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ELEC 390 - Independent Study
Final: Impact Activated GPS Beacon

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1: Introduction

To demonstrate the concepts that were covered during the studies an impact activated GPS beacon was designed and partially built. The main concepts that were covered during this design proccess were.

- Sensors
- Low Power Embedded Devices
- Constrained Design Principles
- Power Electronics

2.1: Identification of Constraints

As the device was targeted to be a battery powered and portable one, 2 main constraints were identified, the battery life of the device, and the susceptibility of the GPS and SIM modules to electrical noise due to the close proximity of the devices brought on by the compact nature of the design.

2.1.1: Noise Susceptibility

To test the noise susceptibility of the GPS Module a DC power supply was connected in series to a waveform generator to form a noisy power input to the module. The readings from the GPS were taken for 5 minutes at a 5 second interval at various noise levels within the given parameters.

- 0.1 to 16MHz frequency
- 100 to 400mV-RMS magnitude

When the readings were examined it was determined that the GPS module was resilient to electrical noise.

2.2: Battery Limitations

With the modules confirmed as resilient against electrical noise, dominant constraint of the device was identified as the battery life of the device. To work around this constraint the device was split into 3 main power consuming sections for a divide and conquer approach. These sections were

- Processing
- Impact Sensing
- Communications

2.2.1: Processing Consumption

As the tasking of the device was to simply receive, parse and transmit GPS data and therefore required minimal computational power, allowing the use of a subset of micro controller units (MCUs) that were laser focused on minimal power consumption. One such device family was the MSP430 Series from Texas Instruments which featured around 550µA of current consumption.

While devices with much lower power consumption, few of which reaching as low as 25µA, these devices were not choosen as they either lacked the means to communicate, as this device required at least one UART interface and an optional I^2C interface for some impact sensing configurations, with the other modules of the device or were not easy to acquire.

2.2.2: Impact Sensing Consumption

Two setups were considered for detecting impacts on the device with varying abilities and power consumptions.

The first setup to be considered was utilizing a standard micro-electro-mechanical accelerometer such as the BMI-160/270 from Bosch Sensortech this allowed a constant monitoring of the acceleration of the device and furthemore allowed easy configuration of the level of impact accelaration required for the device activation.

However this setup required the MCU and the accelerometer to be powered-on at all times. This setup was assembled and tested with the total current measurement being 1.4 to1.6mA, with MCU consuming ~550µA and the accelerometer ~950µA. While it may appear to be a low amount of power consumption, it becomes a significant one when factoring in the continuous nature of it and the small form factor of the available batteries.

As an alternative method, an integrated logic circuit activated by a piezo sensor was designed, inspired by ShockWatch™ stickers commonly found on fragile cargo. Where a strong enough impact would activate a Set-Reset Latch constructed with logic gates which would drive the MCU.

Compared to the accelerometer design this method does not allow continous sensing and only a threshold activations, furthermore, the programming of the threshold is also more difficult as it involves calculating a resistor value using the piezo sensors datasheet and soldering a 0402 Surface Mounted Resistor on the main board.

However, by trading these disadvantages this method achieves a consumption of 100-120μA when assemled and measured, furthermore this consumption can be lowered further to a calculated value of ~20μA by utilising transistors for logic instead of ICs with the added benefit of having a smaller footprint.

2.2.2: Communication Consumption

As communication modules are high power draw devices with little ability in terms of lowering it, the main objective was not to lower consumption but to utilize the on-time of those devices to the fullest. To achieve this a Motherboard-Daughterboard approach was choosen to achieve 3 design points.

First design point was to enable compatibility mainly on the SIM communication module as countries have differing regulations for such devices, region specific boards might need to be used for the beacon, allowing breakout boards with terminals on the main board achieves compatibility with any communication board as long as it has an UART interface and within power limits.

Second design point focuses on the power delivery for the boards, by placing a mosfet inline with the power connection to the communication modules it allows MSP430 to toggle these devices as needed to preserve power and prevent interference between SIM and GPS modules as these devices did not need to work simultaneously.

The final and key point for the splitting boards comes down to signal integrity for these communication devices. As SIM and GPS modules work with highly attenuated signals, ~90dB for GPS and ~75dB attenuation for SIM, extending the antenna connection for these devices are often ill advised. The UART connection on the other hand is much more resilient to travelling longer distances with cables and a breakout design allows the communication modules to be moved to accompany different form factor for the device.

2.2.2: Power Electronics

With battery powered devices one of the main hurdles is the decreasing voltage of the battery throught its usage. Two different conditions that occur during the usage of the battery are. The condition where the voltage of the battery exceeds the voltage limit of the device to the point where damage is probable. And the condition where the battery still contains energy that can be used, but can't be utilized as the voltage is below the operating limit of the device.

To overcome this hurdle a Boost converter was designed. When designing a power circuit the main considerations are the input and output ranges of the device. For the beacon an input range of 2 to 8 volts were choosen this not only allows AAA or AA form factor over the counter batteries to be used but also prevents the batteries from discharging bellow 1.7 volts where cells get damaged. For the output a target of 5 volts and 250mA were choosen to support the mainboard and the variety of communication boards that can be connected. With these guidelines the LT1302 Boost Controller was choosen and designed according to the datasheet of the device.

Although this design was not assembled, SPICE assessments were done to verify the design, results of which is included in this report package.

2.3: Important Notice

On 12/01/2023 during the assembly of the final device a short circuit has damaged the MSP430 and GPS modules preventing assembly at the time of writing this report.