CS25710 - Travel Trouble

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1 Hardware

1.1 Components

1.1.1 Microcontroller

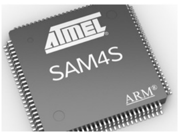


Figure 1: Atmel SAM4SD32B

I began by looking at boards specifically designed for prototyping mobile and embedded devices, such as the Arduino. These devices are typically very well supported, often with a strong community of enthusiastic and knowledgeable users. I decided against actually using an Arduino or similar, however, as they are typically slightly bulkier and more power-hungry than simpler, more bespoke alternatives.

In the end, I have specified an Atmel SAM4SD32B. This microcontroller can run at a lower voltage (1.62 - 3.6v) and is small enough to be attached to the inside of even the smallest suitcase without too much hinderance to the case's primary function of storing one's luggage!

The SAM4SD32B is equipped with 47 general I/O pins, an A/D converter, a Synchronous Serial Controller and USB and SD connections. The microcontroller is also capable of running in a number of low-power modes which will be a necessity in keeping the device's power consumption to a minimum during its operational life.

1.1.2 Accelerometer/Gyro

I have selected a combined Accelerometer-Gyro, the MPU-6050. This is a 3-axis Accelerometer and Gyro built into a single board. The device is capable of measuring movement within a range of programmatically selected ranges which may allow the client to record a range of movement events during the device's deployment.

I intend to make use of the accelerometer's available interrupt routines to wake-up the microcontroller when movement is occurring. I am intending to collect data approximately every 0.5 seconds during 'gentle' movement (such as might occur when walking around with the case). I intend to capture data far more rapidly during 'shock' events, I believe capturing around 1000 times per second (for half a second or so) should be adequate.

Figure 2: InvenSense MPU-6050

I did consider using a separate accelerometer and gyro but these typically will not only take more physical space and power but also, many of the 3-axis gyros I found were actually more expensive on their own than the combined IMU specified above.

1.1.3 GPS

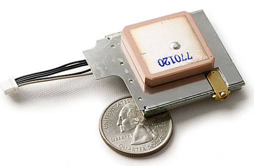


Figure 3: GlobalSat EM-408

When selecting a GPS, I tried to find one with a good signal strength (it will likely be subject to a few layers of various materials which may hamper its ability to communicate with the necessary satellites. I also tried to find devices with an on-board antenna as this will reduce the overall form factor.

In the end, I have specified the EM-408. This is capable of 10m accuracy (which I anticipate will be more than enough for this application), and a high degree of sensitivity (-159dBm). The EM-408 is capable of outputting data in a number of well supported formats and more consultation would be required with the client to ascertain exactly what data they require for their analysis.

1.1.4 Temperature

I have specified the use of a TMP36 temperature sensor. This is a very small, low-powered component which can measure temperature accurate to within 1 or 2 degrees (accuracy is reduced at higher temperatures).

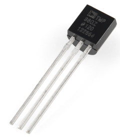


Figure 4: Analog Devices TMP36

1.1.5 Cells

I have calculated that the device will draw around 130mA when capturing data and around 0.2mA in standby mode. I am assuming the device will be in capture mode for approx 5% of its operation. This works out at 2247.84mAh during the device's two-week operation.

Figure 5: OSN Power Tech A123

I have decided to specify a Lithium Ion battery. This has a very low rate of self discharge and should provide a reasonable stable power supply during operation. These cells also have the added benefit of being rechargeable and should last for around 2000 uses if cared for properly.

I have decided to specify the use of 1 A123 (ANR26650M1B) cell. This cell will output 3.3v at up to 150A (capacity 2500mAh. Unfortunately, I have only been able to locate 1 supplier for this exact model of cell which requires a minimum order of 50 pieces. I would be keen to discuss alternative power configurations with the client, but I believe this cell to be the most ideal for the task at hand.

1.1.6 Extra components

I would like to add a single LED indicator which will be switched on when the device is capturing data (i.e. when it's moving). This will enable the user to quickly ascertain whether the device is working or not by simply moving the device (thus triggering the accelerometer) and seeing whether the LED lights up or not.

1.2 Major alternatives

Aside from using an Arduino as the base for the project (outlined above), another option would be to use a smartphone with an open, extensible software platform included (for example, and Android phone). These devices typically have many of the sensory devices required to achieve the necessary functionality (with the omission, perhaps, of temperature sensing). I believe this would significantly reduce the overall cost and development time.

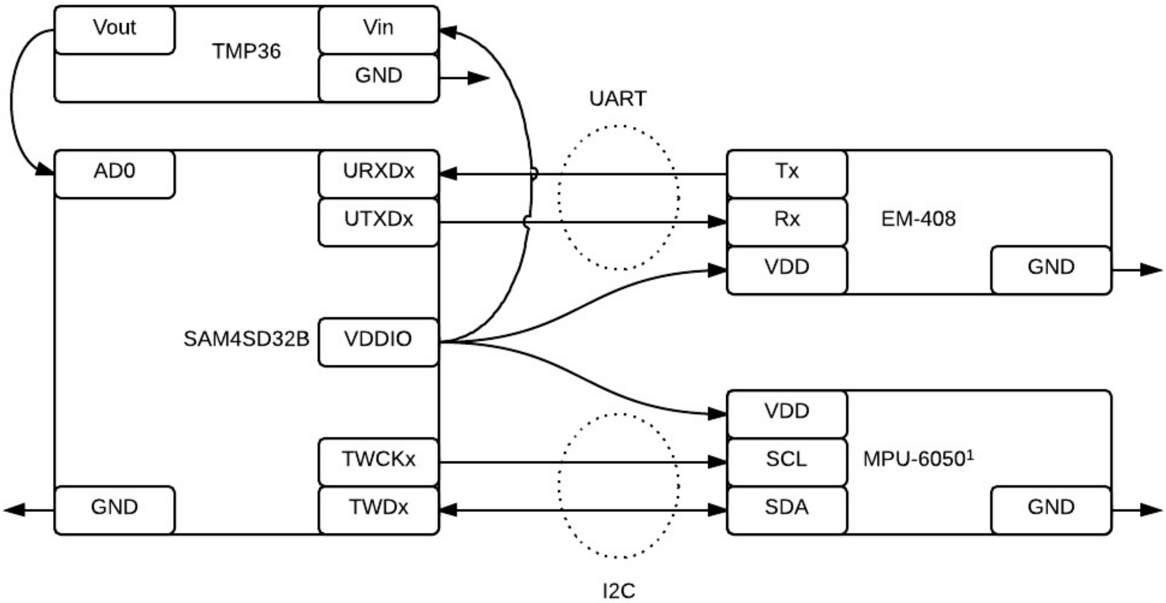
I believe the main drawback of this approach is that the device would not be as flexible in terms of component selection (it would be a much larger operation to, for example, install a different GPS sensor) and the components it contains may not be able to sense accurately or fast enough to capture the level of data required to be useful to the client.

1.3 Data storage

I intend to make use of an SD card to hold the data captured by the device. These are very compact and reasonably priced storage media and will allow the client to simply transfer the card into their own machine to interpret and analyse the data. In addition to this, the microcontroller has 2MB of flash memory built-in which I intend to use as a write cache before the data gets sent to the SD card. This should avoid a bottle-neck of data trying to be written to disk during shock events.

In addition to the accelerometer and gyro information being captured (outlined above), I intend to capture GPS and temperature data around once every 5mins while the device is moving.

1.4 Connection diagram



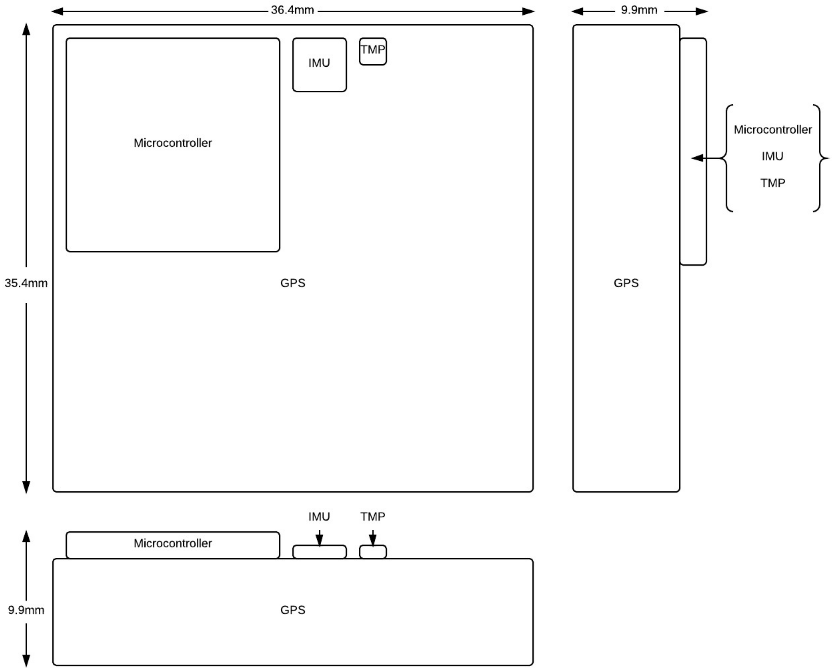
1.5 Power consumption

Device	Active state	Idle state
SAM4SD32B	80mA	32μA
MPU-6050	4.1mA	115μA
EM-408	44mA	N/A
TMP36	50μA	0.5μA
Total	128.15mA	147.5μA

All devices will run at 3.3v. It may be necessary to regulate the voltage from the cells as the actual output voltage is likely to change throughout their discharge cycle but for the sake of brevity, this has not been included in this design; it should be trivial to add one at a later date as needed.

[1] I believe the MPU-6050 will also require the VLOGIC and INT pins to be connected to the microcontroller to enable the microcontroller to wake from sleep mode when movement commences. I have not been able to ascertain from the datasheets available where these connections should be made, however. I believe that the connections are available on the microcontroller though and someone with more experience than myself should not have a problem locating the correct connections.

1.6 Dimensions



The diagram above shows one possible configuration of the devices (albeit without the cell). This configuration maintains the smallest dimensions for the device overall. I would recommend mounting the entire unit inside of a plastic case with battery holder (these are easily available and relatively cheap).

1.6.1 Weight

Device	**Weight**
SAM4SD32B	0.8g
MPU-6050	<0.01g
EM-408	20g
TMP36	5.7g
A123	72.5g
Total	99g

1.7 Bill of materials

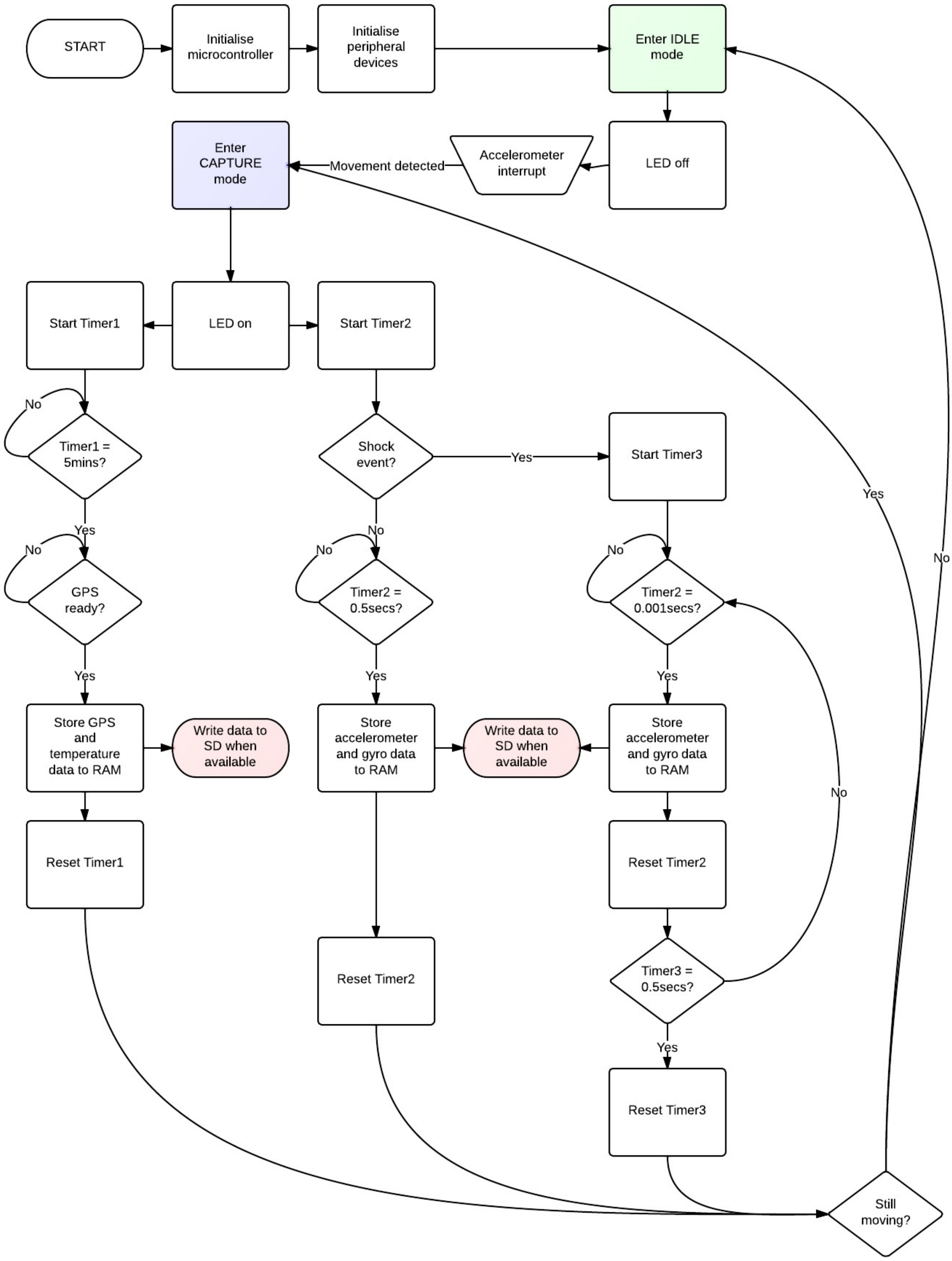
Device	**Single unit**	**100 units**
SAM4SD32B[2]	£96.53	£96.53
MPU-6050	£13.09	£10.47
EM-408	£42.63	£34.10
TMP36	£0.98	£0.79
A123[3]	N/A	Unknown
Total	£153.23	£141.79

[2]This price is based on the SAM4S-EK2 'Evaluation Kit' which contains many extra components used in development of which only 1 or 2 should ever need to be purchased. Your mileage may vary.

[3]I was completely unable to locate an actual price for the cells online so this has not been included in the calculation.

2 Software

2.1 Block diagram



2.2 Detailed description

The software breaks down into 4 main sections:

2.2.1 Initialisation/Idle

When the device first receives power, it will initialise all the devices, including the accelerometer interrupt, and put them into low-power mode. I anticipate the device will spend the majority of the time in this state, awaiting sensory input.

2.2.2 Capture state

When movement is detected by the IMU, the device will enter a capture mode which will capture accelerometer/gyro data every 0.5 seconds. This also starts the GPS routine outlined below. If the force recorded by the accelerometer is great enough, however, the system will switch to Shock state.

2.2.3 Shock state

This state is triggered by excessive, sudden movement being recorded by the accelerometer. This state will start by setting a timer to control the total time spent in this state (0.5 seconds) and will capture data at a higher rate (every 0.001 seconds) until the 0.5 seconds have elapsed.

2.2.4 GPS

In addition to the Capture state outlined above, the device will start another timer when movement is detected. This timer will time a 5minute interval after which GPS and temperature data will be captured.

2.2.5 Other considerations

Attention should be paid to the situations where the device actually writes data to the SD card (marked on the diagram in red). As stated previously, the intention is to use the memory on-board the microcontroller as a write cache and the intention here is to (hopefully) start some subroutine which may handle the writing of the data to the SD card in parallel to the remainder of the operations the device is undertaking to perform during capture states.

It should be noted also that I feel the exact details of how the software moves from capturing data back into an idle state may prove to not be the most efficient use of the low-power modes available; that is, currently, when the device is in Capture mode (recording data every 0.5 seconds), there is no provision for moving into the Idle state if the case is still moving.

2.3 Development plan

The microcontroller's manufacturers (Atmel) provide an IDE specifically for working with this range of devices which I would recommend using. This will, obviously, require a PC capable of running the software in addition to a USB connection to transfer the program onto the board.

I would recommend concentrating on successfully gathering data from the IMU (including registering the interrupts required) as without this, the device will not get past the Idle state. I would then work incrementally, using the diagram above as a template (working from top to bottom and right to left) to implement the remaining functionality; thus ending by writing the sections of the program which will capture GPS and temperature data.

I believe it would be advantageous to make use of 3rd-party code for communicating with the I^{2}C interface on the MPU-6050 and accessing its more advanced and less well-documented features. I have found a potentially lucrative collection of research and code concerning the I^{2}C interface with relation to the MPU-6050 available at *http://www.i2cdevlib.com/devices/mpu6050*

2.4 Usage procedure

The procedure for using the device is simple. The user simply installs a fully-charged battery cell, and checks that the device appears to be operational by triggering the accelerometer and ensuring the LED lights up. Then the device can be installed in the suitcase and left unattended for the duration of the trip.

When the user is ready to pull the data from the device, they simply remove the battery to turn it off. Then they can remove the SD card and use that in any compatible machine to read and analyse the data.

3 References

- Microcontroller - Atmel SAM4SD32B
  http://www.atmel.com/devices/SAM4SD32B.aspx
- IMU - InvenSense MPU-6050
  https://www.sparkfun.com/products/11028
- GPS - GlobalSat EM-408
  https://www.sparkfun.com/products/8234
- Temperature - Analog Devices TMP36
  https://www.sparkfun.com/products/10988
- Cell - OSN Power Tech A123
  http://www.alibaba.com/product-gs/742803918/LiFePO4_battery_A123_26650_with_2500mAh.html