Monash University

TRC3500 Sensors and Artificial Perception
Laboratory Documentation

Assessment:
Students are to work together in groups of TWO (2).

Please only submit ONE copy of the lab report for each GROUP. Clearly indicate in the report and the submission system the members of the group.

Due dates for reports:

Laboratory Exercise 1: Inductive Sensor	5pm Fri 21 Mar 2014
Laboratory Exercise 2: Heart-rate Monitor	5pm Fri 4 Apr 2014
Laboratory Exercise 3: Strain Gauge Load Cell	5pm Fri 18 Apr 2014
Laboratory Exercise 4: Calculating Blob Statistics	5pm Fri 9 May 2014
Laboratory Exercise 5: Decoding an EAN-13 Barcode	5pm Fri 23 May 2014

I Can Guarantee

that occasionally circumstances will arise that will prevent you from handing in your reports at the time you intended. For this reason I recommend that you hand in your reports early. Late reports will be accepted up to 5pm on the Monday following the due date. However, there will be a late penalty. Every attempt will be made to return marks for the reports shortly after the last date for submitting late reports.

Marking scheme:
Each laboratory exercise will count for equal marks (i.e. 4% of your final assessment) This is broken down into 0.5% for attendance, 0.5% for demonstration of success and 3% for the report (fractions of a percent can be awarded).

The essential components of the report are as follows:
1. The report should contain a title, and brief description of the aims of the project. In particular, the expected deliverables should be highlighted.
2. For the first three projects the sensor should be evaluated to identify its characteristics. The results of this process must be documented in your report.
3. Your circuit design for processing the sensor signal should then be documented.
4. Results demonstrating the capabilities of your sensor system should be documented and analysed.
5. The report should conclude with a suitable conclusion.
   In addition to the above components your report should be well laid out and written in clear English without spelling and grammatical errors.
   To gain full marks you must go beyond the basic minimum and provide something extra. This may include extending the capabilities of your circuit or program, performing additional testing and data evaluation, etc.

DO NOT PLAGIARISE. We have access to past year submissions.

TRC3500 Laboratory Safety Procedures

General:

Never adopt a casual attitude in the laboratory and always be conscious of potential hazards.

Never run in the laboratory or corridors.

Always exercise care when opening and closing doors and entering or leaving the laboratory.

Do not place any object other than a floppy disk or CD-ROM in the PC.

Do not handle, store or consume food in the laboratory, particularly liquids.

Do not apply cosmetics in the laboratory.

Do not use laboratory apparatus without prior instruction on safe work procedures and practices.

Do not lift heavy equipment (PCs, oscilloscopes) and always switch off power at the GPO before unplugging equipment.

Observe safety signs at all times.

Keep benches clean and free from apparatus that is not being used.

Keep aisles free from obstructions – place bags in an appropriate location (under your desk or on the window ledges) within the laboratory.

Do not sit on work benches.

A carefully adjusted chair will limit back ache and long term back problems. Be aware RSI can occur from prolonged use of keyboards or the mouse. Correct positioning of arms and mouse can minimise these effects. For more information see: http://www.adm.monash.edu.au/ohse/assets/docs/guidelines/ergonomics-computer.pdf

Do not "wheel" from one location to the next on chairs.

Let any co-workers or visitors know of hazards that exist in your work area.

Take care to ensure that electrical leads are not weakened by pulling and that plugs, sockets, etc, are in serviceable condition.

Do not insert any objects into power sockets other than power plugs.
Report all incidents or near misses to your lab demonstrator. Hazard & Incident form to be completed.

Closed toe shoes, not sandals or thongs, must be worn in the laboratory. Toes must be protected.

Be aware that flashing lights or repetitive noise can precipitate seizures, e.g. Epilepsy.

When Soldering:

Wear safety glasses!

As far as possible, avoid inhaling the fumes given off when solder is melted.

When not in use, return the soldering iron to its stand.

Use the wet sponge supplied to clean the soldering iron tip.

Be aware that the barrel of the soldering iron is **dangerously hot** and **so is any soldered joint before it cools**. If you do burn yourself then hold the affected area under cold running water for at least 2 minutes.

The lead contained in solder is **poisonous** and therefore you should never place solder in your mouth. Wash your hands after soldering and before eating.

In an emergency:

The big red button will cut power to the laboratory in case there is an electrical hazard.

Call 333 using the Red Phone if available.

Be ready to evacuate if you hear the repeating "beep beep" sound.

Evacuate if you hear the repeating "whoop" sound.

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MONASH UNIVERSITY
TRC3500 Sensors and Artificial Perception

Laboratory Exercise 1: Inductive sensor

Andy Russell
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Introduction

In this exercise you will design, build and test a velocity sensor that will measure the speed of a steel washer as it falls past an inductive sensor. The inductive sensor will consist of a coil of 50 turns of enamelled wire wound around a bias magnet. You will design an amplifier to amplify the output of the inductive sensor followed by a peak-hold circuit to record the amplitude of the washer velocity. A graph of the height that the washer is dropped from plotted against circuit output voltage will show how well the system can measure velocity. This exercise will introduce you to inductive sensors, concepts of impedance matching, signal amplification/filtering and special purpose op-amp circuits.

Equipment

The equipment that you will require should be available in a typical undergraduate laboratory:

1) Oscilloscope
2) Multimeter
3) Soldering iron
4) Hook-up wire
5) 5V plug-pac (ensure that you do not short-out or overload the plug-pac)
6) Prototyping plug board

Components

The following components will be available for you to use in your design:

1) LM324 quad operational amplifier (data sheets available on-line).
2) Magnet and enamelled wire
3) Restricted range of 1/8th Watt resistors and electrolytic capacitors.
4) A silicon diode

Recommended Procedure

In this experiment you are to construct an inductive sensor from the parts provided and then to investigate the characteristics of the sensor and consider ways of amplifying its output. A diagram of the sensor is shown below. As a first stage in the process it is recommended that you examine the output of the velocity transducer using an oscilloscope. Select a suitable angle so that the washer slides easily down the plastic channel. Keeping the angle of tilt constant release the washer at different distances along the channel and observe the pulse that the sensor produces as the washer moves past. When you understand the characteristics of the transducer you can design an appropriate amplifier, filter and peak hold circuit.
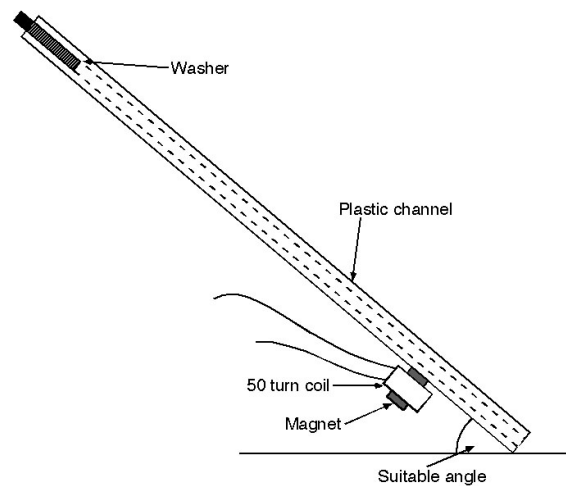

Inductive sensor.

You will need to take into account a number of considerations including:

1) How will you interface to the low impedance of the transducer?
2) What criteria will you use to choose the peak-hold circuit capacitor?
3) How will you reset the peak-hold circuit?

You may consider using the following peak-detector circuit in your design. The diode allows the capacitor C to charge on positive peaks of the input but prevents its discharge when the input falls. Resistor R provides a discharge path for the capacitor to reset the circuit. As an alternative you could use a shorting switch to discharge the capacitor.
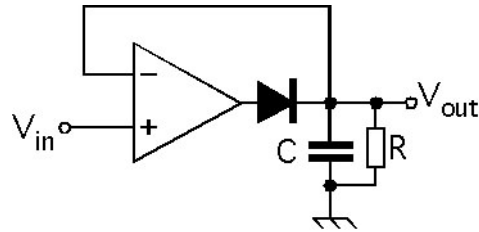
A peak-detector circuit.

Once your circuit is working to your satisfaction perform tests by releasing the washer from a sequence of heights and record the corresponding peak output voltage. Plot a graph of your results.

Assessment

0) Attendance during the laboratory classes is compulsory and you will receive a mark for attendance.

1) You will receive additional marks for demonstrating the final device to the demonstrator.

2) Write a brief report that includes all of the measurements you made, your design procedure, results and discussion. Each group will provide one common report with an appendix indicating the contribution of each individual team member. Submit your report before the due date.

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Laboratory Exercise 2: Strain Gauge Load Cell

Andy Russell

Introduction

In this exercise you will design, build and test a circuit to amplify the signal from a strain gauge. The gauge will be mounted at the proximal end of a steel strip that will be clamped to the edge of a bench. By measuring the change in resistance of the gauge you will be able to calculate the weight of an object suspended from the end of the steel strip. This exercise will introduce you to strain gauges and bridge circuits together with signal amplification and filtering.

Equipment

The equipment that you will require should be available in a typical undergraduate laboratory:
>1) Oscilloscope
>2) Multimeter
>3) Soldering iron
>4) Hook-up wire
>5) 5V plug-pac (ensure that you do not short-out or overload the plug-pac)
>6) Prototyping plug board

Components

The following components will be available for you to use in your design:
>1) LM324 quad operational amplifier (data sheets available on-line).
>2) Steel strip with attached strain gauge
>3) 0.1 kg weight
>4) g-clamp
>5) Restricted range of 1/8th Watt resistors and electrolytic capacitors.

Recommended Procedure

Using the g-clamp provided attach the steel strip to the edge of the bench as shown in the following diagram:
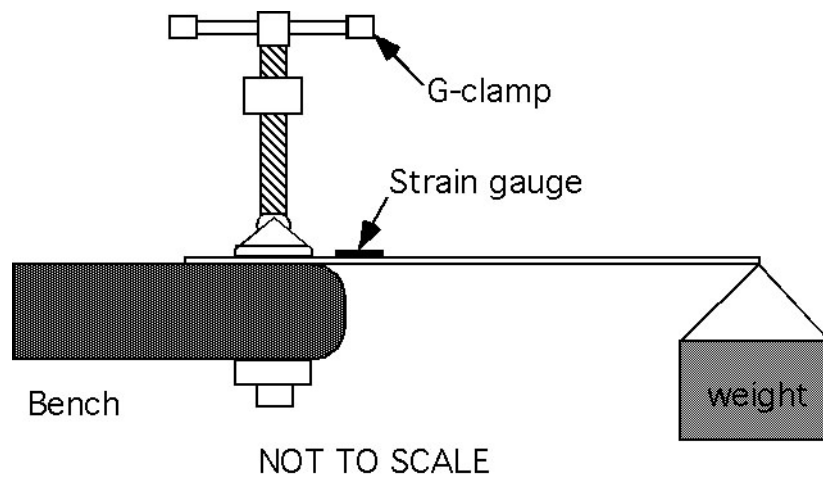
Using the supplied 0.1 kg weight, estimate the Young's modulus of the steel strip material by observing deflection of the rule δ when the weight is positioned at the end of the rule (distance l from the gauge). You will recall the following equation:

$$\delta = \frac{Fl^3}{3EI} \tag{1}$$

Where E = Young's modulus
F = applied force in Newtons

and the second moment of cross-section of a rectangular beam I is:

$$I = \frac{wt^3}{12} \tag{2}$$
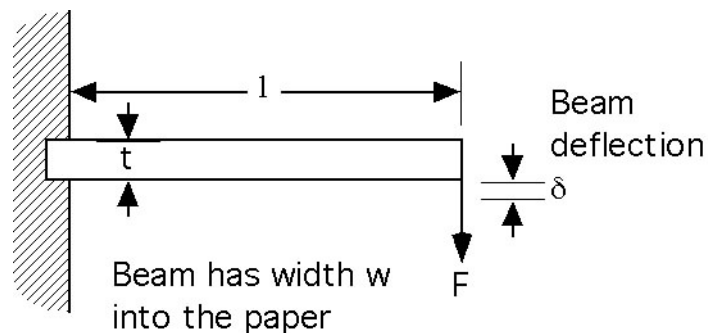
You will then be able to calculate the maximum surface stress σ that the gauge will experience when the supplied weight is attached to the end of the steel strip.

$$\sigma = \frac{3\delta Et}{2l^2} \tag{3}$$

Now using Hooke's law you can work out the maximum strain ε that the strain gauge will encounter when the weight is positioned at the very end of the steel strip and the gauge is close to the edge of the table where the strip is clamped.

$$E = \frac{\sigma}{\varepsilon} \tag{4}$$

Using the strain gauge 'gauge factor' you can then work out the expected change in gauge resistance and hence the change in the strain gauge bridge output voltage.

Then you can work out the amplification that will be necessary to amplify this signal to produce an output swing of 2V when the load is applied. In order to be able to balance the bridge it is recommended that you use a 1kΩ potentiometer to form two arms of the bridge. The other two arms consist of the gauge and a fixed resistor of the same value as the gauge.

When your circuit is working to your satisfaction, record the output voltage change that results when the supplied weight is attached to the steel strip at a number of locations along its length.

Assessment

0) Attendance during the laboratory classes is compulsory and you will receive a mark for attendance.

1) You will receive additional marks for demonstrating the final device to the demonstrator.

2) Write a brief report that includes all of the measurements you made, your design procedure, results and discussion. Each group will provide one common report with an appendix indicating the contribution of each individual team member. Submit your report before the due date.

Laboratory Exercise 3: Heart-rate Monitor

Andy Russell

Introduction

In this exercise you will design, build and test a heart-rate monitor. The principle of operation is to measure the variation in skin reflectance as blood flows through the fine capillaries close to the surface of the fingertip skin. Your heart-rate monitor is to output a 5V logic pulse synchronised to the heart-rate of the person being monitored. The project will introduce you to fundamental concepts of sensing, signal amplification/filtering and thresholding. Your design will include the sensor head, noise filter, amplifier and thresholding circuit.

Equipment

The equipment that you will require should be available in a typical undergraduate laboratory:
- 1) Oscilloscope
- 2) Multimeter
- 3) Soldering iron
- 4) Hook-up wire
- 5) 5V plug-pac (ensure that you do not short-out or overload the plug-pac)
- 6) Prototyping plug board

Components

The following components will be available for you to use in your design:
- 1) LM324 quad operational amplifier (data sheets available on-line).
- 2) Red LED (High brightness)
- 3) CdS photocell
- 4) Plastic block to hold the LED and photocell
- 5) A green LED
- 6) 74HC14 Hex Schmitt invertor
- 7) Restricted range of $^1/_8$ W resistors and electrolytic capacitors.

Theory

Heart-rate is one of the important vital-signs that are used to monitor the health of a patient. A convenient, non-invasive and safe way of doing this is to measure the change in skin reflectance caused by blood-flow close to the surface of the skin. The change in reflectance is of the order of 1% and therefore some care is needed to detect and amplify this signal.

The skin will be illuminated by a bright red light-source and reflected light detected by a CdS photocell (Light Dependant Resistor). The output of the light-sensing circuit will be affected by light reflected from the skin surface but also by interference, particularly that caused by room illumination, and drift in dc levels caused by varying temperature, etc. Sensor output will require amplification to a level appropriate for input to a 74HC14 Schmitt invertor and filtering to remove the effects of interference.

Recommended Procedure

1) A good starting point would be to construct the sensing head that contacts the index finger, illuminates the finger with red light, and detects light returned from the finger while excluding external illumination as far as possible. To help you with this part of the project a plastic block has been manufactured to hold the LDR and LED:
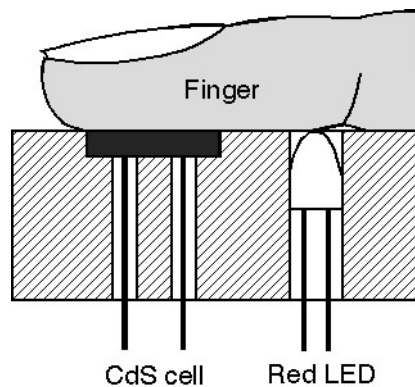
Sensing Head

This can be mounted directly onto the prototyping board. The index finger is positioned to cover both the LED and LDR.

2) Using your own resources you should find out what range of heart beat frequencies your heart-rate monitor is likely to measure. You should also find out how to measure someone's pulse rate so that you can confirm the correct operation of your final circuit.

3) Having chosen appropriate current-limiting resistor for the LED and biasing resistor for the CdS cell the signal from the photocell can be viewed using an oscilloscope. Measure the amplitude of the pulse signal and the amplitude/dominant frequency of associated noise.

4) The signal from the sensor head must be amplified to a level where it can drive a 74HC14 Schmitt logic gate. At the same time noise should be suppressed to a level where it will not interfere with the circuit operation. Design an appropriate amplifier/filter circuit to do this. You can drive a green LED with the output of the 74HC14 to visualise the pulse. Ensure that there are no spurious pulses on the monitor output.

Assessment

0) Attendance during the laboratory classes is compulsory and you will receive a mark for attendance.

1) You will receive additional marks for demonstrating the final device to the demonstrator.

2) Write a brief report that includes all of the measurements you made before starting your circuit design, your design procedure, results and discussion. Each group will provide one common report with an appendix indicating the contribution of each individual team member. Submit your report before the due date.

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Laboratory Exercise 4: Calculating Blob Statistics

Andy Russell

Introduction

In this exercise you will write a program in C to grab an image from a USB camera, convert the image to grey-scale and apply a threshold to produce a binary image. You will then calculate the 0th, 1st and 2nd order moments of area of a single blob and indicate the centre of area and axis of minimum moment of area by displaying them superimposed on the original image. In this laboratory exercise you will be exposed to some introductory ideas concerning image capture and processing together with gaining knowledge of binary image processing.

Equipment and Software

The equipment that you will require should be available in a typical undergraduate laboratory:

1) USB camera
2) a PC
3) Microsoft Visual C++ version 6
4) OpenCV
5) The supplied skeleton program

Theory

Section 9 of the unit notes provides you with background blob statistics. Make sure that you are fully conversant with this material.

Recommended Procedure

1) Grab and display successive images from the USB camera to allow the camera to be focussed and positioned to get a good image of the blob.

2) Leave the grab and display part of your program on a key press from the keyboard.

3) Convert the image to greyscale (a simple way to do this is to add the RGB components of each pixel and divide the result by 3, returning the result to each of the RGB components).

4) Work out a threshold for the image (one possibility is to choose a threshold value half way between the maximum and minimum pixel values)

5) Assume that there is only one blob in the image (therefore you do not have to do connectivity analysis) and calculate zero, first and second order statistics.

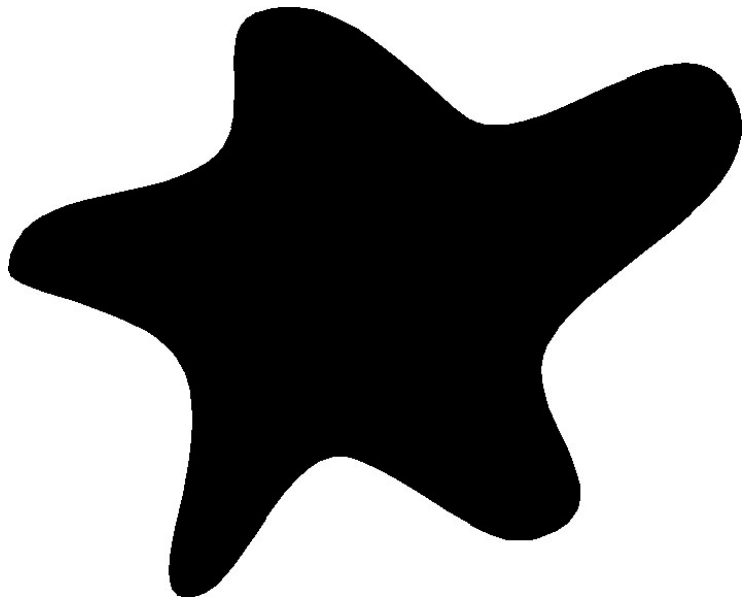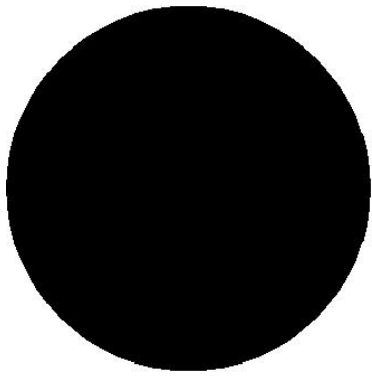6) Calculate the centre of area of the blob and its axis of minimum moment of inertia.
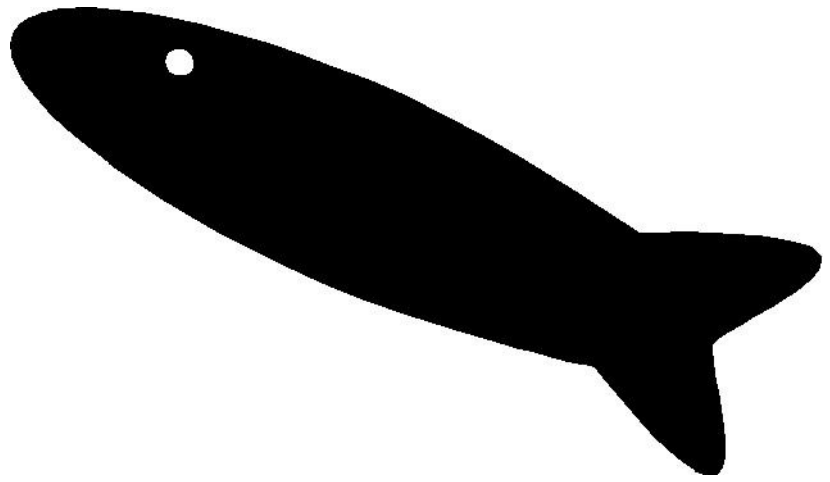
7) As well as printing the calculated statistics to the console window, modify the image displayed in the image window to indicate the blob centre and axis of minimum moment of inertia (draw a cross to indicate blob centre and a line through the centre of the cross indicating the axis).

Assessment

0) Attendance during the laboratory classes is compulsory and you will receive a mark for attendance.

1) You will receive additional marks for demonstrating the final program to the demonstrator.

2) Write a brief report that includes a listing of your program, an explanation of how it works and a discussion/conclusion section. Each group will provide one common report with an appendix indicating the contribution of each individual team member. Submit your report before the due date.

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Laboratory Exercise 5: Decoding an EAN-13 Barcode

Andy Russell

Introduction

In this exercise you will write a program in C to grab an image of an EAN-13 barcode using a USB camera, convert the image to grey-scale and scan across the centre of the image to produce a binary scan of the barcode. Starting from the left-hand side of the image you will then decode the first six characters of the barcode. In this laboratory exercise you will be exposed to some introductory ideas concerning image capture and processing together with gaining knowledge of the structure or commonly used barcodes.

Equipment and Software

The equipment that you will require will be available in the computer laboratory:
    1) USB camera
    2) A PC
    3) Microsoft Visual C++ version 6
    4) OpenCV
    5) The supplied skeleton program

Theory

Section 10 of the unit notes provides you with background to the structure of the EAN-13 barcode. Make sure that you are fully conversant with this material.

Recommended Procedure

I recommend that your program performs the following operations:

1) Grab and display successive images from the USB camera to allow the camera to be focussed and positioned to get a good image of the barcode.

2) Leave the grab and display part of your program on a key press from the keyboard.

3) Convert the image to greyscale (a simple way to do this is to add the RGB components of each pixel and divide the result by 3, returning the result to each of the RGB components).

4) Work out a threshold for the image (one possibility is to choose a threshold value half way between the maximum and minimum pixel values)

5) Scan across the middle of the image (also middle of the barcode) and convert to binary values. It would be a good idea to display the resulting binary image to ensure that the barcode is correctly converted).

6) Count the number of pixels in each successive bar (in the binary image of the centre scan) and store them in an array.

7) You will be decoding the left-hand half of the barcode so for each of the 6 characters calculate the T-values for the character – converting measurements to modules (T1, T2, T3, T4e and T). Note that T4e stands for T4 extended. This quantity is used instead of T4 because it allows for spreading whereas T4 does not. To work out T4e you need to know the width of the black bar at module positions 8+. For the first character next to the guard bars we know that the width is 1 and for later bars the width is known once the previous character is known.

8) Once you know the T values you can use them to work out the character and its parity. I recommend that you use the T values to index into a table of character, parity and 'width of the first bar' values.

9) Print out the character values and their parity.

If you have time (and for no additional marks) you could:
  • decode the other half of the barcode
  • work out the thirteenth character coded into the left 6 characters
  • see if the check sum is correct

Assessment

0) Attendance during the laboratory classes is compulsory and you will receive a mark for attendance.

1) You will receive additional marks for demonstrating the final program to the demonstrator.

2) Write a brief report that includes a listing of your program, an explanation of how it works and a discussion/conclusion section. Each group will provide one common report with an appendix indicating the contribution of each individual team member. Submit your report before the due date.

Data produced by my barcode reading program

Unprocessed barcode

Thresholded image

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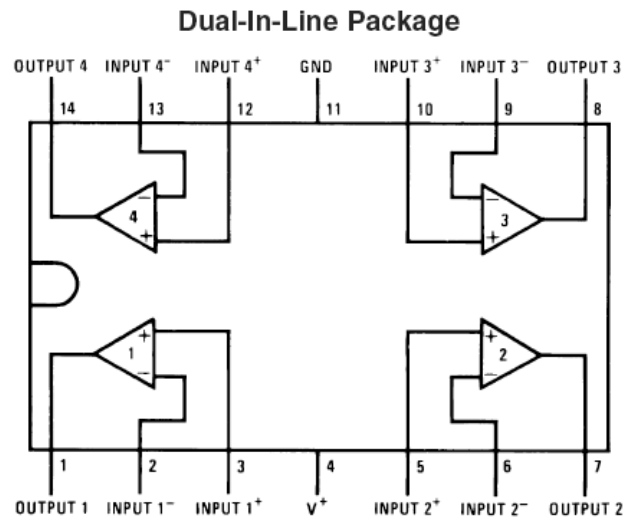# Laboratory Information

Components for TRC3500 labs:

Resistors:

120Ω   349Ω
1kΩ,   2.2kΩ,   4.7kΩ
10kΩ,   22kΩ,   47kΩ
100kΩ   220kΩ
1MΩ   2.2MΩ
1kΩ trim pot

Capacitors (* = electrolytic; means plug them in the correct way round, otherwise boom!)

0.1µF   0.56µF
2.2µF*   4.7µF*
10µF*   22µF*   47µF*
100µF*

Diode: 1N914   Red LED   Green LED (long lead is LED anode, +ve)

Op-amp: LM324 - pinout below

Dual-In-Line Package

OUTPUT 4 INPUT 4⁻ INPUT 4⁺ GND INPUT 3⁺ INPUT 3⁻ OUTPUT 3
14 13 12 11 10 9 8

1 2 3 4 5 6 7
OUTPUT 1 INPUT 1⁻ INPUT 1⁺ V⁺ INPUT 2⁺ INPUT 2⁻ OUTPUT 2

74HC14 – pinout below

Vcc
14 13 12 11 10 9 8

1 2 3 4 5 6 7
GND