LDPS Technical Design Assignment: Band-Pass Filter and PCB Design

Assignment Aim

This is the first opportunity to use some simple design tools that are commonly used in an industrial/commercial setting. The overall aim of this assignment is to produce a well-structured document using the knowledge gained in previous elements of the course. The students need to be able to research the project effectively, use various design tools for circuit layout and produce a clear and concise document that could be used by a manufacturer to create the product that has been designed. For this particular assignment, the product will be a band-pass filter for use in the telecommunication industry.

Target Audience

You should seek to write your report at the technical level of a Do-It-Yourself (DIY) technical magazine. Imagine you need to write an article which explains the principles of a band-pass filter (i.e. the combination of high and low pass filters) and its operation, plus provide a Printed Circuit Board (PCB) layout for the DIY electronics construction. The report must be easy to read, contain enough technical information to explain the operation and enough detail on the construction and technical drawing side to enable the target audience to construct the device.

Report Construction

Your report should at the very least contain the following items:

- An **introduction** to the task which provides a detailed description of what is to be achieved by the project.

- A detailed description of the **theory and design principles** behind a band-pass filter, which is the combination of a low-pass and high-pass filter. The low-pass filter should have a cut-off frequency of approximately 4800 Hz. The high-pass filter should have a cut-off frequency of approximately 200 Hz.
  - A high-level **block diagram** of the system.
  - Lower-level **circuit diagrams** for each of the low-pass and high-pass filters above
  - A **description of the operation** of each of the above filters using standard formulas from circuit analysis, an interpretation of these formulas, the
calculation of the filter cut-off points and plots of amplitude and phase responses.

- **A PCB layout** of the overall design as detailed above. Only the final design should be included in the documentation. This should be obtained by removing the so-called “Top-Silk” layer so that component outlining and labels are not included.

- **Assembly drawings** of a box with coaxial input and output sockets connected to the PCB board which will be contained within the box. The drawings should show where all of the necessary components will sit within or be attached to the box. Any wiring should be shown as well as any mounting hardware. Dimensions should be used wherever practicable.

- **A parts / components list** of ALL materials that are required to build the filter. The list should include prices of each component and the part numbers from the vendor you would consider buying the components from. You may find prices and part numbers for just about everything you need on the Farnell (uk.farnell.com) or RS (http://uk.rs-online.com/web/) websites however feel free to use whichever company you feel is suitable.

**Preparation**

There will be a one hour lecture describing the assignment and two laboratory sessions with access to the design tools and to Microsoft Word. The laboratory sessions should be used for familiarizing yourself to the PCB software (Eagle - www.cadsoftusa.com/eagle-pcb-design-software/) to prepare the drawings in MS Word. It is STRONGLY recommended that you come prepared for the laboratory by understanding the theory aspects of the filter. You should have calculated the values you will be using for your components, and know how they should be connected together. You should have sketched all the theoretical graphs and necessary block diagrams. You will only have a limited time to work on the PCB software and make the necessary drawings so please come prepared! You should also have a look at the project “tips” below so that you will have a better idea of what to do when you get to the laboratory.

Whilst you will be working in pairs on the PCB and assembly drawings, you will need to write up your reports separately. It is recommended that you have all drawings completed before the end of the last laboratory session so that you can write your reports individually.

**Assessment**

Please note that this assignment is not primarily about designing a band-pass filter. The emphasis is on presentation quality and the expectation is to produce a professional document that will allow a technician or someone skilled in the electronics to be able to build what you’ve described.

The final report needs to be handed in to the Teaching Support Office (TSO) by

4:00 p.m. Monday 18th February 2013

Feedback on report will be provided approximately two weeks after the deadline.
Report/Projects Tips

General

- Read the information in the previous section carefully, and produce a document with the specified content and structure.
- Formal reports should be typeset, including figures and graphs. Pencil sketches of graph and tables of data in pencil are NOT ACCEPTABLE at this level.
- When you are asked to provide diagrams (e.g. circuit diagrams), this general means you should author them yourself, not just browse the web for something that approximates what you want. Please note that you are being trained for the situation when you are doing original work and no diagrams pre-exist. If you have denied yourself practice in producing simple diagrams, you have cheated yourself of the learning experience.
- Reference any material that is not your original work. Use only sources that are peer reviewed or can be cited from a textbook. Do NOT use sources such as Wikipedia. Your references should provide enough information so that anyone can easily track down the source. All references should be numbered and those numbers should be used in the text where pertinent.
- When carrying out an individual assignment, you are expected to work independently. If two papers are handed in which are clearly the result of collaboration, the minimum penalty is likely to be a halving of marks, and the maximum penalty may be the award of zero marks.
- Spell out any acronyms on first usage e.g. “A low pass filter (LPF) consists of …”
- Write in complete sentences and paragraphs, not just adding bullet points.

Numbers and quantification

- Quote numbers to appropriate precision. If your circuit components are quoted to 2 significant figures, is it meaningful to quote frequencies to 6 sig. fig. ?
- Do not neglect the effect of component tolerances on your circuit performance. Ideally, work out their effect on your specified pass band.
- All quantities have units – if none, write “dimensionless” as a reminder!
- Numbers should be written in scientific / engineering notations as e.g. $3.0 \times 10^8$ not 3E8.

Figures – general

- All figures need a descriptive caption as well as figure numbers.
- Ensure that any text in the figures is big enough to be legible.
- Where any figure is reproduced from websites or other sources (for example if you are reproducing someone else’s original data for comparison with your own), it should be fully referenced within the caption, for example by adding “(reproduced from reference [3])”.

Figures – Graphs of data

- Graphs are captioned as Figures and numbered in sequence with the other Figures.
- Axes must be correctly labelled
- Axes must have scales and units
- Graphs of data should be plots of calculated data, not sketches of the approximate shape.
• Summarise the essential features of the plot, e.g. “The amplitude transmission of a high-pass filter is plotted in Figure 13, and shows a smooth transition from zero transmission at frequencies well below the cut-off, to unity at frequencies well above the cut-off.”
• If there is more than one line on a graph, you need to state what different lines are.

Tables

• Tables should be numbered and have descriptive captions, e.g. “Table I: Component list for construction of the band pass filter”.

Equations

• If you write down an equation, say in words what it is for or what it represents.
• All symbols should be defined (in words) on first use (even if YOU think it’s obvious!)
• Strictly speaking, in a report all equations should be numbered, e.g. Eq. 1.
• Avoiding copy-and-paste of equations from websites. What would you do if you needed to rename one of the variables?? Much better to learn how to use e.g. Equation Editor which is built into Microsoft Word.
• You don’t need to show trivial arithmetic steps when presenting theory in a formal paper or report. Show the starting point and the final results, and any key or tricky steps.

Circuit Diagrams

• Distinct symbols should be used for the high- and low- pass filter components.
• Symbols in the diagrams should be consistent with your equations and text.

PCB Design

If you want to get a head start on understanding the PCB layout software you will use in the laboratory, you can download a trial version of CadSoft EAGLE PCB Design Software (http://www.cadsoftusa.com/download-eagle/). The software is not hard to use but it does take some practice to get comfortable with it.

Once you understand the theory behind a band-pass filter and have identified the component values you will be using in your design, have a look on the Farnell (uk.farnell.com) or RS (http://uk.rs-online.com/web/) websites to get an idea of what sorts of dimensions the components will have (i.e. the lead spacing and overall dimensions of the components). You will need this information in order to draw the components in the software. Here are some things to consider when using the software:

• Start using Eagle by adding those components to the component library (they are there already, but it helps to know how in case you need to add more complex components in the future).
• Select the required components from the Eagle library, position them on the board and label them.
• Interconnect the above components using appropriate tracks – you need to try one copy with hand-routed tracks and one with autorouted tracks to see how they compare.
• Add input and output terminals (or “pads” in Eagle speak).
• Edit and add any labels as necessary using the appropriate labelling tool including a label for the design as well as another indicating your name(s).
• Try changing the “pad” and track characteristics (or “styles” in Eagle speak) i.e. their width and comment on potential advantages/disadvantages
• Try using more sizeable component-connecting elements (or “shapes” in Eagle speak) - instead of thin tracks - to produce an alternative layout and comment on potential advantages/disadvantages.
• Try making the “shapes” connecting directly to the earth more sizeable than all others (and speculate why this could have a practical benefit).
• Try to modify the “shapes” so that they have rounded corners (and speculate why this could have a practical benefit)
• Make sure you think through your design before implementing it. Will it fit in the box you’ve chosen? Are the holes for the leads too close together or are you wasting materials by having them too far apart? Is it going to be easy/cost effective to build?

Assembly Drawings

You should show:

• PCB and means of attaching to box
• Sockets and means of connecting to PCB including any wire and types of wire
• All dimensions, means of closure, materials & construction

Parts List

• All information should be provided in a table.
• Provide a detailed description of the part and any pertinent dimensions of the component used (e.g. 100uF electrolytic capacitor with 5mm lead spacing). Please note that the components you choose should fit the board that you’ve drawn (i.e. if you draw a component on the PCB with a 5mm spacing, the component you list in your Parts List should have leads with a 5mm spacing)
• Provide the unit price of the component. Good websites to get prices from are Farnell (uk.farnell.com) and RS (http://uk.rs-online.com/web/). You may use the bulk quantity values (e.g. cost per unit for orders of greater than 1,000 units).
• Provide the part number and the source (e.g. 1166134 (Farnell))
• Provide the part quantity used in your design.
• Provide a part designator (i.e. the name you used in your drawing such as “C1” for the first capacitor, etc.)

Marking Scheme

The report should be clear and concise with complete sentences used as much as possible. It should contain all the relevant theory so that any necessary troubleshooting can be undertaken by the technician building the filter. The drawings should be clearly labelled and dimensions should be given where pertinent. The total marks available for this assignment is 100. The following scheme will be used to mark the assignment.
<table>
<thead>
<tr>
<th>Item</th>
<th>Marks</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Introduction</strong></td>
<td></td>
</tr>
<tr>
<td>Clear and concise introduction to the report. It should state what a Band-pass filter is and what this type of filters are used for.</td>
<td>5</td>
</tr>
<tr>
<td><strong>Theory/Background</strong></td>
<td></td>
</tr>
<tr>
<td>Clear and concise discussion of a <strong>low-pass filter</strong>. This should include the equations of the gain and phase response as a function of frequency. All equation symbols should be defined. The definition of the break frequency should be defined. The calculated values to achieve a 4,800 Hz break frequency should be provided. If the components chosen do not provide an exact value of 4,800 Hz, the deviation from this value should be provided.</td>
<td>4</td>
</tr>
<tr>
<td>Graphs showing the behaviour (both amplitude and phase) of a <strong>low-pass filter</strong>. All axes should be labelled and have the correct units. The cut-off frequency should be clearly identified in all graphs.</td>
<td>4</td>
</tr>
<tr>
<td>A component level circuit diagram of the <strong>low-pass filter</strong> should be provided. All components (e.g. resistors and capacitors) within the diagram should be clearly labelled including the ground, input and output.</td>
<td>4</td>
</tr>
<tr>
<td>Clear and concise discussion of a <strong>high-pass filter</strong>. This should include the equations of the gain and phase response as a function of frequency. All equation symbols should be defined. The break frequency should be defined. The calculated values to achieve a 200 Hz break frequency should be provided. If the components chosen do not provide an exact value of 200 Hz, the deviation from this value should be provided.</td>
<td>4</td>
</tr>
<tr>
<td>Graphs showing the behaviour (both amplitude and phase) of a <strong>high-pass filter</strong>. All axes should be labelled and have the correct units. The cut-off frequency should be clearly identified in all graphs.</td>
<td>4</td>
</tr>
<tr>
<td>A component level circuit diagram of the <strong>high-pass filter</strong> should be provided. All components (e.g. resistors and capacitors) within the diagram should be clearly labelled including the ground, input and output.</td>
<td>4</td>
</tr>
<tr>
<td>A high-level block diagram demonstrating how the filters fit together in the system. Each block should be clearly labelled in addition to the input and output. It is acceptable if a complete schematic has been provided instead of a block diagram.</td>
<td>3</td>
</tr>
<tr>
<td>Graphs (both amplitude and phase) should be provided showing the response of the Band-pass filter. This graph can be the combination of the high-pass and low-pass filter graphs. The axes should be clearly labelled with the correct units. The break frequencies should be clearly identified on the graphs.</td>
<td>3</td>
</tr>
<tr>
<td>PCB Layout</td>
<td></td>
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<td>------------</td>
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<tr>
<td>A layout of the PCB should be provided. The layout should be to scale and no dimensions or labels should be shown on the image. The components should be reasonably spaced but not so much that board space is wasted. There should be holes for the input/output signal wires and their respective grounds.</td>
<td>10</td>
</tr>
</tbody>
</table>

| Assembly Drawings |
|--------------------|-----------------|
| Drawings showing the top, side and front view of the case that the PCB board will fit in. A single 3-D image may be used instead of the three view method. The drawings should show how the signal will be taken from the board and to the connectors. The connector position should be shown on the box. The PCB position should be shown in the diagram and the method for fastening the board to the box should either be stated or drawn in the diagram. | 10 |

| Components List |
|-----------------|-----------------|
| A table of all components used in the fabrication of the box should be provided. The price of each component should be given. If the student uses discounted costs for large orders (e.g. £0.10 each for order of 1000+ units), the number of units for the given price should be provided. The price for the PCB board material or the wire does not have to be stated. The part number and the source (e.g. Farnell or RS) of the part number should be given. If the manufacturer’s part number is given then the source does not have to be stated. The quantity of each component should be given as well as its designation (e.g. C1, R1) with respect to the PCB. | 10 |

| References |
|------------|-----------------|
| All pertinent references for the theory of the Band-pass filter should be provided. Hyperlinks to the information may be provided but the reference should be to a reputable source (e.g. no Wikipedia!). | 5 |

| Extras |
|--------|-----------------|
| Appendices providing further information on the construction of the filter or about any of the components such as spec sheets or additional versions of the PCB board where dimensions and component labels are given. | 5 |

| Use of surface mount components in lieu of through-hole components. | 5 |

| Detailed or extended descriptions of the hardware or components used in the construction of the filter (e.g. #4-40 screws, washers and nuts to fasten the connectors to the case). | 5 |

| Component tolerances are considered in all calculations. | 5 |

| Use of filters other than first order RC filters in the Band-pass design. | 5 |
Useful links


Questions

If you have any questions please come and see me (Room 35BA01) or contact me at: p.barnaghi@surrey.ac.uk

Acknowledgements

- Lab partner; technical staff in lab when particular help has been given.
- Parts of the descriptions for this assignment are adapted from Dr. William Headley’s (CCSR, University of Surrey) EDPS assignment in 2012.