Lab 2 (2018)
Analog Circuits and Filtering

Objective

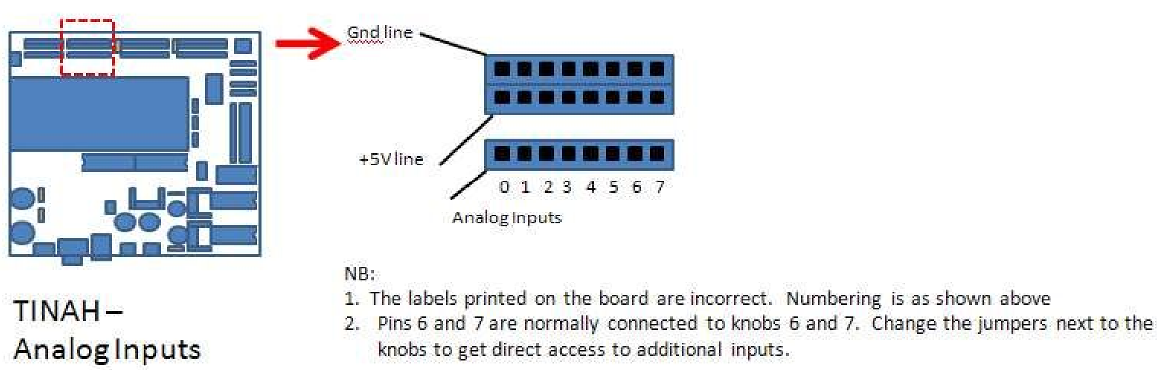
- To amplify a signal from an IR (infrared) receiver, change its DC level and amplitude, filter it to remove unwanted noise, and then convert its amplitude into a DC signal for peak detection. These functions are the core elements of an infrared homing system.
- You will also connect the final output from the circuit into analog input of the TINAH board.

References

- [TL082 Operational Amplifier Datasheet]
- [QSD124 Phototransitor Datasheet]

Pre-Lab

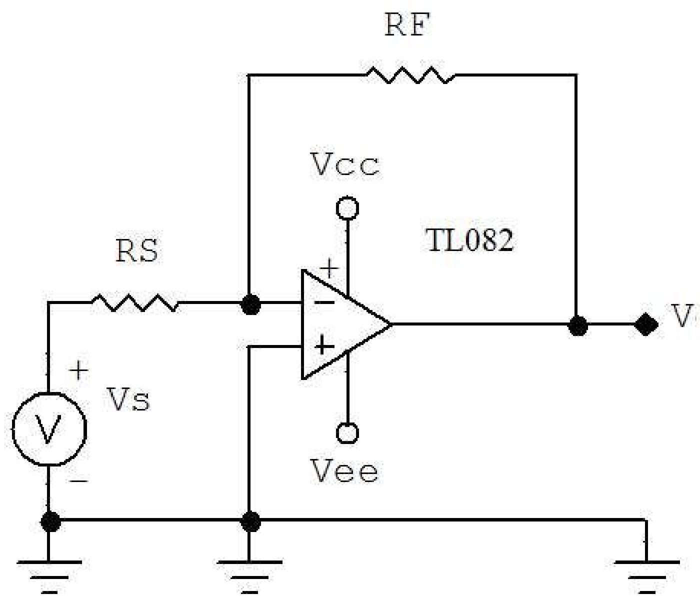
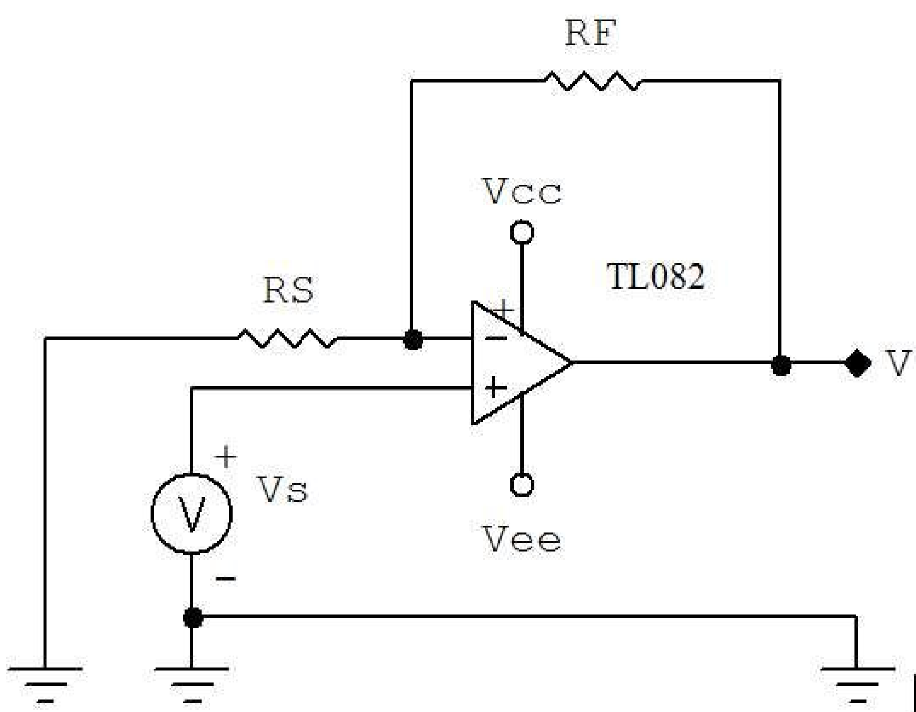
- Draw a frequency response plot for the passive low pass filter shown in Fig. 1.5
- Derive a transfer function for the active bandpass filter in Fig. 1.6
- Review the data sheets on QSD124 and TL082.
- Learn the **difference between DC and AC coupling** on your Oscilloscopes. (this is often a problem when trying to interpret the voltage signals on the scope)
- Read the notes on the TINAH Hardware, and be sure to note the following:
    - *The labeling on the Analog Input pins is incorrect, the pin labeled "7" is actually "0", and vice-versa.*

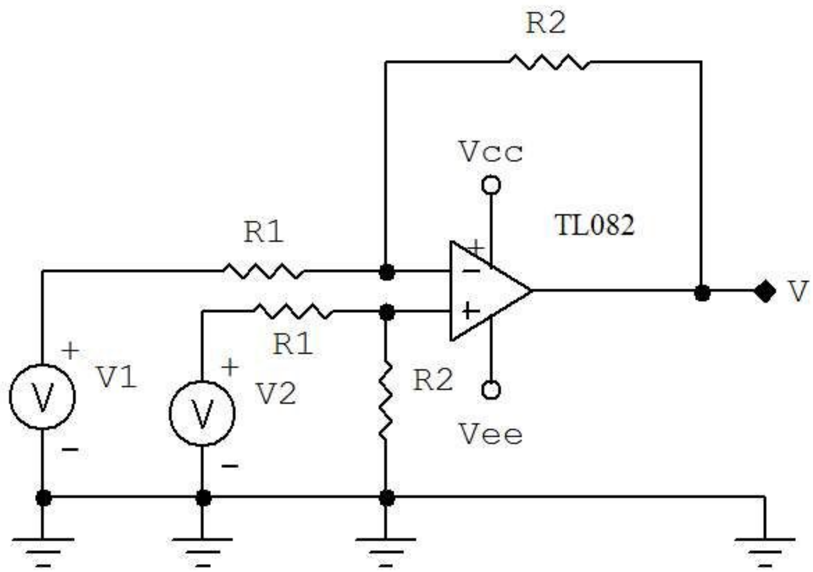
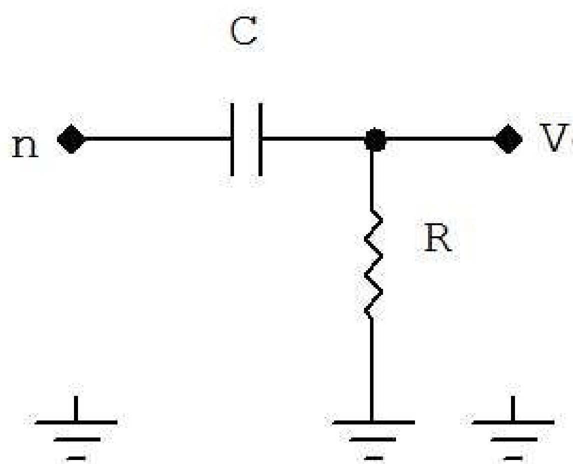


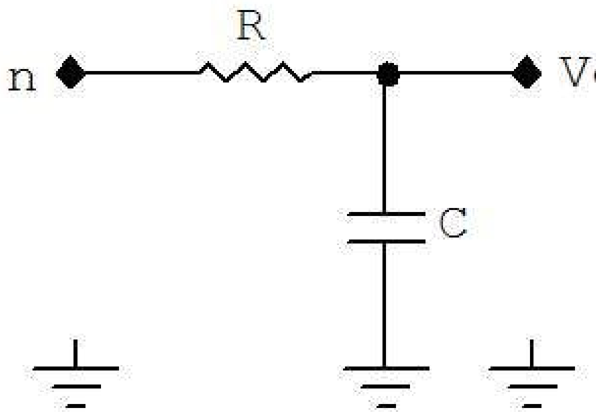
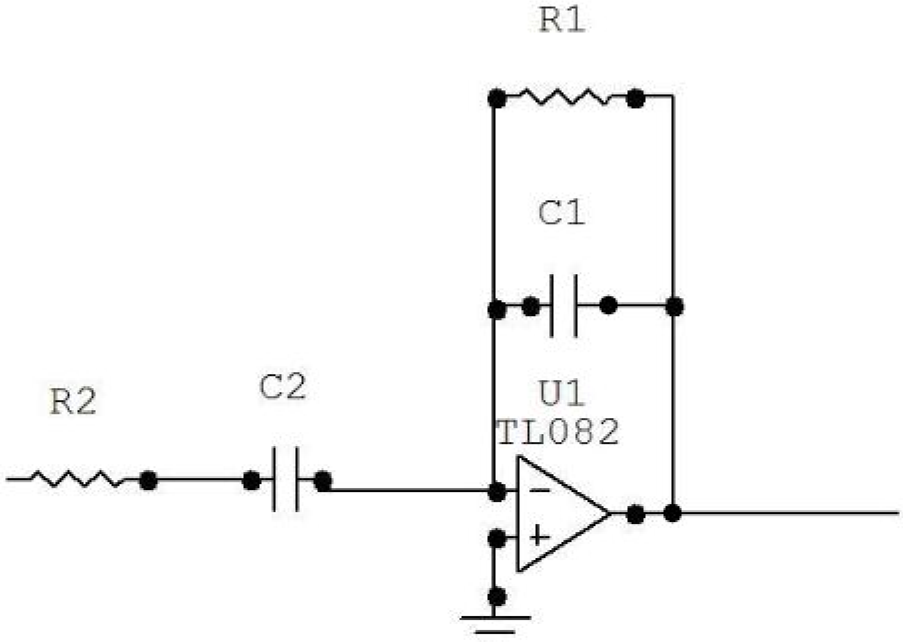
    - Knob 6 and 7 are connected to Analog Inputs 6 and 7 by default. To gain access to the analog inputs on lines 6 and 7 and bypass the knobs, shift the position of the jumpers next to the knobs.

- The TINAH Board's A/D resolution is 10 bits. Determine the precision to which you will be able to measure the angular position of the potentiometer.

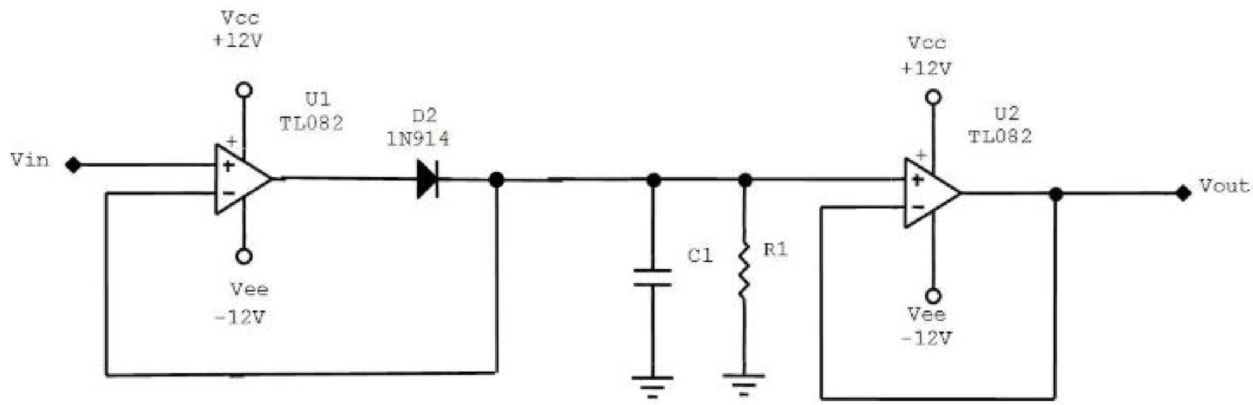
Operational Amplifier Circuits

Inverting Amplifier. In this configuration, the input signal is connected to the inverting (negative) terminal, while the non-inverting (positive) terminal is connected to ground.	 Figure 1.1
Non-Inverting Amplifier To avoid the negative gain present in the inverting amplifier, the noninverting amplifier configuration is used. Just as the name indicates, the input signal is connected to the noninverting terminal.	 Figure 1.2

Differential Amplifier This configuration is used in situations where the difference between two signals needs to be amplified.	 Figure 1.3
High Pass Filter (passive)	 Figure 1.4

Low Pass Filter (passive)	 Figure 1.5
Active first order band pass filter	 Figure 1.6

Peak Detector
This circuit is capable of tracking the amplitude of a sinusoid with a response time constant of R1C1, where R1C1 determines the response time of the peak tracking.



Vcc and Vee are 15/-15V, not 12 as shown

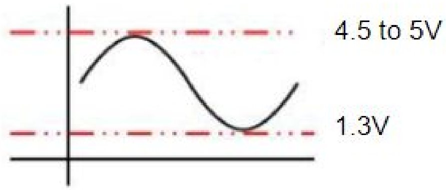
Lab

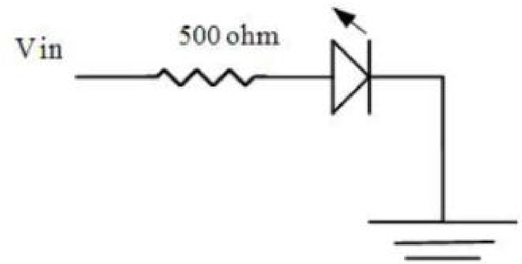
Read through all lab steps, and **draw proper schematics** for each stage in your logbook. Have all calculated component values for your filter circuit ready to show.

1. **Wire up a phototransistor QSD124 on your protoboard.**
   Build a test circuit as shown in lecture 2. Make sure to not exceed the QSD's max. values for allowable power dissipation and the resulting current through the device.

2. **Expose the phototransistor to a flashing IR source.**
   Measure the output of the waveform on the oscilloscope. Note the amplitude and frequency response of the phototransistor.

   Build your own IR Emitter to do this.
   Note: There are four IR Emitter Box sources in the classroom (the grey aluminum boxes) which can produce 1 kHz and 10 kHz sine waves (and can switch to square wave) output in the infrared. If you want to use these IR Emitters, you may want to carry their special battery charger with them as well, as their battery does not last very long.
   However, there are only four of these IR sources, and the frequencies are fixed. It is advantageous for you to make your own IR LED emitter source, and drive it with the function generator. You can keep this setup at your workbench, and you can vary the frequency continuously and see the frequency response of your system, while you are working on it. See the diagram below for a schematic of the IR LED with resistor, and the desired output from the function generator (question: what happens if the voltage going to the IR LED goes below ground?)





3. **Design and wire up amplification and filtering in your circuit.**
   You may decide to put amplification before filtering, filtering before amplification, or amplification before and after filtering, it's up to you. Keep in mind that to make debugging easier, it is usually best to to build and test each stage separately if possible (or at least to allow for each stage to be disconnected and tested separately if it doesn't work out nicely).

4. **Design and wire up an amplifier or sets of amplifiers to amplify the output waveform.** A few points to keep in mind as you include amplification in your circuit
   a. Do not exceed the gain-bandwidth product of the TL082 op-amps, use multiple stages if necessary to achieve your desired gain without losing frequency response.
   b. Remember to block the DC component of the signal before amplifying.

5. **Design and wire up a band pass filter to detect a 10 kHz IR sine wave signal and reject noise at other frequencies.** Test the amount of rejection you have achieved by exposing your circuit to a 1 kHz IR sine wave and compare against the desired 10 kHz signal. When designing the circuit, make sure the output of your peak detector swings between 0-5V to match the input range of the TINAH Board.

6. **Design and build a peak detector to produce a DC analog signal proportional to the amplitude of the detected IR signal.**
   As you put this together, think about what RC time constant you should aim for in your peak detector circuit.

7. **Examine the input and output voltage limits of the amplifier.**
   Note what happens to the output voltage as the input voltage gets close to the power rails values (close to -15V or to +15V). You can see this effect when you have a stage with high gain, and increase the input to "saturate" the circuit.   You should examine your output stage by stage, and see the effects of saturating your signal and how it cascades through each stage of your circuit.

   Go through all these previous steps slowly, as there are often subtle issues with amplification, saturation, and exceeding voltage levels which can be traced back to input or output levels exceeding the maximum ranges.

8. **Connect the IR circuit output to an Analog Input on the TINAH board.**
Hook up the output of your IR detector circuit to an analog input. Write a program to display IR amplitude readings on the LCD display. You will also want to protect the output using Overvoltage protection with a zener diode, described here:

Overvoltage protection: Use a zener diode to make sure the signal is in the range 0 to 5V before plugging it into the TINAH Board. The zener diodes available in the lab are BZX79C5V, rated for 0.5 Watt of power. Work out an appropriate resistor value for placing in line with the output value if the input of the circuit. Here's a good read to see how to use zener diodes as voltage clamps for overvoltage protection (and more): The Circuit Designer's Companion, pg. 120, Tim Williams

Milestones

Show the following to a TA/instructor:

- **A DC signal proportional to the amplitude (or distance) of the IR beacon to the TINAH board on the oscilloscope.**
- **The DC signal above acquired by the TINAH board.**
- **Demonstrate the the level of noise rejection due to the filtering stage of your circuit.**
- **The drawn & labeled schematics for your circuit (so we can check your component selections and values)**

Hints That Can Save You A Lot Of Time

- Use tabs in your browser, keep everything you need permanently open: Lecture slides, lab notes, datasheets, etc. Don't waste time reloading the same websites over and over again.
- Remember to run your op-amps on +/-15V.
- Don't build everything at once and then plug it in, hoping it will work. Chances are it won't.
- Instead, do the opposite: Built smallest sections, and as soon as a functional unit is reached, test that section of your circuit to make sure it works as intended.
- Build these sections in the order of your incoming signal. As you build up your circuit, follow your signal along to verify each section after you have built it.
- Use your oscilloscope for signal tracking, and your multimeter for simple tasks such as verifying supply voltages for ICs and continuity testing
- Again, make circuit sections separable, enabling you to isolate any part of your larger circuit for independent testing
- When measuring, distrust (always double and triple-check) your bench setup: Does the protoboard work? Are the contacts actually making contact? Are your probes OK? Wires plugged in? Measure, test, probe, signal-follow.
- Keep things tidy! The more your setup (and your workbench in general) looks like a pile of spaghetti, the harder things are to troubleshoot.

Other References

- Horowitz & Hill "The Art Of Electronics": A Classic just like Romeo and Juliet.
- The elusive biquad filter! Look for it in the aforementioned.
- Direct link to the datasheets on our website. Go to Newark.ca or Digikey.ca for other components.