Beaglebone: The Perfect Telemetry Platform?

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What is the Beaglebone?

- Low cost AM335x SoC platform
  - $89 from various source (Mouser, Digikey, Amazon)
- 3.3v I/O can interface with many ICs and sensors out of the box, or with cheap 3.3v to 5v logic converter.
  - I2C
  - SPI
  - GPIO
- 1.8v I/O Analog In (ADC) pins.

Introduction to Capes

- Daughter cards that connect to the expansion headers
- Examples of ones that currently exists and provide addition functionality
  - Audio Cape
  - DVI Cape
  - Camera Cape
  - Weather Cape
- Expansion header allows easy breadboard access

Starting a Beaglebone Telemetry Project

- What to design?
- How to design it?
  - Fritzing – Open Source circuit design
    - More hobbyist + breadboard friendly
  - Eagle PCB – Not free but affordable for hobbyists
    - Larger learning curve + schematic first designing.
- Materials and hardware skills required
  - Soldering Iron + Minimal electrical engineering knowledge
- Software skills
  - Any language for reporting

Practical Applications

- Weather Reporting Station
- Radiation Monitoring
- Earthquake Detection Mesh Network
- Home Security System
- Entropy Pool Generation

What kind of data can we report?

- Barometric
- Temperature
- Radiation Exposure (Counts Per Minute)
- Earthquakes
- GPS + Orientation + Compass Heading
- Ambient Light

How can we share data?

- Cosm (Formerly Pachube)
  - Free for typical usage.
- Allows reporting of almost any sensor possible visa feeds
- Simple JSON or EEML interface
- Handles graphing all datasets and points
  - Allows settings triggers when thresholds are peaked (Twitter or HTTP POST)

Sample Reporting Snippet

```
def read_bmp085_pressure():
    f = open("/sys/bus/i2c/drivers/bmp085/3-0077/pressure0_input")
    return "%.2f" % (int(f.read().strip()) / 100.0)
….
def start_reporting(pac, w1_serial_id):
    while True:
        if w1_serial_id:
            pac.update([eeml.Data("w1-temp", read_w1_temp(w1_serial_id))])
        bmp085_pressure = read_bmp085_pressure()
        pac.update([eeml.Data("bmp085-temp", read_bmp085_temp())])
        pac.update([eeml.Data("bmp085-pressure", bmp085_pressure)])
        pac.update([eeml.Data("sht21-humidity", read_sht21_humidity())])
        pac.update([eeml.Data("sht21-temp", read_sht21_temp())])
        pac.update([eeml.Data("tsl2250-lux", read_tsl2550_lux_value())])
        pac.put()
        sleep(1)

if __name__ == "__main__":
    API_KEY = get_env_value("COSM_KEY")
    …
    API_URL = "/v2/feeds/%s.xml" % feed
    ...
        pac = eeml.Cosm(API_URL, API_KEY, use_https = False)
        start_reporting(pac, w1_serial_id))
```

Sample COSM Data


```
<eeml xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance" xmlns="http://
    www.eeml.org/xsd/0.5.1" xsi:schemaLocation="http://www.eeml.org/xsd/0.5.1 http://
    www.eeml.org/xsd/0.5.1/0.5.1.xsd" version="0.5.1">
  <environment>
     <data id="w1-temp"><current_value>25.00</current_value></data>
     <data id="bmp085-pressure"><current_value>1004.00</current_value></data>
     <data id="sht21-humidity"><current_value>39.74</current_value></data>
     <data id="tsl2250-lux"><current_value>0</current_value></data>
     <data id="sht21-temp"><current_value>26.45</current_value></data>
     <data id="bmp085-temp"><current_value>25.50</current_value></data>
  </environment>
</eeml>
```

Developing Telemetry Platform

- How are you going to place everything?
  - SMD, THT, etc
- Cost of sensors and how important accuracy and precision are.
  - You get what you pay for…
- Sensors interfaces to use
  - I2C, SPI, Analog In, etc, etc.
- Pins to use and what other capes you many want to use.

Cape Software Design

- EEPROM identification
- Little to no user intervention required to configure
- Device tree initialization
  - Capebus patchset handles cape setup and definition
  - Conflict detection
- Sysfs run-time changes whenever possible
- Actual working software before calling the cape project complete.
  - U-boot demo apps don't count…..

Capebus + Device Tree

```
…
&bone_geiger_cape {
        board-name = "Geiger Cape";

        pinctrl-names = "default";
        pinctrl-0 = <&bone_geiger_cape_pins>;

        pwms = <&ehrpwm1 0 500000 0>;
        pwm-names = "bone-geiger-cape";

        pwm-frequency  = <20000>;       /* 20KHz */
        pwm-duty-cycle = <60>;          /* 60% */

        event-blink-delay = <30>;       /* 30ms */

        gpios = <&gpio3 17 0>;
```

… Continued on next page …

Capebus + Device Tree

```
…
	gpio-leds {
		compatible = "gpio-leds";
		pinctrl-names = "default";
		pinctrl-0 = <&bone_geiger_cape_led_pins>;

		geiger-led0 {
			label = "geiger:green:usr0";
			gpios = <&gpio2 23 0>;
			linux,default-trigger = "geiger-run";
			default-state = "off";
		};

		geiger-led1 {
			label = "geiger:red:usr1";
			gpios = <&gpio2 25 0>;
			linux,default-trigger = "geiger-event";
			default-state = "off";
		};
	};
};
```

Capebus (Working Example)

Confirm Capebus picked up device

```
# cd /sys/bus/capebus/devices/bone-0\:3
# cat id
Geiger Cape,00A0,Geiger Inc,
```

(start running)

```
# echo 1 > run
```

(power LED turns on and the event LED lights up on a “click”)

Display counts:

```
# cat counter
4344
```

Display VSENSE (voltage feedback loop) in Millivolts:

```
# cat vsense
538004
```

Geiger Counter Project

- Reason for picking this project
  - Simple + Fun
  - Practical purpose
  - Nature gives a perfect test source since atoms are always decaying.
  - Excuse to test out various consumer and scientific items for radioactivity.

Geiger Counter Continued

- Data points provided are simple "clicks" in time
- All the magic happens in how you report and display the data
- Remote stations need to take in account for power usage
  - CPUFreq 'powersave' governor *e.g. cpufreq-set –g powersave*
  - Adjust sample update rate
  - Offload any data processing upstream off the device.

Subsystems Used

Beaglebone

Device Tree + Capebus

Pin Control

Weather Cape | Geiger Cape

I2C | One Wire | GPIO | PWM

Geiger Counter Reporting Flow

Radiation Event → GPIO Interrupt Event ~1 millisecond pulse → COSM Reporting → COSM Graphing +Alerts

Geiger Cape Pinout

Table 11. Expansion Header P9 Pinout

SIGNAL NAME	PIN	CONN		PIN	SIGNAL NAME
	GND	1	2	GND	
	VDD_3V3EXP	3	4	VDD_3V3EXP	
	VDD_5V	5	6	VDD_5V	
	SYS_5V	7	8	SYS_5V	
PWR_BUT*		9	10	A10	SYS_RESETn
UART4_RXD	T17	11	12	U18	GPIO1_28
UART4_TXD	U17	13	14	U14	EHRPWM1A
GPIO1_16	R13	15	16	T14	EHRPWM1B
I2C1_SCL	A16	17	18	B16	I2C1_SDA
I2C2_SCL	D17	19	20	D18	I2C2_SDA
UART2_TXD	B17	21	22	A17	UART2_RXD
GPIO1_17	V14	23	24	D15	UART1_TXD
GPIO3_21	A14	25	26	D16	UART1_RXD
GPIO3_19	C13	27	28	C12	SPI1_CS0
SPI1_D0	B13	29	30	D12	SPI1_D1
SPI1_SCLK	A13	31	32	VDD_ADC(1.8V)	
AIN4	C8	33	34	GNDA_ADC	
AIN6	A5	35	36	A5	AIN5
AIN2	B7	37	38	A7	AIN3
AIN0	B6	39	40	C7	AIN1
CLKOUT2	D14	41	42	C18	GPIO0_7
	GND	43	44	GND	
	GND	45	46	GND	

- Green – Ground
- Red – Power Supplies
- Blue – PWM
- Purple- I2C
- Black – Analog In

Sensor Selection (Geiger Counter)

- Geiger tubes have various features of quality
  - Dead time
  - Sensitivity
  - Type of radiation it can detect
    - LND-712 was selected since it can detect all three main types of radiation (alpha + gamma + beta). Most expensive tube of it's type.
    - SBT-9 (Soviet-Era tube) was a close second but not as sensitive or available in North America.
- Voltage needed to register counts vary greatly
  - LND-712 – 500 volts
  - SBT-9 (and most Soviet tubes) – 300 to 400 volts.

Geiger Counter Circuit

- Tube is a large capacitor that gets charged up, and when hit by ionizing radiation causes an “overcharge”. Excess charge has to go somewhere and that causes a “click”.
- Logic level and pulse shifter design
    - Extends a short microsecond pulse to ~1 millisecond

Safety (Geiger Counter)

- High voltage is sourced to the tube. Current boost converter can provide about 600V
  - Although almost no current is flowing. It still can be dangerous…
  - Analog-in pin used for feedback loop to measure voltage.
  - Keep HV traces short as possible
- MOSFET can be asserted on at 100% which is very bad.
- To resolve an accident initial state add a I2C GPIO expander to allow toggling of power state to cape. Never trust expansion header pin states..
- Do use a current limiter circuit (INA138 for example) to force system reset or device shutoff.

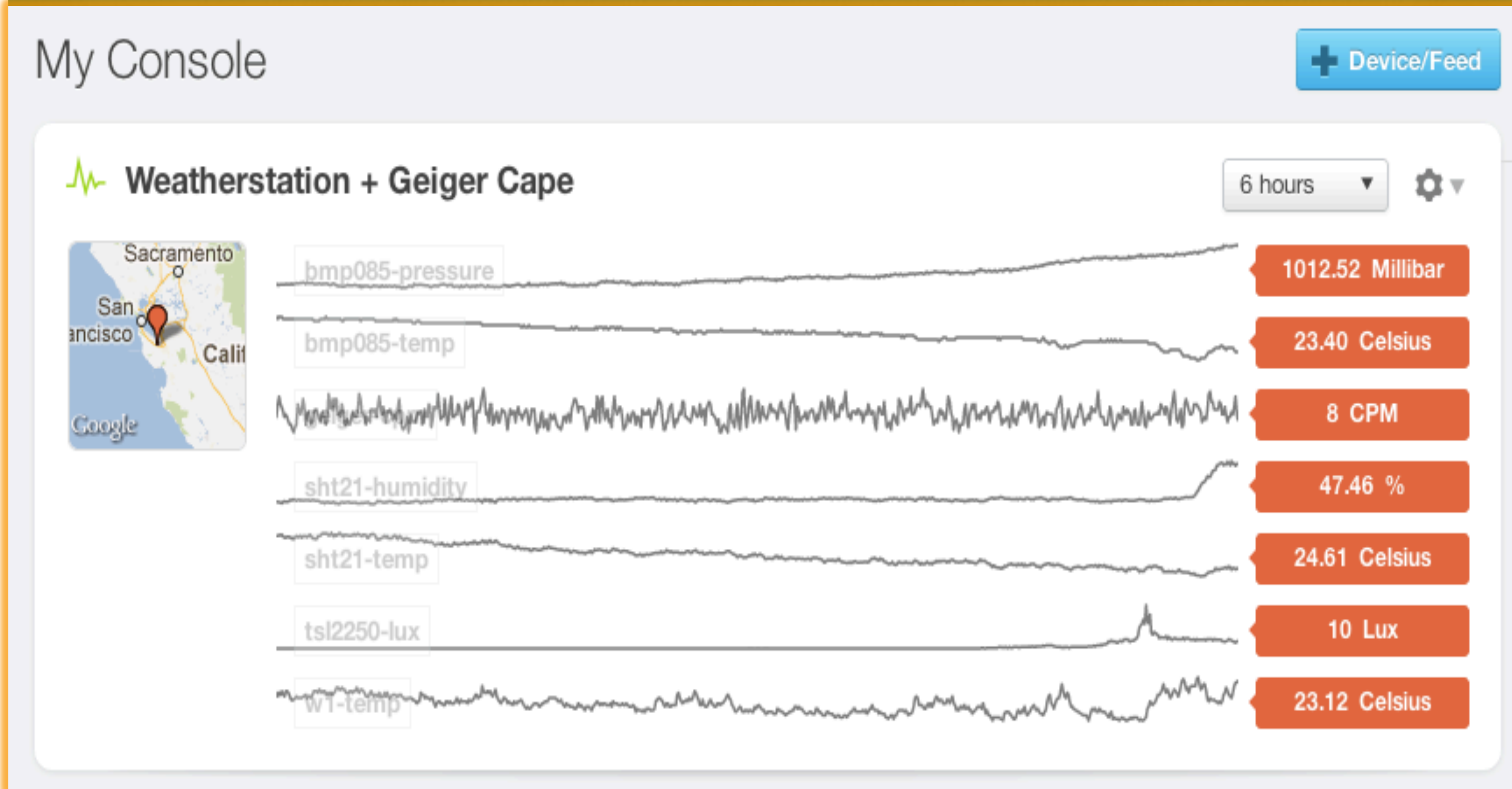
E-ELC Demo Setup (Geiger Counter)

- Geiger Cape (Prototype Rev) + LND-712
- 1.8" Adafruit TFT SPI interface display
- Beaglebone Rev A6

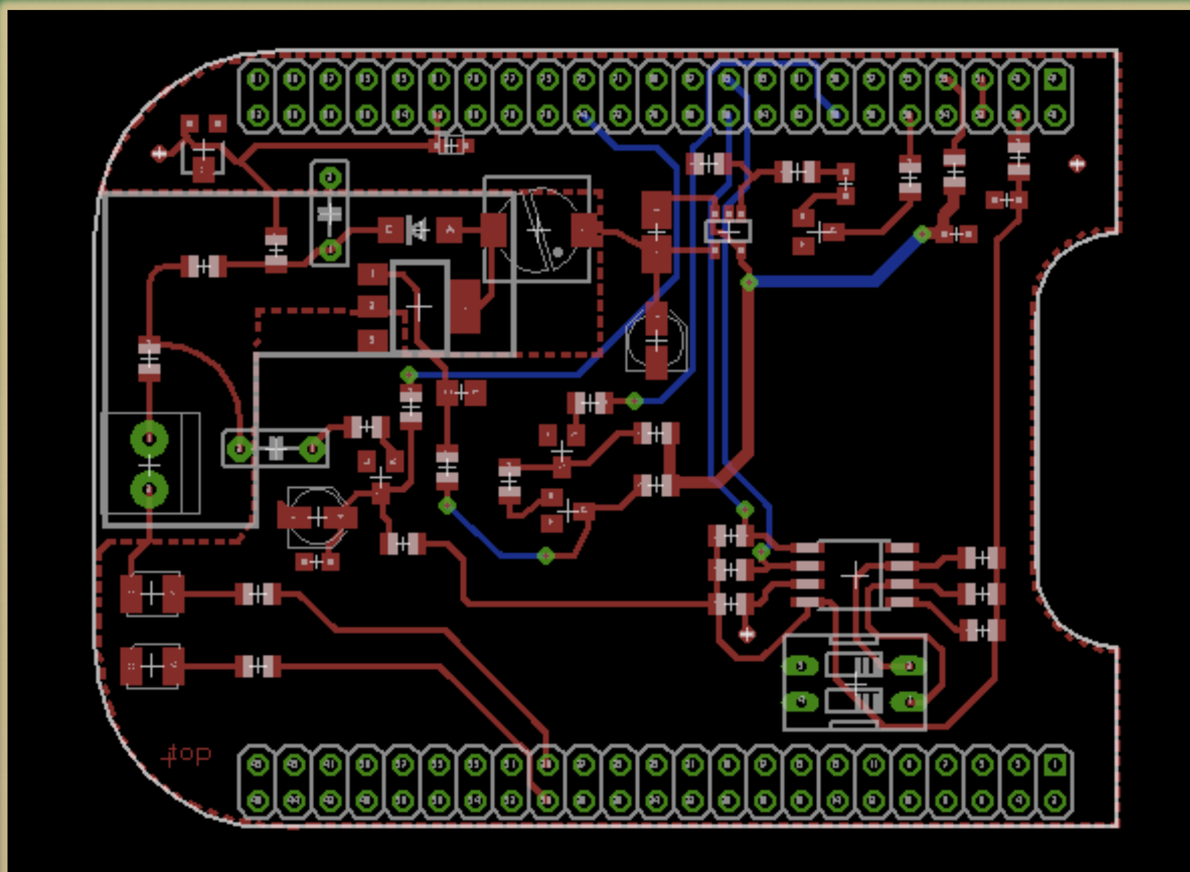
Weather + Radiation Station

- Geiger Cape (Prototype Rev) + SBT-9
- CircuitCo Weather Cape
- Beaglebone Rev A6

Weather + Radiation Station Continued



PCB Design



Lessons Learned

- Know what functionality your device has and use it.
- Avoid bitbanging interfaces that already available.
- Microcontroller Unit != Microprocessor Unit treat it as such.
- Watch initial states
- Example of a bad states would be a PWM pin that is shared with a GPIO that gets asserted on…
- Watch GPIO states on pins…
- Capebus will not save you every-time…

Lessons Learned Continued

- Watch the logic voltage level
- Watch the pin muxing..
- Really easy to conflict with another cape.
  - Device tree holds the hope for the future
  - Possible damage.
- Test on breadboard first
- Analog In (ADC) safety. Absolute 1.8v LIMIT!
  - Invest in some 1.8V Zener diodes, especially if you use sensors that may output higher voltage.
  - For THT applications two standard rectifier diodes will give you a equivalent 1.4V Zener diode
- Show Demo! No magic smoke, no whammy!

Questions?

References

- Beaglebone SRM
  - http:/beagleboard.org/static/beaglebone/latest/Docs/Hardware/BONE_SRM.pdf
- Cadsoft Eagle PCB
  - http://www.cadsoftusa.com
- Adafruit Eagle Library (Beaglebone Cape Part)
  - https://github.com/adafruit/Adafruit-Eagle-Library
- Fritzing
  - http://fritzing.org
- Fritzling Parts (Beaglebone Cape Part)
  - https://github.com/ohporter/fritzing-parts

References Continued

- Cupertino (Indoors) Radiation + Weather
  - https://cosm.com/feeds/73056
- Slides + Demo Source Code
  - https://github.com/mranostay/beaglebone-telemetry-presentation
  - https://github.com/mranostay/cosm-analog
- Thanks to other Geiger Cape team members
  - Dimitris Sapountzakis (Hardware)
  - Pantelis Antoniou (Software + Capebus patchset)
  - Koen Kooi (Design Advice)

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  - https://github.com/koenkooi/linux/tree/3.7-for-panto-rebase
- LND-712 End Window Alpha + Beta + Gamma detector datasheet
  - http://www.lndinc.com/products/pdf/711/
- SBT-9 Soviet-era Alpha + Beta + Gamma tube
  - http://gstube.com/data/3004/ (Russian)