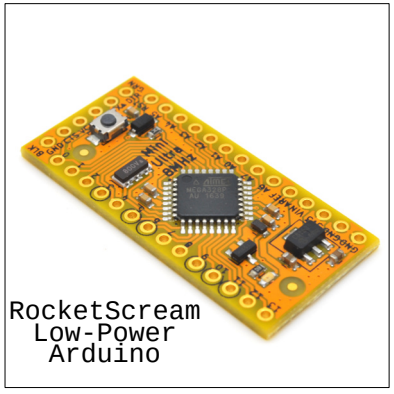


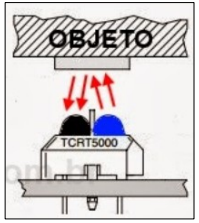


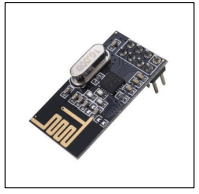

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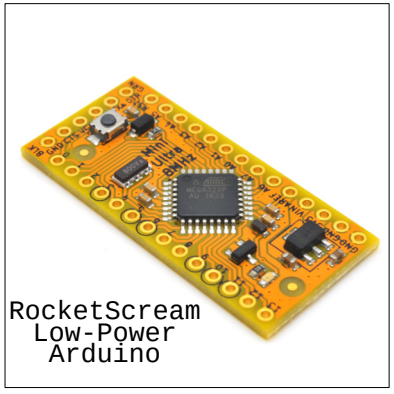


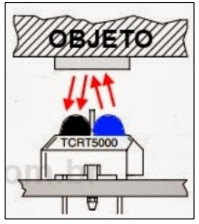


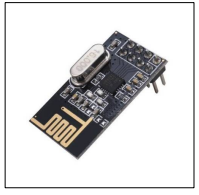

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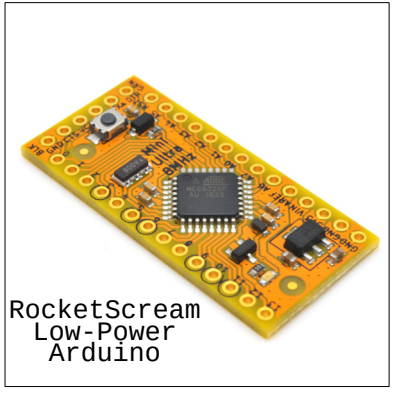


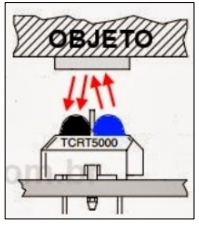


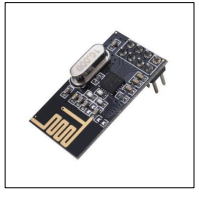

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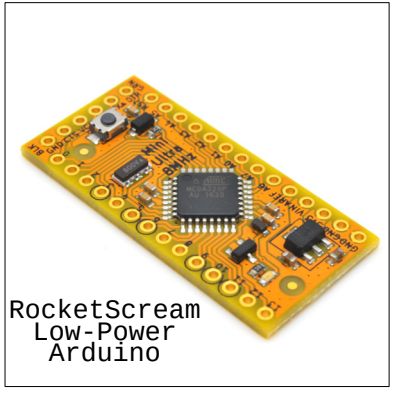


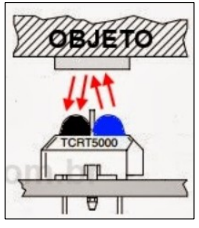


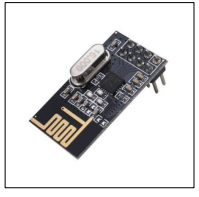

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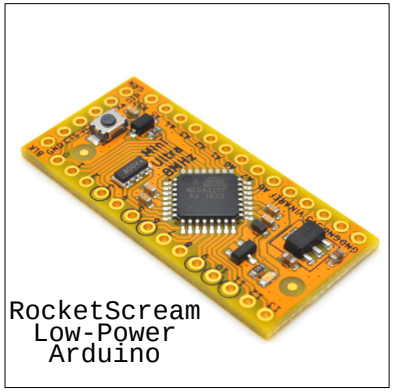


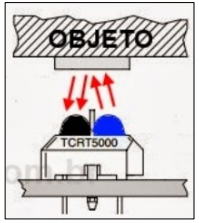


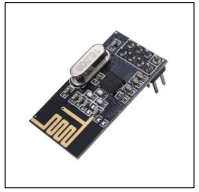

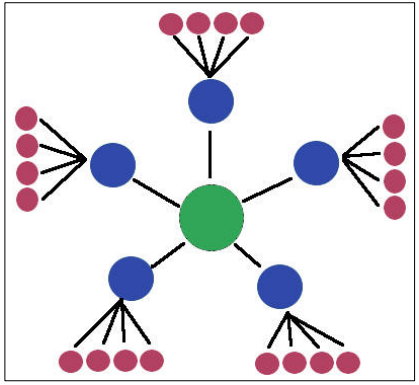

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## (standby, constrained, programming language, transparent)

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par/or do
  await RadioAvail();
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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**

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- Software infrastructure
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