Project Lab Sheet A: Reversing Alarm

Two projects must be submitted; see details on QMPlus.

1 Aims

The aim of this lab is to implement a simple reversing alarm:

- An IR emitter and IR detector are used to detect light reflected from an object.
- An audible tone is generated when an object is detected.

1.1 Earlier Lab Projects

You may find it helpful to adapt code from earlier lab projects to complete the requirements described here.

1. **Analogue to digital**: Lab 5 demonstrates the use of the ADC converter. You need this to measure the input from the IR detector.
2. **Tone Generation**: Lab 6 demonstrates two techniques to generate variable tones.

2 Project Requirements

The system functional requirements are:

1. A button should be used to arm the system and then disarm it. In a car, this is done when the reverse gear is engaged.
2. When it is engaged, the system should give a brief audible confirmation that it is working.
3. When an object is detected, an intermittent audible tone is generated and becomes increasingly noticeable as the distance decreases. At least two of the following must change to make the warning clear as the object gets closer: volume, frequency and the on / off times of the intermittent tone.

You need to clarify these requirements to make the behaviour precise.

3 Using the IR Emitter and Detector

The proximity sensor uses an IR emitter (LED) and an IR detector (phototransistor) pointing in the same direction to determine if any object is reflecting IR energy from the LED.

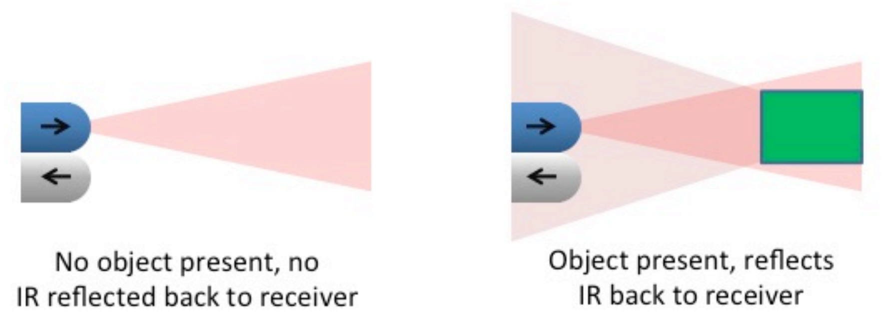


Figure 1. Proximity sensor method of operation.

Sensing occurs in two steps:

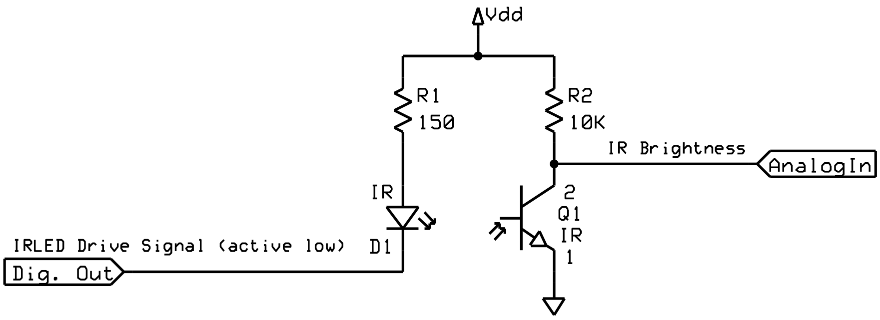
1. First, the software measures the IR light level (using IR-sensitive phototransistor Q1 and the analog to digital converter) when the IR-emitting LED is **turned off**.

2. Second, the software measures the IR light level when the IR LED is **turned on**.

If there is an object nearby reflecting the IR from D1 back to Q1 the second measured voltage will be lower.

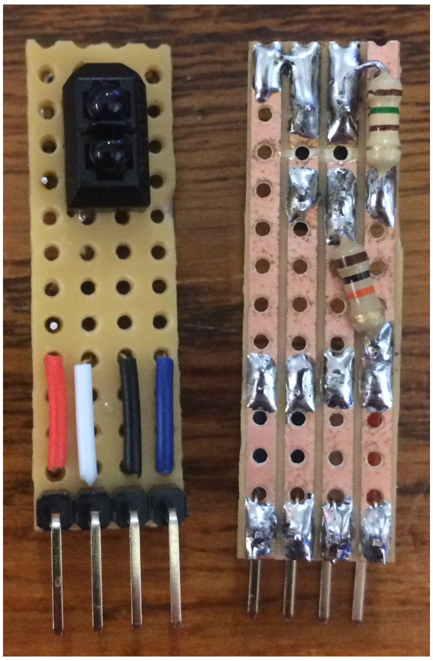
3.1 Circuit and Operation

The circuit used is shown below.



As the IR energy increases, the conductivity of the phototransistor Q1 increases and lowers the output voltage. However, the phototransistor takes time to respond i.e. the voltage does not change immediately the IR source changes. You should allow 1ms (you may also try measuring the delay with an oscilloscope).

The components have been mounted on a small circuit board:



The connections are:

Colour	Use
Red	Vcc 3.3 volt
White	Analog input (to MCU): measure IR brightness
Black	Gnd 0v
Blue	Digital output (from MCU): switch on IR emitter

You may be able to check that the IR LED is turned on by viewing it with a digital camera (e.g. in a mobile phone), as these may be sensitive to IR energy[1].

3.2 Software for Distance Measurement

The steps for the range measurement software are:

- Take distance measurements when (i) the IR LED is on and (ii) when it is turned off.
- The difference between the two voltage measurements indicates the presence of a reflecting object and the greater the difference the closer the object.
- The reading will not stabilise immediately when the IR LED goes from off to on or from on to off, so a delay is needed between switching the IR emitter on or off and measuring the voltage. This should be of the order of at least 1ms (longer is ok too).
- The IR receiver is liable to receive some 50Hz interference. A simple approach is to average the result of multiple measurements (say 5-10). However, it matters when the measurements are made: they need to be roughly evenly spaced over a 20ms period. (Some more detailed notes on how to deal with this are given in the next section.)

4 Suggestions

This section contains some additional information that may be useful. You do not have to read this section if you do not wish to.

4.1 Software Requirements

Work out the detailed software requirements. For example:

- How will you indicate that the alarm is working when it is engaged? Can you avoid confusing this with the warning?
- How will you make the warning tone more noticeable?

It is best to work incrementally: start simply and then add more functionality. You may also wish to set the on-board LEDs as a simple way to confirm the operation is an expected.

4.2 Use of Pins

Create a table of the I/O pins by function, pin name and FRM-KL25Z header/pin number. You need this to wire the system correctly. In addition, it is possible that the pins used in the demonstration projects clash (*if so, it is not deliberate*).

4.3 Software Design

For a cyclic system[2] design:

- What tasks will you have?
- What states does each task (or the system overall) have?
- How the tasks communicate?
- What ISRs are needed (SysTick at least). Will you poll buttons or use interrupts?

Then plan the functions you will need, for initialisation and for the cyclic tasks.

[1] Unfortunately, this only works with very old phone cameras.
[2] You can use the RTOS if you wish.

4.4 Calibration

You may need to adjust the physical layout or the software parameters of the system for it to work well. This section has some suggestions.

4.4.1 Ambient Light

Does the ambient light make a difference? Disconnect the IR emitter. Is the phototransistor reading steady or variable?

4.4.2 Range Calibration

The detection of the object will depend on its reflectivity[3]. Choose an object to work with (such as a sheet of paper).

Calibrate your system to record the voltage difference against distance (for a particular object). You should complete a table like this and use this to control the audible warning.

Voltage Drop	Distance	Notes
5%		Max range (approx. 20cm)
	1cm	Max difference

4.5 Advanced Notes (Not Required)

The notes in this section assume concepts not covered in detail in the module. Ask if interested.

It is likely that the IR detector has a 50 Hz noise signal. You may wish to use an oscilloscope to check this. If so, it should be sampled at a frequency >= 100 Hz to avoid aliasing. The signal should then be filtered to with a low pass filter as the frequency of the signal we are interested in is low. This filtered signal should then be averaged when the IR emitter is on and off.

Two possible simple filters type are:

1. A moving average filter. This has the form $y_t = (y_t + y_{t-1} + y_{t-2} + \dots + y_{t-N-1})/N$. It involves storing the last N sampled values. (Note that there is no need to do the division, if we only wish to compare values).
2. A simple exponential filter. This has the form: $y_t = (1-\alpha) * y_{t-1} + \alpha * t$. No storage is needed for this type of filter. A suitable value of α is 0.2.

An alternative approach is to configure the ADC to take multiple samples and average them, with completion generating an interrupt. Additionally, to ensure that the samples are at regular interval, the PIT should be used to trigger the sampling. This configuration has not been covered in any examples.

[3] The IR sensor is not suitable for a real reversing system as you could reverse into black objects.