Project – Data Logger

Introduction. Specifications. Logbook. Requirements for design approval. Testing. Presentation and oral exam. Topics for discussion. Tips.

Introduction

Your firm is currently developing a microcontroller-based general-purpose data logger. You have been given the task of designing an embedded system to sense the signal from an analog sensor, e.g. a photoresistor, temperature sensor, pressure sensor, etc. The sensor should be connected to the system in as simple a manner as possible – sensors with digital outputs or that require only ratiometric analog-to-digital conversion are acceptable. The embedded system should record the readings in a suitable non-volatile memory for later download to a PC via a USB interface. The unit is battery powered, and battery life is of prime concern.

The data logger is designed to take periodic measurements of an analog quantity, at a maximum rate of 1 per second, to an accuracy of 8-bits. The minimum capacity of the non-volatile memory will be 8 Mbits.

The embedded system is to meet the following thermal, electrical, EMC and mechanical specifications. It is envisaged that the embedded system will be installed in a fairly harsh environment (electrically and chemically).

Preliminary designs should be finalised with your project supervisor during the Week 5 schematic review session.

It is your responsibility to manufacture a printed circuit assembly (PCA) based on your design, i.e. a complete printed circuit board (PCB) with all components mounted.

One prototype unit, together with supporting documentation, is to be supplied for evaluation by the date specified in the timetable. Late submission will incur penalties.

Specifications

Electrical

Each unit will meet the following **electrical** specifications:

(i) DC power is to originate from a battery for remote operation and from the USB interface (with or without a battery) when connected to a PC.

(ii) DC voltages are to be within 3% of nominal value with peak-to-peak ripple less than 2% of nominal value.

(iii) A USB 1.1 full speed (12 Mbit/s) low-power compatible interface is to be provided for connection to a PC (so that data can be downloaded).

(iv) The average power consumption when on battery power is to be less than 75 mW, measured over a one minute interval. Power from the USB must conform to the USB specification for a low-power device.

(v) Clock generator to use a discrete crystal and be accurate to ±150 ppm over the operating temperature range and lifetime of the product.

(vi) PCBs are to use SMT where possible. For manufacturing ease, the **minimum** track width is to be 8 mil, **minimum** track spacing is to be 8 mil, and all vias are to have a 20 mil hole with a 32 mil pad. A 2 mm border is to be kept free of copper around the edge of the board. Use the **Mechanical 1** layer to specify the outline of the board to facilitate panelization.

Thermal

Each unit will meet the following **thermal** specifications:

(vii) Operating ambient temperature -5°C to + 50°C .

(viii) Electronic components are to adhere to the reliability temperature limits as listed in **Table 1**.

Table 1 - Operating Limits for Good Reliability

Type of Component	**Maximum Temperature**
Field effect transistor	125°C junction
Diodes, except LED	125°C junction
LED	110°C junction
Linear semiconductor	105°C junction
Digital semiconductor	110°C junction
Hybrid semiconductor	110°C junction
VLSI, FPGA, μP, μC	125°C junction
Memory	125°C junction
Capacitor	Max. ambient rating + 10°C
Resistor - composition	Max. ambient rating + 30°C
Resistor - film	Max. ambient rating + 40°C
Resistor – wirewound, accurate	Max. ambient rating + 10°C
Resistor – wirewound, power	Max. rating or 125°C case
Potentiometer	Max. ambient rating + 35°C
Inductor	Hot spot rating + 15°C

Electromagnetic Compatibility (EMC)

Each unit will meet the following **EMC** specifications:

(ix) Where applicable, each unit will meet the conducted and radiated RFI of AS/NZS CISPR 14.1:2013.

(x) Each unit shall follow “good practice” in its layout to minimise EMI internally and externally.

(xi) Each unit must be shielded from power frequency (50 Hz or 60 Hz) magnetic fields.

Mechanical

Each unit will meet the following **mechanical** specifications:

(xii) All components to be housed in a metal enclosure of **maximum** dimensions 65 mm x 100 mm x 45 mm.

(xiii) All electrical leads entering or leaving a metal enclosure will be securely anchored to the enclosure.

(xiv) All signal leads will pass through the outer walls of the enclosure through appropriate electrical connectors or cable glands.

(xv) All exposed surfaces of a metal enclosure will be protected from corrosion.

Note:

A comprehensive CAD package for mechanical design is Autodesk’s Inventor:

http://www.autodesk.com/education/free-software/inventor-professional

Autodesk provide free education licences valid for 3 years.

Environmental

Each unit will meet the following **environmental** specifications:

(xvi) The product lifetime is to be 10 years.

(xvii) Each unit will meet the collection, storage, transport and treatment of end-of-life electrical and electronic equipment requirements as outlined in AS/NZS 5377:2013.

Logbook

Good engineering is likely to come from good professional habits. In the context of a company, a task that is not documented did not happen. A task that is not well documented did not happen well.

As a member of a firm, you are obliged (as a matter of basic professional practice) to maintain a comprehensive log of work that is easily comprehensible by replacement staff (should you be transferred to another task) and by following staff (should the project be successful). It is recommended that you adhere to the following guidelines.

- The “logbook” is to be in electronic format, such as *Microsoft OneNote,* that can be easily organised into sections and pages. It will detail project design, measurements and testing during the life of the project, together with other details, such as relevant theory and circuit analysis, design time estimates and costing.
- You should create relevant sections based on the different subsystems (e.g. microcontroller, power supply, non-volatile memory), and within each section you should record your work chronologically.
- Calculations carried out on loose sheets of paper will be penalised. **The log book should contain all of your jottings, calculations, circuits etc. as they occur.**
- The logbook should be “cloud-based”, so that you can access it anywhere and make it available for discussion at any time.
- You should keep the logbook **up-to-date**, with all material pertinent to the design work included. Relevant pages from device datasheets should be included for easy reference.
- The logbook should be intelligible to others that follow you, as noted above. Therefore, a logical framework, clarity and neatness are required. Experiments and tests that failed must be part of the document, to avoid others following the same false trails.
- The progress of the project should be clear to any assessor with an examination of the logbook. To that end the logbook should be written in clear English language, with entries in sufficient detail to enable easy understanding. **Reasons for decisions concerning the design or modifications to any aspect of the design must be clearly explained.**

Format

- Relevant headings and subheadings used for different sections.
- All entries dated, entries easy to read.
- All design material (e.g. datasheet extracts) placed into logbook.

Content

In each of the following sections relevant material should be recorded. The **REASONS** for your choices/decisions associated with the design should be **FULLY EXPLAINED**. Discuss any problems along with suggested solutions.

Section 1

- Your own objectives for this subject.
- A table containing a detailed list of activities to be completed, an estimation of time in hours required and the actual time spent on each.
- Relevant background theory for the design including a consideration of other possible solutions.
- The design approach and all relevant calculations to meet **each** of the electrical specifications.
- A block diagram of the overall system.
- A full schematic of your design that includes any custom components, has proper component labelling, uses appropriate connectivity methods (net labels, ports, etc.) and incorporates a parameter table that includes full component details (e.g. part number, rating, type, manufacturer, supplier). A bill of materials should also be produced, that incorporates the full component details.
- How you chose appropriate components, with relevant datasheets. Include an analysis of **ALL** the relevant characteristics of the various passive and active components e.g. supply voltage and external interfaces of a microcontroller, tolerance and type of dielectric for a capacitor, ratings of diodes, etc. Calculations should be performed to support the analysis. Vague generalisations such as “the tolerance should be as small as possible” are **not** acceptable.

"The most reliable components are the ones you leave out."
- Gordon Bell, father of the minicomputer at DEC

Section 2

- The design approach to meet the EMC specifications, e.g. inputs and outputs meet conducted EMC requirements, strategies to minimise common impedance, capacitive and inductive coupling, proper power supply distribution and decoupling.

- The design considerations for the layout of the PCB including size, track widths, component placement etc. as well as a printout of each layer of the PCB.

- A spatial visualisation including a front panel layout and an isometric view with covers removed showing major component locations. A consideration of connectors and / or cable entry. Show all dimensions in mm.

- Costing of the entire project from design through to manufacture. Cost of testing / calibration (if any). Make assumptions about labour costs, overheads, etc., or use your experience.

- The methods and results of **ALL** tests carried out on the prototype, including hardware fix-ups and testing / debugging software.

- A summary of specifications as achieved in the final design.

As marks for the logbook will be based on the above items make sure that you submit each item.

Requirements for the Schematic Review

You must have an **up-to-date** logbook for the schematic review session.

Your logbook should contain the following:

1. Your **own** objectives for this subject. Don't just copy those from the subject guide!

2. A table containing a **detailed** list of activities to be completed during the semester and an estimation of time (hours) required for each as well as actual time spent on each to date.

3. An overview of relevant background theory (e.g. sensor operation, power supplies, non-volatile memory, serial digital interfaces).

4. Design approach to meet each of the electrical specifications of the circuit e.g. power supply, USB interface, clock design, etc.

5. A block diagram of your design, with as much detail as possible, e.g. choice of microcontroller, sensor interface circuit, etc.

6. A consideration of other possible designs and the **reasons for choosing your particular design**.

7. A preliminary schematic.

Requirements for the PCB Review

You must have an **up-to-date** logbook for the PCB review session.

Your logbook should contain the following:

1. Complete schematics of the design, including manufacturer part numbers and datasheets, with mechanical footprint details.

2. A bill of materials.

3. Design strategy to conform to good EMC practice.

Your PCB design will be reviewed in Altium during the session.

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Testing

You must have an **up-to-date** logbook for the testing session.

Each of the following sections will be tested in the laboratory.

Software

- A modular approach is used.
- Timing uses an ISR.
- Appropriate software style.
- Appropriate comments.
- Ease of use.

Functional Testing

- Power supply (battery / USB).
- Sensor input.
- Data logger functions correctly.
- USB interface is operational and outputs stored data.
- Timing to within 1%.

Accuracy

- Voltages generated are within tolerance.
- Noise is minimised with appropriate power supply filtering.
- Power consumption
- Clock is accurate to ±150 ppm.
- Operation over required temperature range.

Presentation and Oral Exam

Your presentation is for an audience of senior engineers, and takes the form of a design review (imagine you are making a case for moving your design from a prototype to a marketable product).

You should outline the overall concept of your design, and then focus on what you consider to be unique or advantageous aspects of your design. Include a consideration of manufacturability, cost, ease of deployment and reliability.

Presentation

The following are general guidelines for the presentation:

- Duration is between 10 and 15 minutes.
- Should be created using Microsoft® PowerPoint® presentation manager.
- Maximum of 10 slides (counting the title page).
- Slides with full schematics may be used as an "appendix" to the presentation. That is, they do not contribute to the 10 slide limit, and they do not form an integral part of the presentation. They are so that any technical questions can be answered in a timely fashion.

Oral Exam Questions

There are ten topics. Only **FIVE** will be chosen by the subject coordinator in the question time at the end of your presentation (the oral exam).

- The question time is between 15 and 20 minutes.
- The subject coordinator will ask questions first. Fellow students will then be invited to critique / ask questions if time permits.

Topics for Discussion

1. Explain how the power supply was chosen / designed – including the selection of appropriate components. What part of your design consumes the most amount of power, and why? What can you do to minimise the power consumption?

2. Explain the design of the software. How did the design impact on the accuracy of the device? What constraints limited the software design (e.g. time, memory, peripherals, I/O)?

3. Explain the reasons for choosing some of the major integrated circuits (e.g. μC, power supply IC, NVM).

4. Explain *qualitatively* how the data logger works, including the sensor circuit, your software, and the logger's connectivity circuit.

5. Explain how you tested the data logger – experimental setup, equipment used, expected results, specifications, etc.

6. Reflect on your design. Suggest improvements. What will you do differently in a similar project?

7. How would you minimise the cost of volume production (>1 000 units) of your device?

8. Discuss the steps taken to conform to good EMC practice in your design (components, PCB layout, enclosure etc).

9. Explain the various digital protocols that communicate between the microcontroller, the NVM, and the PC.

10. Discuss the various uses and types of capacitors in your circuit.

Tips

Some general tips are listed below.

1. Read the datasheets carefully. The PIC is especially notorious for powering up with analog input pins and you specifically have to turn them into digital pins, otherwise their digital function will not work (e.g. SPI pins may also be analog pins).
2. Mixed voltage systems require careful planning. If you are using an FTDI USB converter chip, be aware that it requires 5 V at some point to program its internal configuration EEPROM to use its internal oscillator. 5 V CMOS and 3.3 V CMOS are compatible in only one direction.
3. Linear regulators provide the best noise performance, but are very inefficient in this application.
4. Switch-mode power supplies should not be "overrated", since then there is a possibility of operating in "discontinuous mode" for small load currents – resulting in large switching transients and possibly a lower than expected output voltage.
5. Automatic battery / USB supply change-over circuits require Schottky diodes of the correct rating to work properly. A p-channel MOSFET is preferable to a PNP BJT for the switch.
6. If using a PIC, take note of the requirements for the programming header, and in particular the diode required on the Vpp line to protect other chips from the programming voltage which could be up to 12 V.
7. Use LEDs to provide a visual indication to the user of the circuit's mode.
8. Provide test points and "links" at key locations. Isolating the power supply circuitry during PCB population can be very handy.
9. Buy more parts than you need – you will inevitably require spares, and lead times can be a problem.