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Fault finding in electronic circuits

LK9333

MATRIX

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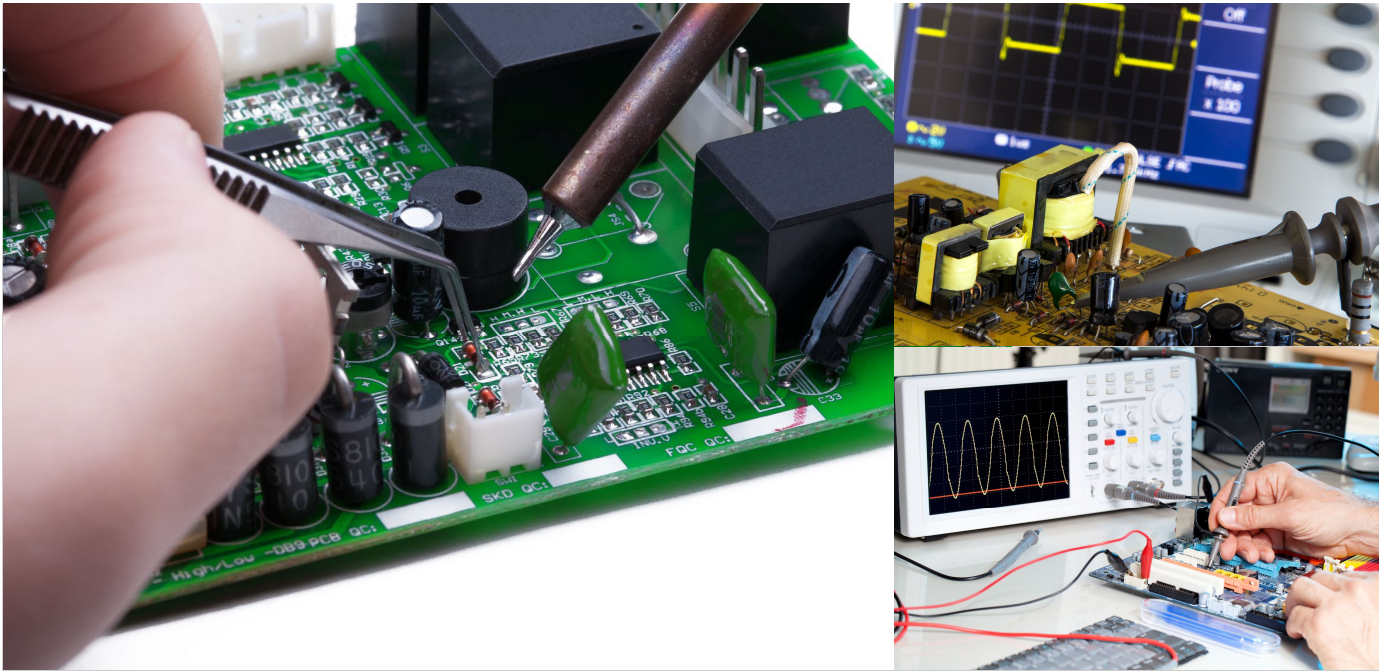## Fault finding in electronic circuits

Student handout

Introduction to fault finding

Designing an electronic system is one thing - checking that it works, time after time, in a production setting is quite another. Both are equally challenging and equally rewarding. Both require a solid understanding of the underlying electronics theory.

Successful fault finding calls for an additional skill set, including the ability to:

- devise a plan;
- think logically;
- select and use a range of test equipment;
- make a detailed record of the process.

In this field, nothing is more valuable than experience. The exercises you will be working through aim to start off the process of building that experience.

Like all training, the scenarios are artificial, designed to simplify complex situations to focus on particular aspects. In particular, these exercises come with two important rules:

You are not allowed to:

- dismantle the circuit;
- isolate any component in it for testing.

In fault finding, time is of the essence, for a number of reasons:

- The electronic system may play a part in keeping your work colleagues safe. While it is faulty, their safety must not be compromised.

- It may be an expensive piece of equipment.

- While down, creation of further products, and hence wealth creation, stops.

- You have been brought in as an outside contractor to find and resolve the fault in the system. The company wants the problem resolving quickly - they are being charged 'by the hour'.

Introduction to fault finding

Five Steps to Fault Finding

- Step **1** - **Prepare**
    - Are there any safety issues?
    - What test equipment do you intend to use?
    - *Document your findings!*

- Step **2** - **Observe**
    - Are there signs of damage - overheated components, melted insulation, frayed wire, bad solder joints?
    - Can you smell burning or overheating?
    - Take voltage measurements from a working circuit.
    - Take voltage measurements from the faulty circuit to compare.
    - *Document your findings!*

- Step **3** - **Identify** the problem subsystem
    - Which subsystems are operating correctly?
    - Where does the problem seem to lie?
    - *Document your findings!*

- Step **4** - **Suggest** possible causes
    - Check likely components:
        - switches, fuses and bulbs tend to wear out or burn out.
    - Check possible components:
        - motors, relays, inductors - components with coils - may overheat.
    - Check connections:
        - look for faulty connections or loose contacts which may offer high resistance.
        - look for stray connections that can short-circuit.
        - look for breaks that create open-circuit conditions.
    - *Document your findings!*

- Step **5** - **Test** and repair
    - Be safe! Remember -
        - capacitors can store electrical charge and give electric shocks;
        - inductors can store energy in a magnetic field and give electric shocks.
    - Take measurements around the circuit, but mentally predict what they should be.
    - In this way, home in on the problem component(s), and replace it(them), observing all safety procedures.
    - Next, re-test the system to ensure that no other faults exist.
    - *Document your findings!*

Introduction to fault finding

**And, in particular, for these exercises ...**

Remember the rules -

You are not allowed to:

- dismantle the circuit;
- isolate any component in it for testing.

- On the **working** circuit:
    - measure the power supply voltage, and notice the orientation;
    - think about the role of each component in the circuit;
    - trace the signal path through the circuit;
    - where appropriate, inject a signal from a signal source, and examine it as it passes through the system - document your investigation;
    - measure and record the DC voltage levels at the input and output of significant components.

- On the **faulty** circuit:
    - check the layout against the circuit diagram (which is correct);
        - are there any safety issues:
            - high voltages;
            - components connected the wrong way round - electrolytic capacitors, LEDs, transistors, diodes, ICs etc.;
        - are there any missing, or incorrect connections?
    - measure the power supply voltage at the beginning and end of the power rails.
    - measure and record the DC voltage levels at the input and output of the components you examined in the working system;
    - where appropriate, inject a signal from a signal source, and examine it as it passes through the system - document your investigation;
    - use your results to formulate a theory as to the problem;
    - document it, with reasons for your choice;
    - present your findings to the instructor.
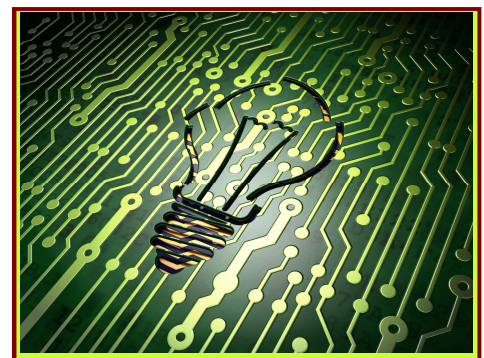
Introduction to fault finding

Specific issues ...

- **Resistor**:
  - can overheat if the current is too large - may indicate incorrect value - check the colour code.

- **Potentiometer**:
  - can overheat - may indicate incorrect connection;
  - has three terminals, but the Locktronics carrier has four, and so two are joined together.

- **Electrolytic capacitor**:
  - has a working voltage (printed on casing) - should be higher than power supply voltage;
  - is polarised - must be connected the right way round, open rectangle (+) on the symbol more positive than the filled rectangle.

- **Diode**:
  - can overheat if the current is too large for the power rating;
  - is polarised, and passes current in one direction only.
  Zener diode:
  - is used in reverse bias, (anode to 0V, cathode towards positive rail);
 - then has a constant voltage across it, for a range of current.
  LED:
  - needs a current-limiting resistor (built into the LED carrier);
  - normally drops around 2V, (anode to cathode,) when lit.

- **Transistor**:
  - has three terminals, emitter, base and collector, but the Locktronics carrier has four, and so two are joined to the base terminal, (often the input);
  - the arrow on the emitter indicates normal current flow direction;
  - 'npn' transistor - collector nearer the positive rail and emitter nearer the 0V rail;
  - 'pnp' transistor - the other way round;
  - is a current amplifiers - collector current is much bigger than base current;
  - has a voltage drop of around 0.6 to 0.7V between base and emitter when conducting;
  - has a collector - emitter voltage of
    - around 0.2V when saturated (turned on completely);
    - close to the full supply voltage when turned off completely.

- **Chip carrier**:
  - may require additional power supply connections.
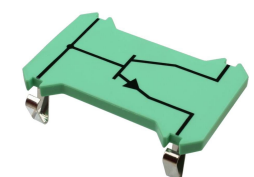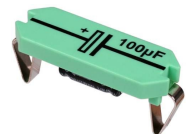
Introduction to fault finding

The tool-box

Multimeters

Digital versions, called DMMs (digital multimeters) are now much more common (and cheaper) than analogue multimeters. Essential items in the fault-finding toolbox, (two even better than one,) they allow you to measure both voltage and current. Although they offer this for both AC and DC, usually DC measurement is sufficient. (Symbols -   DC➔══ AC➔〰)

They also measure resistance, over a huge range, and may have a built-in continuity tester (giving an audible tone for low resistance). Other functions (e.g. transistor tester, capacitance meter and frequency meter) are useful, not essential.

Signal Source

In circuits that process AC signals, such as audio amplifiers, it helps to have a reliable, continuous AC signal source. The output frequency must match that expected by the circuit. A radio receiver needs a RF (radio frequency) signal source, whereas an audio amplifier needs AF (audio frequency). Signal sources, also known as signal generators, or function generators, usually have controls to adjust the output frequency and amplitude and may offer the ability to add a DC signal to the output, (known as a DC offset,) useful when testing amplifier circuits. Where there is a square wave output, it can be used to provide a clock signal for sequential digital circuits.

Oscilloscope

To test amplifier and many logic circuits, an oscilloscope is almost essential to view the varying signals.

It can be a peripheral device, attached to a computer, such as the 'PicoScope' in the photograph, or a self -contained device, either hand-held and portable, or mains- powered and bench-based.

A **logic analyser** is similar, but dedicated to looking at digital signals, whereas an oscilloscope uses an analogue-to-digital converter (ADC) to create accurate voltage/time graphs of the signal. The logic analyser can monitor hundreds of sig- nals, whereas most oscilloscopes look at a maximum of four.

Warning: An oscilloscope cannot be used in the same way as a multimeter (unless it is a self contained hand-held unit), since one probe terminal is connected to mains safety earth. This may lead to an unwanted short-circuit in the system under test.

Introduction to fault finding

When and how to use them ...

- **Multimeter**:
    - always useful, especially for measuring the DC voltage drop across terminals of a component - if there is a voltage drop, there must be a current flowing!
    Voltage measurement is non-intrusive - simply connect the multimeter, set to the correct voltage range, in parallel with the terminals.
    - current measurement can be tricky!
    Many multimeters have an internal fuse which may have 'blown' earlier, because of misuse. Current measurement involves breaking a connection and connecting the two ends created to the ammeter terminals on the multimeter.
    - can be used to measure the resistance of a component , or circuit, but only when it is isolated from the power supply. (To keep within the rules of these exercises, the only use for the resistance function is to measure the resistance between the power rails when the power supply is disconnected. This allows you to distinguish between an open-circuit and a short-circuit.)

- **Signal source**:
    - provides a test signal for a circuit which processes analogue signals.
    - to begin with, keep the amplitude small, to avoid saturating transistors.
    - start with a frequency that is not challenging for the circuit.
    For example, with audio systems, the expected frequency range is from 20Hz to 20kHz. Some systems may struggle to deliver performance at either end of this range, so initially choose a mid-range frequency such as 1kHz.
    - where there is a choice of signal type, e.g. sine, triangle, square, choose sine wave.
    It is the simplest, containing just a single frequency, whereas the others include a series of high frequency components.
    - where the signal generator provides DC offset, make sure that it is set to zero, unless you specifically want it (to provide DC bias for a transistor, for example.)

- **Oscilloscope**:
    - provides a voltage/time graph of time-varying signals, such as sine waves.
    - is used much like the multimeter, with its probes connected in parallel with the component terminals under investigation.
    However, ***heed the warning*** on the previous page, that one probe may be connected to 0V, and may short-circuit the signal or power supply in the system under test.
    - the time base is set to match the frequency of the signal. For example, when using a 1kHz sine wave signal, a time base setting of 0.5ms/cm is suitable.
    - start with the 'Y-amplitude' (names vary) or vertical voltage sensitivity set to a fairly high value, such as 5V/cm. It can be adjusted down when the signal is found and stable.
    - may provide a file storage facility for you to preserve the signal for later inclusion in your documentation.

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Exercises

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Exercise 1
Logic System

Electronic logic systems make decisions based on information supplied in the form of binary numbers, a series of 0's and 1's. The system studied here could be used to control a car alarm. When any sensor is activated, the alarm is triggered. Similar systems control household objects, like toasters, microwaves or even Christmas lights. Combined together in huge numbers, these logic functions form large scale digital systems, like computers and digital televisions.
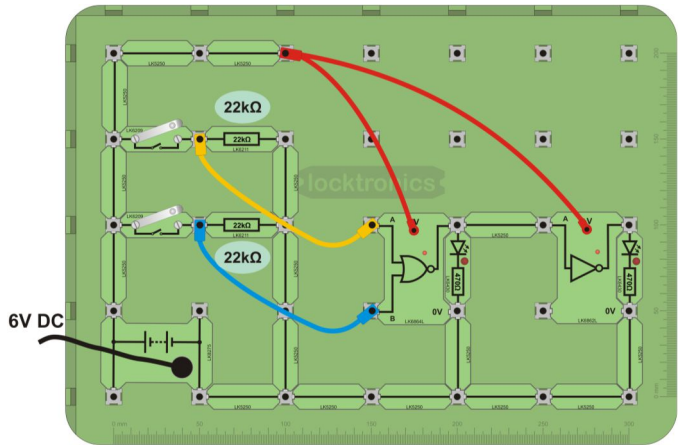

Over to you:

In this worksheet we are using combinational logic; a NOR gate and a NOT gate. Build the circuit as instructed below and test what the switches do. Note down the sequence so that when a fault is introduced you can determine which area of the circuit is no longer working.

Circuit diagram:

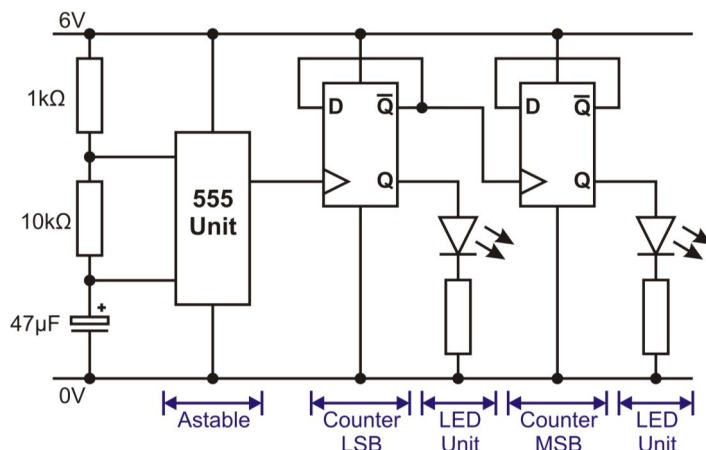Layout diagram:

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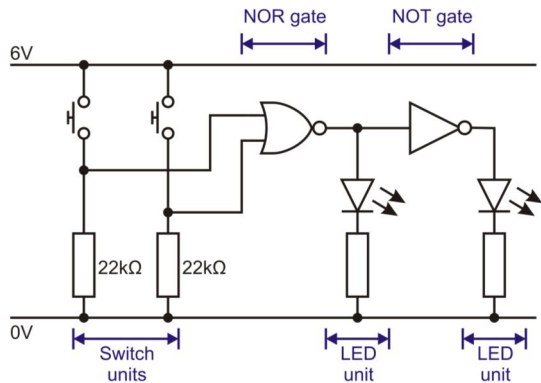
Exercise 2
Counter

The picture shows a machine that counts bank notes - something that must be done accurately! Previously, this was done by a cashier, but humans make mistakes, and can count only slowly. This counter can count a thousand notes each minute - precisely!

Over to you:

In this worksheet we are using D-type flip-flops to create a simple counter. Connect the circuit and observe its operation. Before a fault is introduced, ensure you correctly understand its operation and have noted down data from any relevant measurements. Allow a fault to be introduced and determine which area of the circuit is no longer working, and why.

Circuit diagram:

Layout diagram:
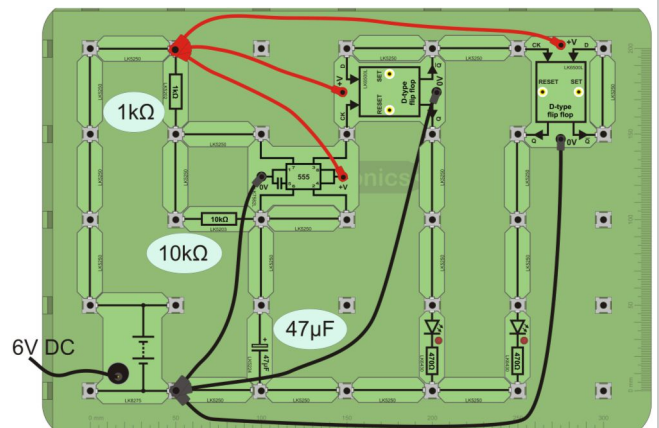
Considerations:

- This is a two-stage binary counter, capable of counting up to 11_2 (=3 in decimal.) Each stage is formed by a D-type bistable. The first generates the least-significant-bit, (LSB), meaning the 'units' value. The second stage generates the most-significant-bit, (MSB).

- The clock pulses are provided by a 555 timer in astable mode. The pulse frequency is set at around 1.6Hz, by the 1kΩ and 10kΩ resistors, and the 47μF capacitor.

- The output of the counter is displayed on the LEDs. A LED lights when the output of that stage is logic 1.

- The 'Set' and 'Reset' inputs on the D-type bistables are not needed in this application.

Don't forget the rules:
You are not allowed to dismantle the circuit or isolate any component in it for testing.

Exercise 3
DC Power Supply

A DC power supply converts high-voltage AC electrical power, generated and transmitted by power stations, into low-voltage
DC for electronic systems such as computers, mobile phones and e-readers. This approach delivers much cheaper electrical energy than using non-rechargeable batteries.

This exercise looks at a circuit at the core of many of these DC power supplies, designed to deliver an output voltage which is:

- smooth (no AC components),
- steady (same voltage for all currents),
- immune to small changes in the AC supply voltage.

Over to you:

In this worksheet we will convert an AC signal into a 'smoothed' DC output, which will power our bulb.

We are no longer working only with digital signals, but with AC also, so it's essential you use an oscilloscope to help analyse the circuit operation. Ensure you fully understand the circuit before a fault condition is introduced. Work to diagnose the fault based on knowledge of the working example.

Circuit diagram:
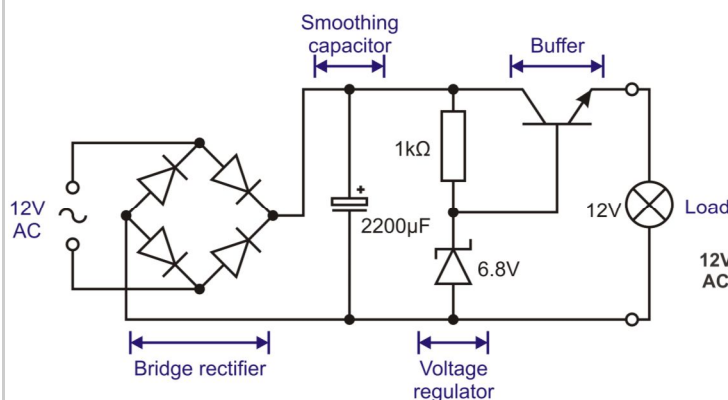
Layout diagram:
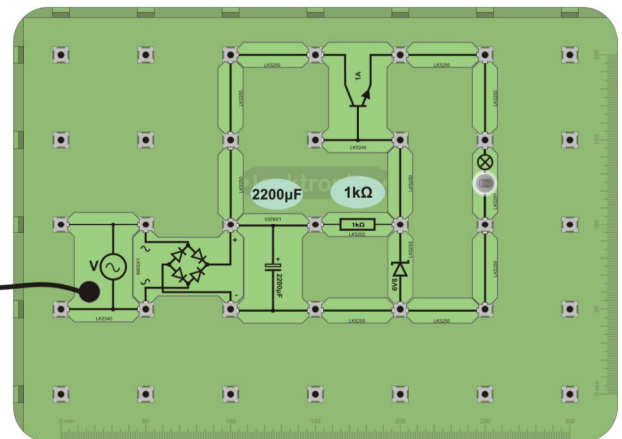
Considerations:

- The bridge rectifier is the component that converts AC to DC voltage.
- Despite the rectifier, a smoothing capacitor is used to 'smooth' the DC output waveform in the circuit.
- The voltage across the Zener diode should be clamped at 6.8V.
- You will lose a small voltage across the transistor base-emitter junction. Take this into consideration.

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Exercise 4
Transistor amplifier

Fault Finding
Student Notes

Many sensors - microphones, opto-sensors, thermocouples etc. produce signals which are too small to use directly. Amplifiers are used to increase the amplitude of these signals, while retaining their other characteristics.

At the heart of most of these amplifiers is the transistor, a tiny solid-state device able to amplify signals by using a small current to control a much bigger one.
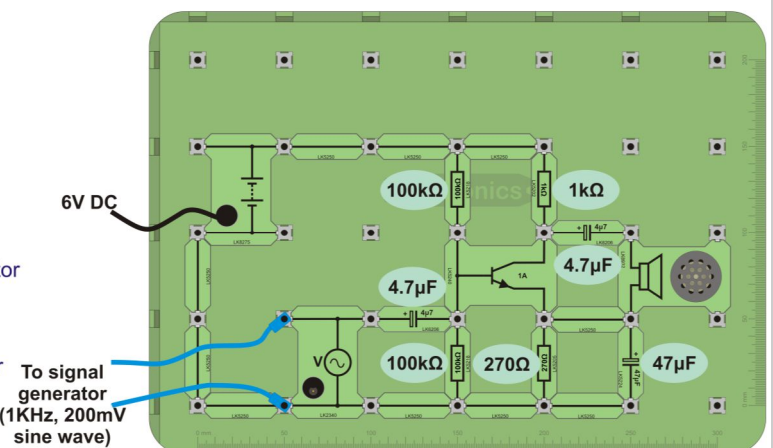
Over to you:

In this worksheet we are using a transistor to amplify our small 200mV signal. We want to be able to produce an audible noise on our speaker. Connect the circuit as shown in the images and use a signal generator to provide an AC signal. Ensure you fully understand the circuit operation before you introduce any faults.

Circuit diagram:
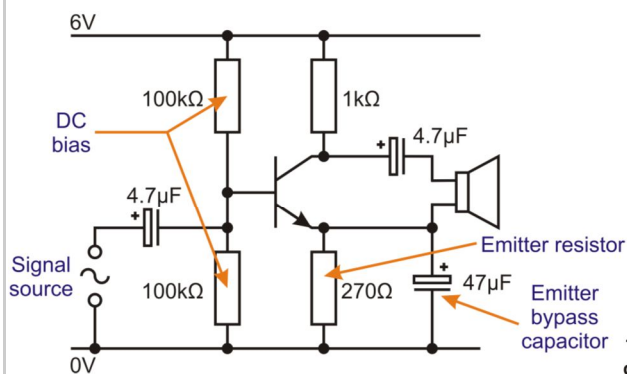
Layout diagram:

Considerations:

• The two 100kΩ resistors form a voltage divider to provide the DC bias voltage at the base of the transistor so that it conducts even when no signal is present. As a result, the output voltage should be around half of the supply voltage when there is no signal present.

• The 270Ω emitter resistor provides negative feedback that keeps the amplifier performance stable. Should the output (collector) current increase, the voltage across this resistor increases, reducing the DC bias voltage at the base and so reducing the output current.

• The emitter resistor reduces the voltage gain of the amplifier. The emitter bypass capacitor (47μF) allows the AC signal current to flow around the emitter resistor, preserving AC voltage gain.

• The two 4.7μF capacitors block any DC voltages present in the signal from affecting the operation of the transistor.

Exercise 5
Motor controller

The simplest motor controller is a switch - the motor is on or off. For more sophisticated motor speed control, a system like the one in this exercise can be used.

Speed controllers are used in a wide range of appliances, from washing machines, DIY drills and even toy car racing games.

Over to you:

In this worksheet we have created a circuit that allows us to control both the direction and speed of a motor using a simple potentiometer. Analyse the circuit, note its normal operating conditions and introduce a fault.

Circuit diagram:

Layout diagram:
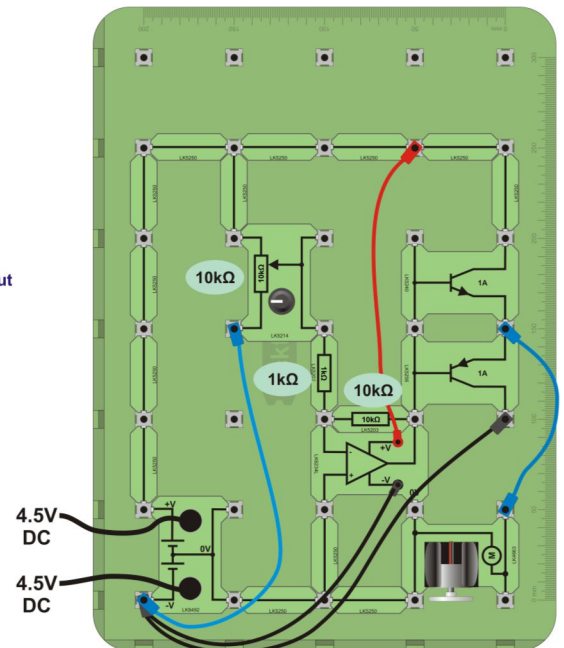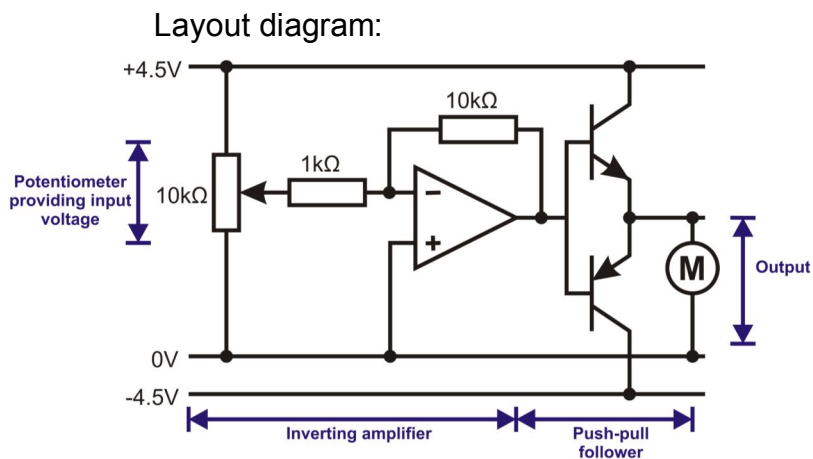
Considerations:

- The 10kΩ potentiometer can change the input voltage within the range +4.5V to -4.5V.

- The inverting amplifier has a voltage gain of -10, so the output should be ten times bigger than the input voltage and inverted (provided the output is not saturated).

- The op-amp requires a positive supply of +4.5V, and a negative supply of -4.5V in this arrangement. Its non-inverting input ('+') is connected to 0V.

- The push-pull follower copies this voltage to the motor (apart from dropping 0.7V between base and emitter of the conducting transistor.)

- When the output of the inverting amplifier is bigger than +0.7V, the NPN transistor conducts. When it is less than -0.7V (e.g. -1.0V,) the PNP transistor conducts. The small current drawn from the inverting amplifier controls a much bigger current flowing from the power supply to the motor.

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Instructor guide

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# Instructor Guide

Fault Finding

This course introduces some of the techniques involved in troubleshooting faulty electronic systems.

In this field, nothing is more valuable than experience. The exercises that make up the course aim to start off the process of building that experience.

The student is allowed to study a working circuit, built using Locktronics, and is then given a faulty version to investigate. This tests their understanding of electronics, as well as their powers of logical thought and deduction. There is no time to look up notes, or use an internet browser!

To make it more realistic, the student is not allowed to:

- dismantle the circuit;
- isolate any component in it for testing.
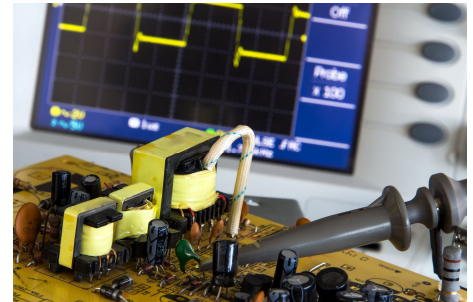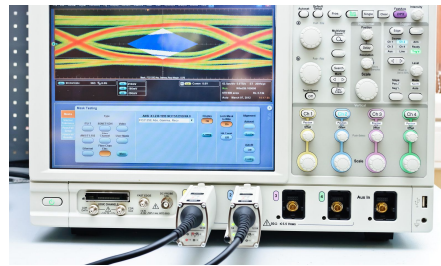
The Importance of Fault Finding

- Safety -
    - Safe plant operation:
      The electronic system may play a part in the safe running of a bigger system. Without it, the bigger system must be shut down.
    - Fire risk:
      The fault might risk causing a fire, bringing even more damage to the organisation.
- Economic -
    - Loss of production:
      The organisation needs the electronic system to function again quickly. It is losing money while the system is 'down'. The longer it takes to repair, the more money the organisation loses.
    - Repair costs:
      An engineer is being paid to repair the system. The longer it takes, the more that repair costs. The labour costs are likely to far outweigh the cost of the components needed. Nevertheless, only defective components must be replaced.

Speed is essential, for the reasons given above. The engineer will not have time to research topics on the internet, read books or telephone friends! There must be a logical, practised sequence of fault diagnosis, carried out in proficient manner.

One such sequence is outlined on the next page.

Instructor Guide

The student handout includes the following fault-finding guide:

Five Steps to Fault Finding

- Step **1** - **Prepare**
    - Are there any safety issues?
    - What test equipment do you intend to use?
    - Document your findings!

- Step **2** - **Observe**
    - Are there signs of damage - overheated components, melted insulation, frayed wire, bad solder joints?
    - Can you smell burning or overheating?
    - Take voltage measurements from a working circuit.
    - Take voltage measurements from the faulty circuit to compare.
    - Document your findings!

- Step **3** - **Identify** the problem subsystem
    - Which subsystems are operating correctly?
    - Where does the problem seem to lie?
    - Document your findings!

- Step **4** - **Suggest** possible causes
    - Check likely components:
        - switches, fuses and bulbs tend to wear out or burn out.
    - Check possible components:
        - motors, relays, inductors - components with coils - may overheat.
    - Check connections:
        - look for faulty connections or loose contacts which may offer high resistance.
        - look for stray connections that can short-circuit.
        - look for breaks that create open-circuit conditions.
    - Document your findings!
- Step **5** - **Test** and repair
    - Be safe! Remember -
        - capacitors can store electrical charge and give electric shocks;
        - inductors can store energy in a magnetic field and give electric shocks.
    - Take measurements around the circuit, but mentally predict what they should be.
    - In this way, home in on the problem component(s), and replace it, observing all safety procedures.
    - Next, re-test the system to ensure that no other faults exist.
    - Document your findings!

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Instructor Guide

Evaluation

In real life, the engineer should try to determine the reason for the malfunction.

- Did the component fail due to age?
- Were factors in the working environment responsible for the failure?
- Did it fail due to improper use?
- Is there a flaw in the design that caused the failure?

Detailed documentation is invaluable in tackling these questions. The student should be encouraged to present a 'diary' of each exercise, in agreed format. This can form part of the eventual assessment of the module.

Common faults and their symptoms:

- short circuit:
  - zero volts between positive and 0V power rails everywhere;
  - power supply output voltage restored when the circuit is removed from the supply;
  - excessive current drawn from power supply;
  - the fuse protecting the circuit may 'blow';
  - zero ohms between power rails, (with circuit removed from power supply.)
- open circuit:
  - zero volts between positive and 0V power rails at one end of the circuit, but not the other;
  - part of the circuit may function while another part does not;
  - reduced or zero current drawn from power supply.
- reverse connection:
  - can occur in 'polarised' components - ones which only work when connected the 'right' way round, e.g. diodes, LEDs, transistors and some capacitors;
  - can be the result of the power supply or battery being connected to the circuit the 'wrong' way round;
  - produces an unusual voltage drop across the component.
- incorrect value or faulty component:
  - an incorrect value can be identified by examining the component against that specified in the circuit diagram;
  - a faulty component may show signs of overheating or mechanical damage;
  - both produce an unusual voltage drop across the component.
- incorrect component:
  - can be identified by examining the component against that specified in the circuit diagram;
  - produces an unusual voltage drop across the component.

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Instructor Guide

Delivering the module:

There are a number of ways in which the module can be delivered, depending on the type of institution, class size, age and experience of the students, and philosophy of the instructor. The approach will be developed and honed each time it is offered. Above all, it should be seen by the students as an enjoyable but challenging experience - fun!

Before starting the exercises, students should be familiar with the particular test equipment available to them. Depending on their previous experience, this may require some preliminary practical work, especially with a signal generator and oscilloscope.

It is suggested that students work in pairs, with a partner of similar ability. In this way, both should contribute in equal amounts, and work at a level that both understand. Each exercise could be a timed activity, adding to the challenge and mirroring real life.

In tackling an exercise, students should be encouraged to investigate and take measurements on a working version of the system first. For some, initially, this may require some guidance from the instructor. The students may be given a document template on which to record these measurements.

The instructor, unseen by the students, then introduces a fault into the circuit. Suggested faults are listed later in this Instructor Guide. Some of these are less challenging then others. Again, knowing the capabilities of the students, the instructor can select an appropriate fault, or series of faults. It is always important that the student succeeds in at least part of the challenge.

Be aware that, in testing the modified circuit, the student may unwittingly introduce further faults, or damage components etc. If the exercises are being done as a 'circus', the instructor needs time to check that the original, working circuit still works before handing it to the next group.

The documentation accompanying the module includes a student handout, describing the five step general approach to fault finding, described earlier, and outlining the available range of test equipment. The instructor may decide that students take away a copy of this for their records.

The exercise sheets themselves outline possible applications for the circuit, give the circuit and layout diagrams and give advice on what test equipment is needed. There is no specific guidance on test procedure, deliberately. The instructor is best placed to determine how much help is needed, knowing the students' strengths and weaknesses. One approach is to hold a 'briefing'/brainstorming session with the class before the practical work starts.

The students do not need their own copies of the exercise sheets themselves. However, they should produce a record of the tests they carried out, with results, in attempting to discover the faults. This builds up into a portfolio of work, useful for assessment and external verification of their practical work. A circuit diagram, but not a layout diagram, is an important constituent. Photographs may play a role in this document.
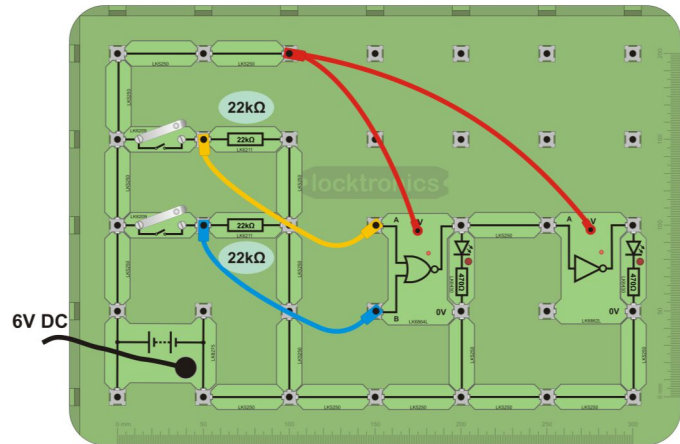
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Exercise 1
Logic System
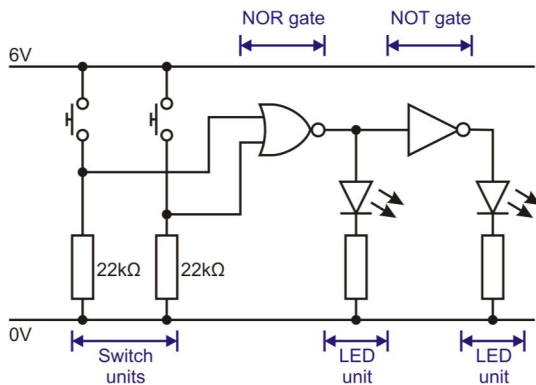
Circuit diagram:

Layout diagram:

Equipment Needed;

- 6V DC PSU
- DMM

Faulty carriers required:

- LK6990 - Faulty LED carrier (reverse biased)
- LK5582 - Faulty link carrier (open circuit)
- LK7550 - Faulty cable (open circuit)
- LK6995 - Faulty switch (short circuit)
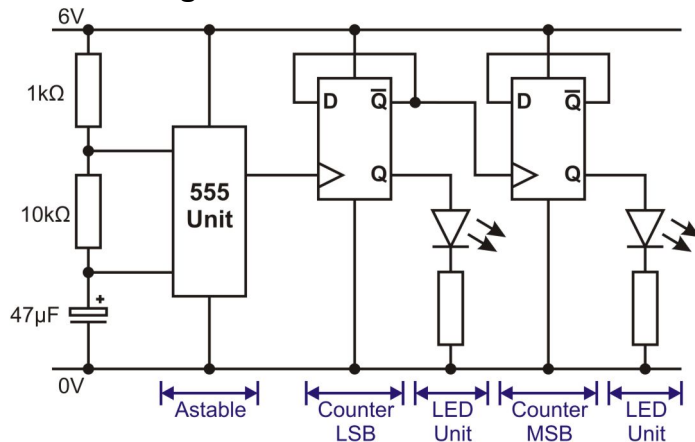
Possible faults:

- Fault 1; Connect the faulty LED carrier (LK6990)
  - LED will no longer light
- Fault 2; Place the open-circuit carrier link between NOR and NOT carriers (LK5582)
  - NOR gate will work correctly, NOT gate will always be ON
- Fault 3; Use open-circuit cable between lower switch and NOR input 'B' (LK7550)
  - Lower switch will no longer do anything. Upper switch will work as normal
- Fault 4; Connect the always-closed faulty switch instead of the top switch (LK6995)
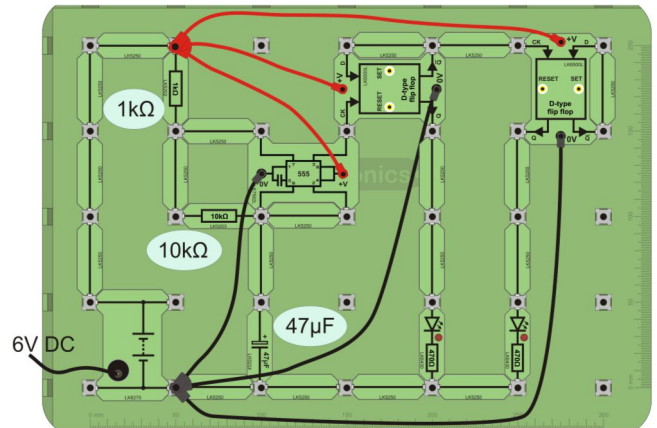 - NOT gate will always be 'ON', neither switch will do anything

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Exercise 2
Counter

Circuit diagram:

Layout diagram:

Equipment Needed;

- 6V DC PSU
- DMM
- Oscilloscope may be useful to observe the 555 timer output signal

Faulty carriers required:

- LK6990 - Faulty LED carrier (reverse biased)
- LK5582 - Faulty carrier link (open circuit)
- LK6945 - Faulty 555 timer IC (pin 8 open circuit)
- LK6985 - Faulty 1kΩ resistor carrier (open circuit)
- LK6950 - Faulty 47µF capacitor carrier (4.7µF)

Possible faults:

- Fault 1; Connect the faulty LED carrier (LK6990)
  - LED will no longer light
- Fault 2; Connect the faulty link carrier between pins 2 and 6 of the 555 timer carrier (LK6945)
  - LEDs will stay in a fixed state or change at irregular intervals
- Fault 3; Connect the faulty 555 timer carrier (LK6945)
  - Pin 8 is V_{cc} (power) so circuit will no longer work. LEDs may remain powered in last sequence
- Fault 4; Connect the faulty link carrier between the two flip-flops (Q' and CK) (LK5582)
  - Flip-flop 1 (LSB) will work correctly, Flip-flop 2 (MSB) will no longer work and may flicker
- Fault 5; Connect the faulty link carrier between the Q' and D of flip-flop 1 (LK5582)
  - Circuit may still work, but speed will slow and it will operate at irregular intervals
- Fault 6; Connect the faulty 1kΩ resistor carrier (LK6985)
  - Open circuit carrier, so circuit will no longer work
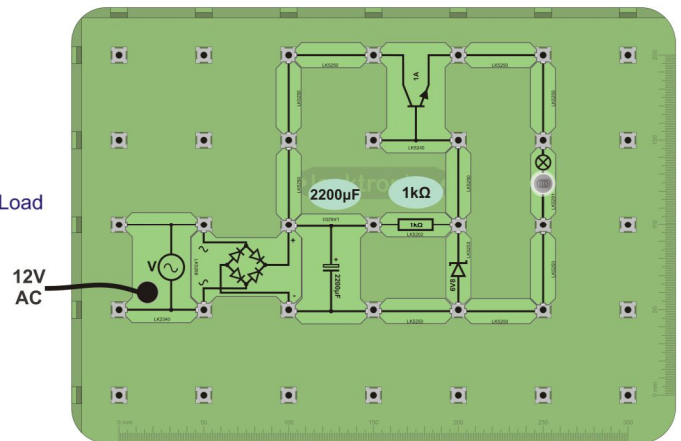- Fault 7; Connect the faulty capacitor carrier - may need power reset to activate fault (LK6950)

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Exercise 3
DC Power Supply

Fault Finding
Instructor Guide

Circuit diagram:
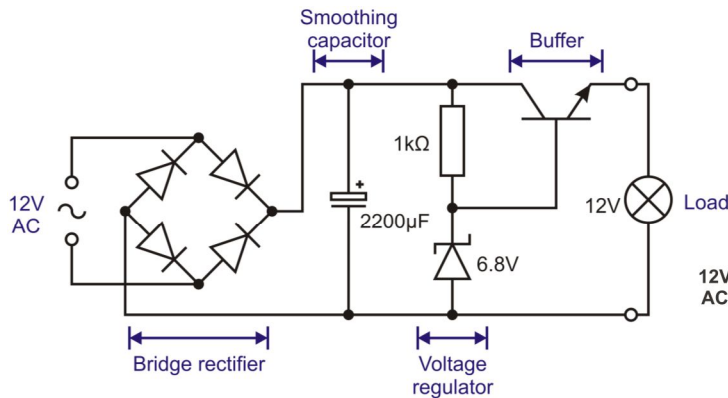
Layout diagram:

Equipment Needed;

- 12V AC PSU
- DMM
- Oscilloscope to monitor smoothing capacitor

Faulty carriers required:

- LK6925 - Faulty bridge rectifier (one diode is reverse biased)
- LK6930 - Faulty Zener diode (short circuit)
- LK0665 - Faulty Zener diode (reverse biased)
- LK6940 - Faulty transistor (open circuit base)
- LK3192- Faulty transistor (short between base-emitter)
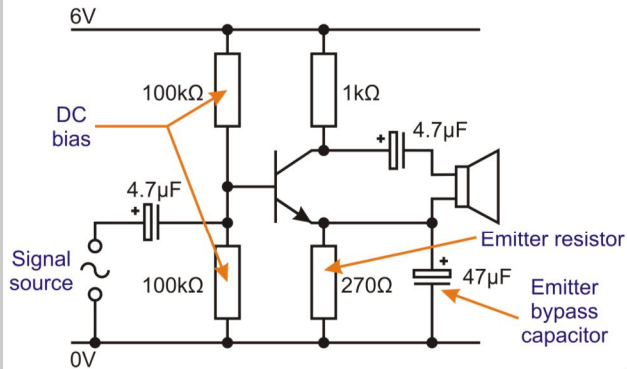- LK6970 - Faulty 2200µF capacitor carrier (4.7µF)

Possible faults:

- Fault 1; Connect the bridge rectifier incorrectly (rotate rectifier 180°)
  - Circuit will not work at all
- Fault 2; Connect the faulty bridge rectifier (LK6925)
  - Circuit will not work at all
- Fault 3; Connect the faulty Zener diode (LK6930)
  - Bulb will not illuminate. Transistor is 'off' as no V_{BE}, so all current goes through 1kΩ res
- Fault 4; Connect the faulty Zener diode (LK0665)
  - Bulb will not illuminate
- Fault 5; Connect the faulty transistor (LK6940)
  - Bulb will not illuminate as transistor is off
- Fault 6; Connect the faulty transistor (LK3192)
  - Bulb will not illuminate. Transistor is 'off' as no V_{BE}, so all current goes through 1kΩ res
- Fault 7; Connect the faulty capacitor carrier (LK6970)
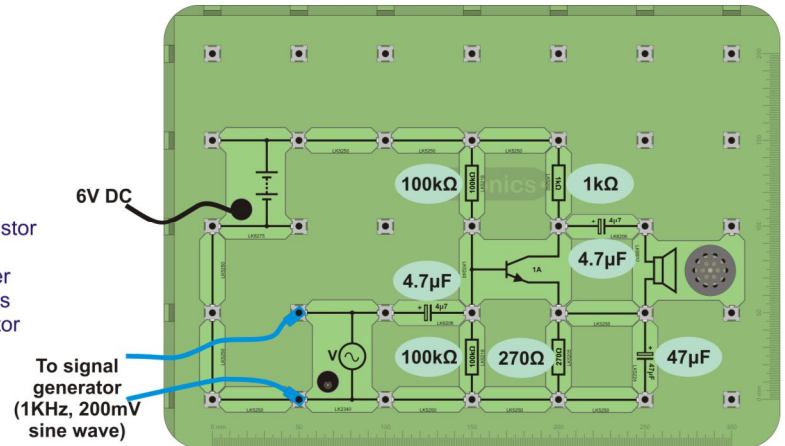 - Visually unchanged, however, the DC ripple is much larger across capacitor. Use an oscillo-

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Exercise 4
Transistor amplifier

Circuit diagram:

Layout diagram:

Equipment Needed;

- 6V DC PSU
- DMM
- Oscilloscope to monitor smoothing capacitor
- Signal generator set to 1kHz, 200mV$_{pp}$ sine wave output

Faulty carriers required:

- LK6940 - Faulty transistor (open circuit base)
- LK3192 - Faulty transistor (short between base-emitter)
- LK5582 - Faulty carrier link (open circuit)
- LK6950 - Faulty 47µF capacitor (4.7µF)
- LK6985 - Faulty 1kΩ resistor carrier (open circuit)
- LK6955 - Faulty 100kΩ resistor carrier (1kΩ)

Possible faults:

- Fault 1; Connect the faulty transistor (LK6940)
  - Speaker does not sound
- Fault 2; Connect the faulty transistor (LK3192)
  - Transistor is 'off' as no V_{BE}
- Fault 3; Connect the faulty link carrier (LK5582) between emitter and speaker
  - Speaker will sound, but quietly as AC signal will not feedback through system
- Fault 4; Connect the faulty capacitor (LK6950)
  - Speaker sounds same as normal, but students should monitor output on oscilloscope
- Fault 5; Connect the faulty 1kΩ resistor (LK6985) on transistor collector
  - Transistor is turned ON, but collector is open circuit, so no current will pass through transistor
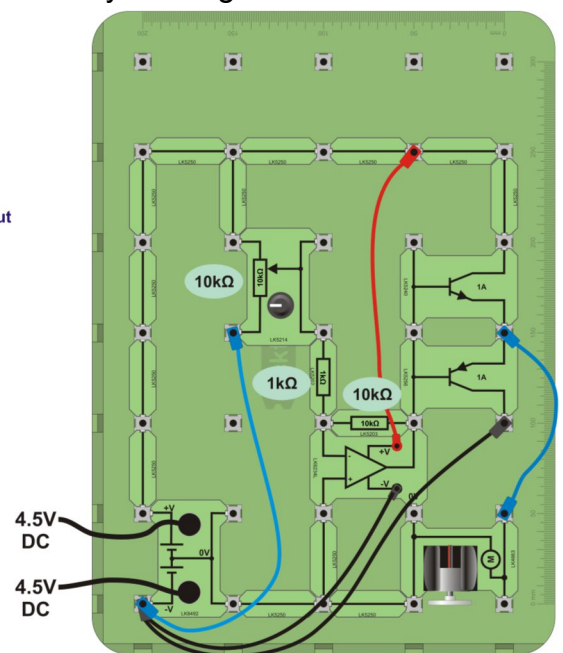- Fault 6; Connect the faulty 100kΩ resistor (LK6955) between transistor base and 6V rail

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Exercise 5
Motor controller

Fault Finding
Student Notes

Circuit diagram:
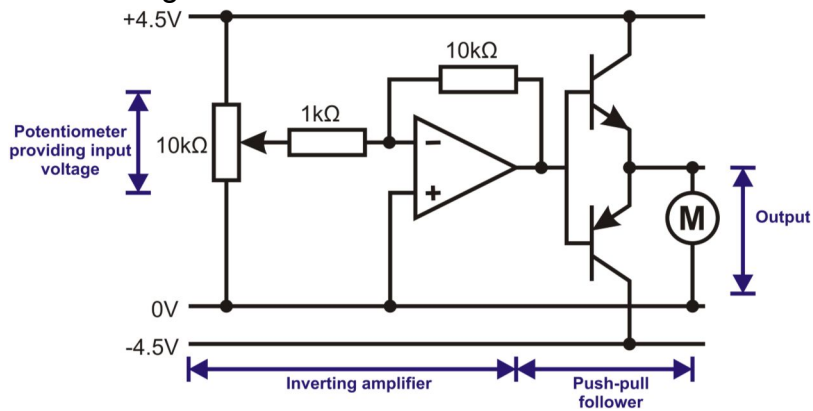
Layout diagram:

Equipment Needed;
- 2 x 4.5V DC PSU
- DMM

Faulty carriers required:
- LK7550 - Faulty cable (open circuit)
- LK5582 - Faulty carrier link (open circuit)
- LK6985 - Faulty 1kΩ resistor carrier (open circuit)
- LK6980 - Faulty 10kΩ resistor carrier (10Ω)
- LK6940 - Faulty transistor (open circuit base)
- LK6935 - Faulty op-amp (pin 6 open circuit)

Possible faults:
- Fault 1; Connect the faulty blue open circuit cable (LK7550) between potentiometer and –4.5V
  - Motor will only spin counter clockwise, at a fixed speed
- Fault 2; Connect the faulty link carrier (LK5582) on top power rail (+4.5V)
  - Motor will only spin counter clockwise, but the potentiometer will vary the speed
- Fault 3; Connect the faulty cable (LK7550) between transistor outputs and motor
  - Voltages will all be correct, but motor will not spin
- Fault 4; Connect the faulty 1kΩ resistor (LK6985)
  - The motor will not spin, the pot will still change the voltage, but it will not get into the op-amp
- Fault 5; Connect the faulty 10kΩ resistor (LK6980)
  - The motor will not spin due to incorrect feedback loop resistance
- Fault 6; Connect the faulty transistor with open base (LK6940)
  - The motor will only spin counter clockwise, as NPN transistor does not work
- Fault 8; Connect the faulty op-amp (LK6935)
  - The motor will only spin counter clockwise as output pin is open circuit. Current will flow through 10k resistor and switch on NPN transistor.

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Fault Finding Appendices

Apparatus for this course

All of the Locktronics apparatus for this course is available from Matrix TSL—product code LK3566. This contains six trays of apparatus—one tray for each of the worksheet exercises, plus an additional tray containing the 'faulty' carriers that the tutor will use to introduce faults into the circuits. The 'faulty' components are marked on their underside to enable the tutor to identify which carriers are required for each experiment.

The apparatus trays are complete with all leads and power supplies required for the experiments. However, there is some equipment which is not supplied, to avoid extra cost and duplication of apparatus that is commonly found in many electronics laboratories.

In addition to this apparatus, you may also require…
- A multimeter capable of measuring voltages up to 12V DC and AC, with a continuity test function.
- An oscilloscope for displaying AC waveforms. Only one trace is required.
- A signal source capable of generating up to 1V peak-to-peak at 1kHz

Version Control

Version	Released	Notes
LK9333-80-01	2015 Jun 02	First public release
LK9333-80-02	2015 Oct 23	Changes to worksheet order and circuit schematics
LK9333-80-03	2017 Jul 31	Changed to use the LK7582 555 carrier