MATRIX | locktronics™



TRANSISTOR AMPLIFIERS

CP4403

Inspiring The Next Generation Of Engineers

www.matrixtsl.com

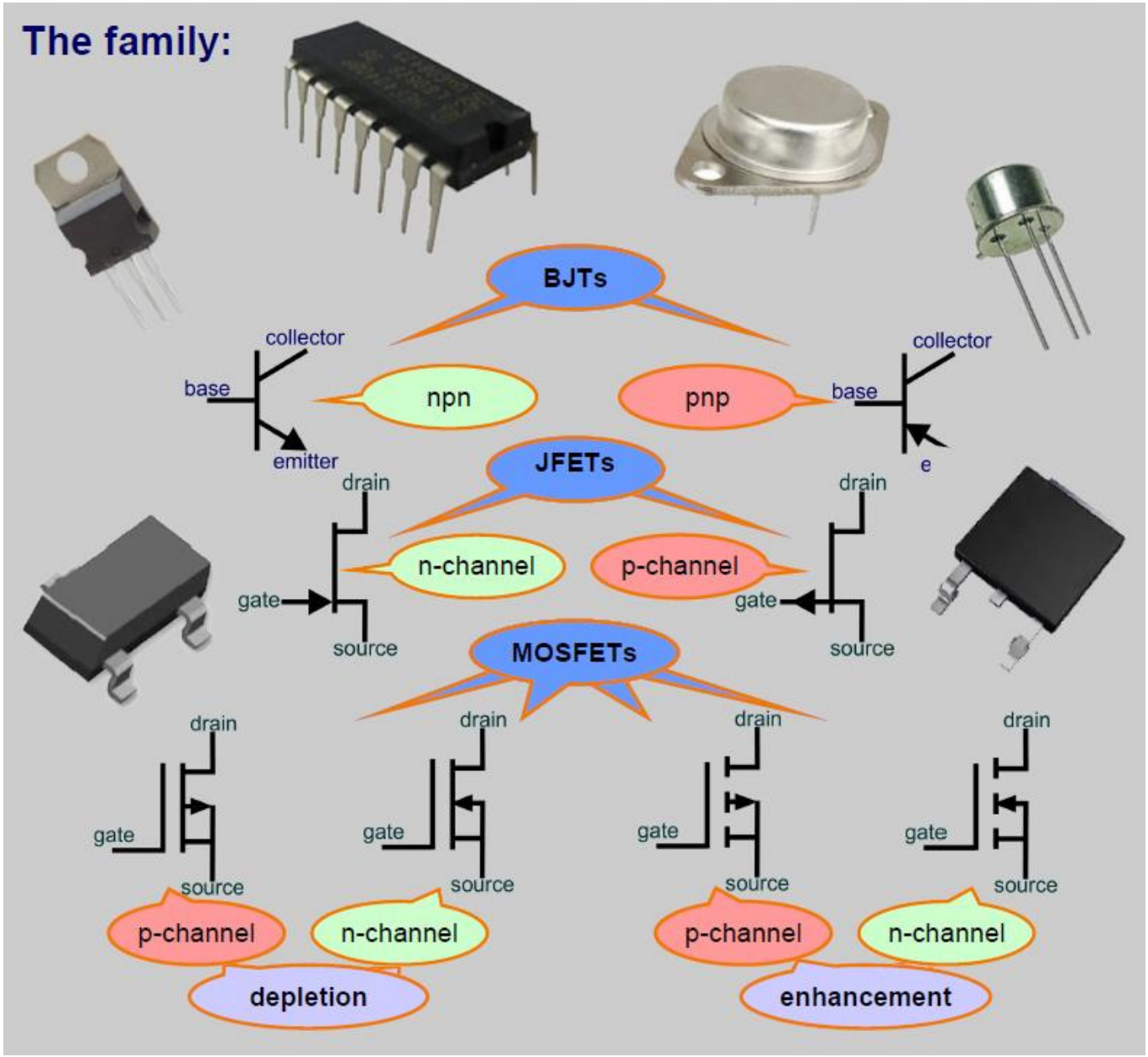
Copyright © 2023 - 2026 Matrix Technology Solutions Limited

Contents

Introducing transistors	3
Worksheets	5
Worksheet 1 - Testing BJT transistors	6
Worksheet 2 - BJT transfer characteristics	8
Worksheet 3 - BJT output characteristics	11
Worksheet 4 - Transistor as a switch	13
Worksheet 5 - Transistor as an amplifier	15
Worksheet 6 - Transformer-coupled amplifier	17
Worksheet 7 - Stabilised common-emitter amplifier	19
Worksheet 8 - Emitter follower behaviour	21
Worksheet 9 - Emitter follower - AC behaviour	23
Worksheet 10 - Push-pull follower	25
Worksheet 11 - FET transfer characteristics	27
Worksheet 12 - FET output characteristics	29
Worksheet 13 - MOSFET switch	31
Worksheet 14 - MOSFET applications	33
Student handout	35

Copyright © 2023 - 2026 Matrix Technology Solutions Limited

Introduction



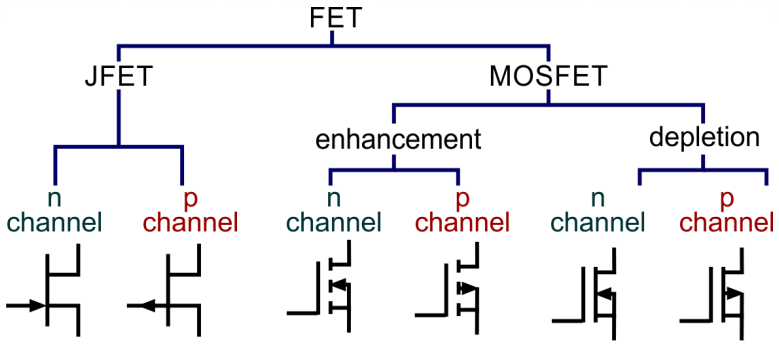
The hardware:

- Bipolar junction transistors (BJT) come in two types, npn or pnp, depending on which impurities are used to 'dope' the single crystal of silicon it is made from.
- Each has two p-n junctions, (n-p p-n) for the npn and (p-n n-p) for the pnp. These are made by diffusing impurities through a photographically-reduced mask into different sections of the silicon.
- There are three regions in the transistor, called collector, base and emitter.
- Various 'leaded' and 'surface-mount' packages, such as TO92 and SOT-23, are used to house the silicon crystal. Some are shown in the photographs at the top of the page. The manufacturer's data sheet may be needed to identify which is which.

Copyright © 2023 - 2026 Matrix Technology Solutions Limited

Introduction

Field-effect transistors (FETs) have a bigger family than BJTs as the diagram illustrates:



- All share the same principle - the resistance of the conducting channel between drain and source depends on the voltage applied to the gate terminal.
- The family has two branches - JFETs and MOSFETs. In both, the gate terminal is insulated from the conducting channel. The mechanism behind this is different:
- In JFETs (Junction FETs) - it is a reverse-biased p-n junction;
- In MOSFETs (Metal-Oxide-Silicon FETs), it is a thin layer of insulating material.
- In general, n channel FETs switch faster than p channel devices because electrons move faster through the silicon lattice than do holes.

MOSFETs:

- Are further subdivided into depletion mode and enhancement mode types.
- Depletion mode devices are similar in performance to JFETs in that when the gate voltage, V_{GS},is zero, the drain current is at its maximum. As V_{GS} increases, the drain current decreases.
- Enhancement mode MOSFETs have the opposite behaviour - no current flows when V_{GS} is zero but it increases as V_{GS} increases.
- switch faster than BJTs because the drain current is a flow of majority carriers, (electrons in a n channel device, holes in a p channel device,) not minority carriers. Minority carriers can experience delays in passing through the silicon lattice.
- Have an extra terminal, the 'Body', usually connected internally to the source.

All FET devices are possible but production issues mean that p-channel depletion MOSFETs are rare. The most common format is the n-channel enhancement MOSFET.

BJT vs FET:

- The FET gate is insulated from the remainder of the device, as described above. As a result, the input current is minute. This leads to FETs being described as voltage-controlled - the drain current is controlled by the gate **voltage.**
- The BJT is a **current** amplifier - a small base current controls a much larger collector current. It is a current-controlled device. The input current flows through a forward-biased p-n junction - a relatively small resistance. The relatively large input current means that the BJT has relatively large input power requirements.

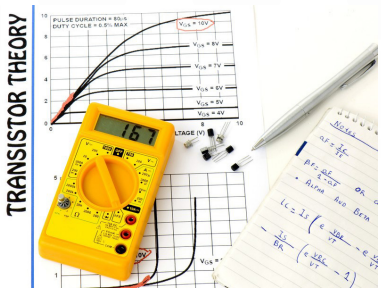
Copyright © 2023 - 2026 Matrix Technology Solutions Limited

WORKSHEETS

Copyright © 2023 - 2026 Matrix Technology Solutions Limited

WORKSHEETS

Worksheet 1 - Testing BJT Transistors

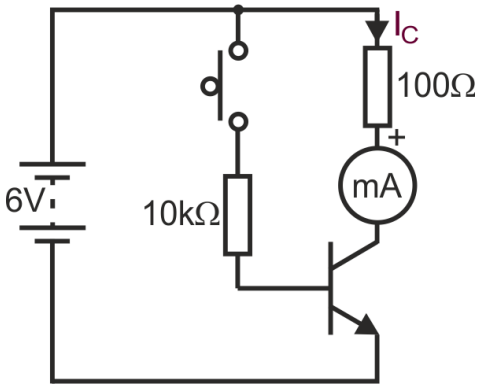


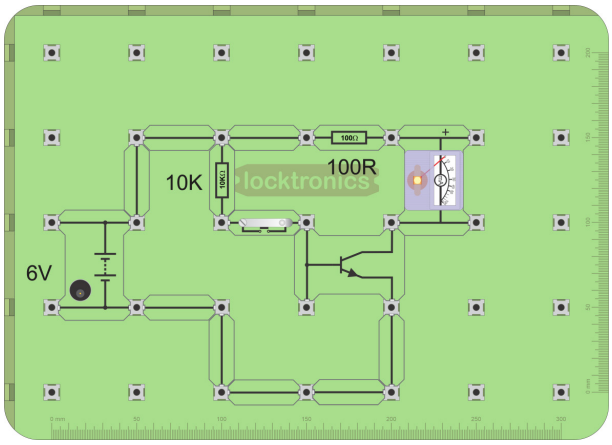
Originally called a 'transfer resistor', the transistor is found in almost every electronic circuit, either as a discrete component or within an integrated circuit (IC). ICs contain many hundreds, thousands or even millions of transistors.

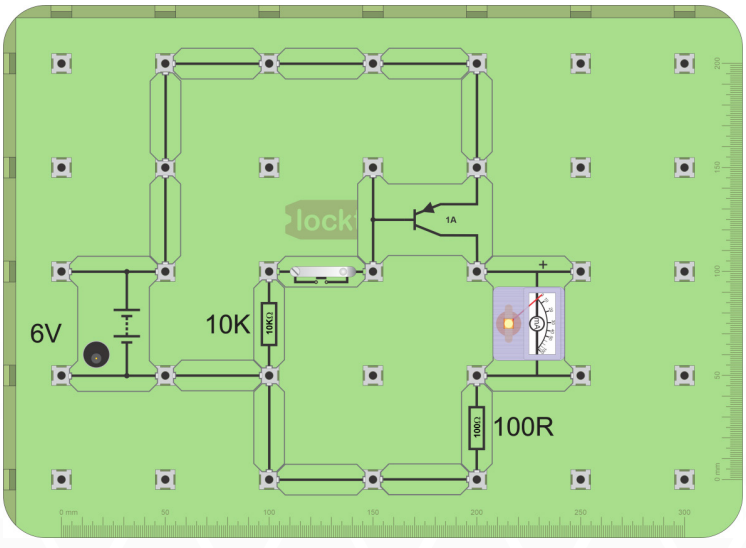
This worksheet shows how to carry out basic checks on BJT (bipolar junction transistors) - both npn and pnp transistors.

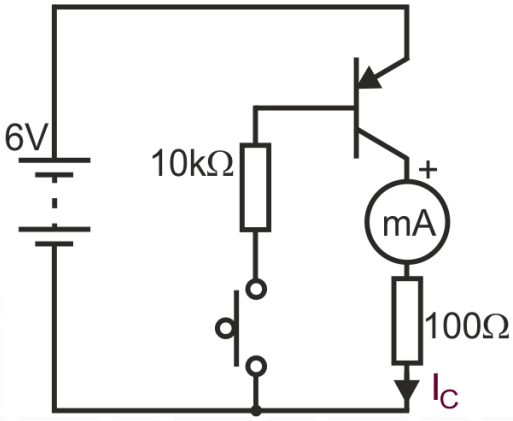
Over to you:

- Build the circuit shown here designed to test npn transistors. A suitable layout is shown.
- Set the DC power supply to output 6V.
- Measure the current flowing in the collector.
- Record the collector current in the table below.
- Press the switch and hold it closed.
- Measure and record the new current.
- Now, build the other circuit, to test the pnp transistor.
- Compare this circuit to the previous one.
- Repeat the same procedure as for the npn transistor.
- Record the results in the table.









Copyright © 2023 - 2026 Matrix Technology Solutions Limited

WORKSHEETS

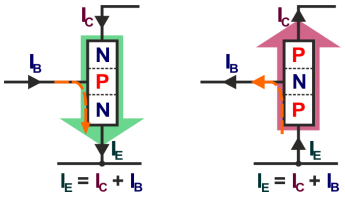
Worksheet 1 - Testing BJT Transistors

Switch	Base current I_B	Collector current I_C
Open	0	
Closed	0.5mA	

Switch	Base current I_B	Collector current I_C
Open	0	
Closed	0.5mA	

So What?

- Transistors are made from an almost pure silicon crystal, but impurities added to it affect its electrical properties hugely. The impurity concentrations are typically much less than one impurity atom per million silicon atoms.
  The impurities are allowed to diffuse, at high temperature in known concentrations, through a 'mask', producing n-type or p-type regions in the appropriate regions of the crystal depending on the impurity. Adding arsenic or phosphorus creates n-type silicon. Adding boron or gallium creates p-type. N-type silicon contains more free electrons than holes. P-type contains more free holes than electrons.



- Bipolar junction transistors (BJTs) come in two types, npn or pnp. Both contain two p-n junctions, but in a different order, either (n-p p-n), or (p-n n-p).
- The diagrams show the direction of current flow in npn and pnp transistors. You can see why the pnp transistor can be thought of as a mirror-image of the npn device.
- Although it wasn't measured, the base current was around 0.5mA when the transistor was conducting. (When the switch is pressed, there is a voltage drop of ~ 0.7V across the base/emitter junction of a conducting transistor, leaving ~(6 - 0.7) V across the 10kΩ resistor. This causes a base current of ~ 5.3/10 = ~ 0.5mA.)
- The transistor is a current amplifier. If it is working, the collector current should be at least 50 times bigger than the base current, or at least 2 5mA. This is the test of whether it is working properly. Check your results against this criterion.

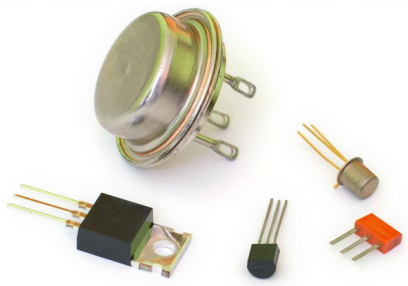
A challenge:

Many multimeters have a transistor-check facility, allowing you to check a transistor quickly. Use one to check some discrete transistors!

For your records:

- Copy the circuit diagrams for the npn and pnp transistor tests.
- Write instructions so that one of your colleagues could carry out the tests.
- Explain to your colleague why the base current is likely to be around 50µA when the switch is pressed.
- Estimate the base current if the 10kΩ resistor were swapped for a 100kΩ resistor.
- Copy the formula for current gain h_{FE}.

Copyright © 2023 - 2026 Matrix Technology Solutions Limited



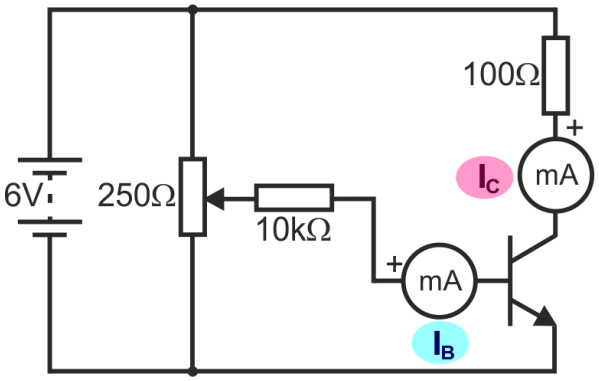
The performance of a transistor can be assessed from graphs that show how base current, collector current and collector-emitter voltage are related.

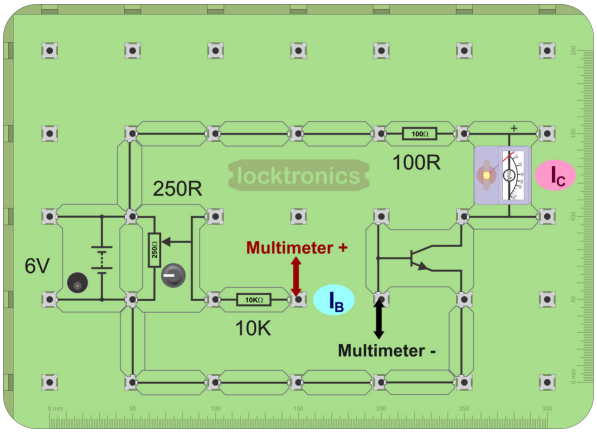
These graphs allow you to predict how a transistor will behave in a particular circuit, and whether or not it is a suitable choice.

In this worksheet you plot the first of these, known as the current transfer characteristic, I_C plotted against I_B.

Over to you:

- Build the circuit shown opposite. A suitable layout is shown below it.
- Be careful to connect the 'pot' the right way round!
- Use a multimeter, on the 2mA range, to measure base current, I_B. (It is too small to measure accurately on a needle ammeter.)
- Set the DC power supply to output 6V.
- Use the 'pot' to vary base current, I_B, shown on the multimeter, from 0 to 0.5mA in 0.1mA steps.
- At each step, measure the collector current,
- IC on the needle ammeter.
- Copy the table and record your results in it.
- Use them to plot a graph of I_C against I_B, (known as the current transfer characteristic.)
- Suitable scales are given on the template below.
- Assume that it is a straight line graph and draw the best fit through the experimental points.

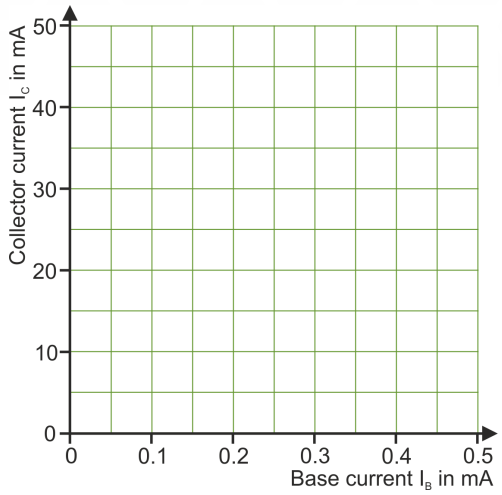




Copyright © 2023 - 2026 Matrix Technology Solutions Limited

Worksheet 2 - BJT Transfer Characteristics

I_B in	I_C in
0	
0.1	
0.2	
0.3	
0.4	
0.5	



So What?

- Transistors can be categorised by their current gain, called h_{FE} , the ratio of collector current (I_C) to base current (I_B).
- In other words, $h_{FE} = I_C / I_B$
- For example, a BC108 transistor can have a current gain of 300, meaning that the collector current will be 300 times bigger than the base current.
- A base current of 10µA results in a collector current of 300 x 10 µA or 3mA.
- However, a current of 100mA does NOT result in a current of 300 x 100 mA (i.e. 30A!) An effect called saturation limits the maximum collector current. In any case, if the power handling of the transistor is exceeded, it will probably be destroyed!
- The formula implies that a graph of I_C plotted against I_B will be a straight line. This is nearly true, but the current gain does change a little with collector current. One way to obtain the value of current gain is to measure the gradient of the graph you plotted earlier.
- Transistors are mass-produced. The manufacturer will quote typical values for the current gain, but two individual devices may have widely different current gains.

A challenge:
Test different BC108 transistors (or any other type available to you) with a multimeter transistor tester to see the variation in current gain.

Copyright © 2023 - 2026 Matrix Technology Solutions Limited

For your records:

- Copy the circuit diagram for the circuit you set up in this investigation.
- Describe the steps taken to obtain the current transfer characteristic for the transistor.
- Measure the gradient of the graph you plotted to give you an estimate of the current gain of the transistor.
- Identify the transistor used on the transistor carrier. Look for the writing on the transistor body. It may be a ZTX 451. Use the internet to check the manufacturer's value for current gain with the one you obtained.
- Copy the following table and complete it.

Transistor type	Current gain	Base current	Collector current in mA
BC108	500	10mA	
BFY51	60		300
BD437		8mA	500
BC546	200		100
2N3904		100mA	12

Copyright © 2023 - 2026 Matrix Technology Solutions Limited

Worksheet 3 - BJT Output Characteristics

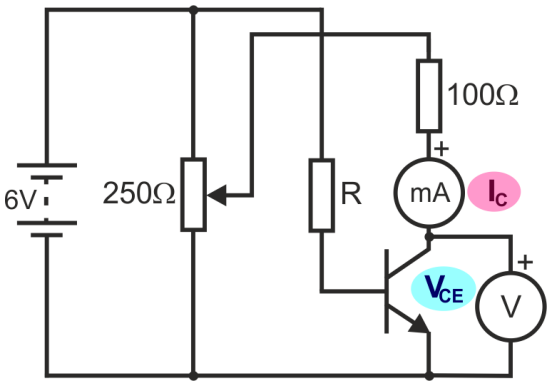


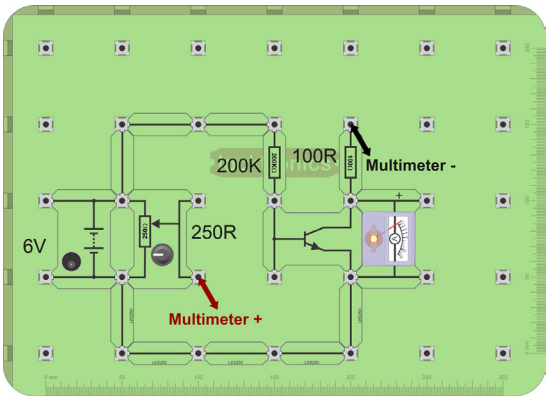
The next characteristic connects the collector current, I_C, with the collector-emitter (output) voltage, V_{CE}.

This allows us to estimate the output resistance of the transistor, which governs how effectively it will pass on a signal to the next subsystem in the circuit.

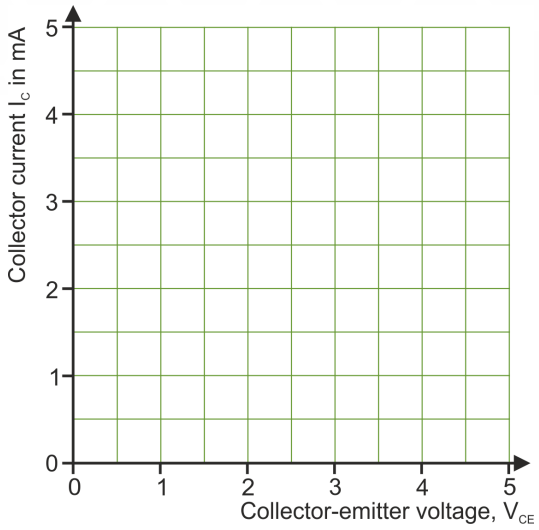
Over to you:

- Build the circuit shown opposite using a value of 200kΩ for R. The layout shows one way to do this. The multimeter, set up as an ammeter, provides the connection between the 'pot' and the 100Ω resistor.
- Set the DC power supply to output 6V.
- Set the multimeter on the 20mA DC range.
- Use the 'pot' to vary the collector voltage, V_{CE}, shown on the needle voltmeter, from 0V to 5V in 1V steps.
- At each step, measure the collector current, I_C, shown on the multimeter.
- Copy the table that follows and record your results in the centre column.
- Use your results to plot the output characteristic, I_C against V_{CE}. The template opposite suggests suitable scales.
- Now, replace the 200kΩ resistor with a 100kΩ resistor, to give a bigger base current.
- Repeat the process, recording your results in the third column of the table.
- Plot a second output characteristic curve on the same axes.



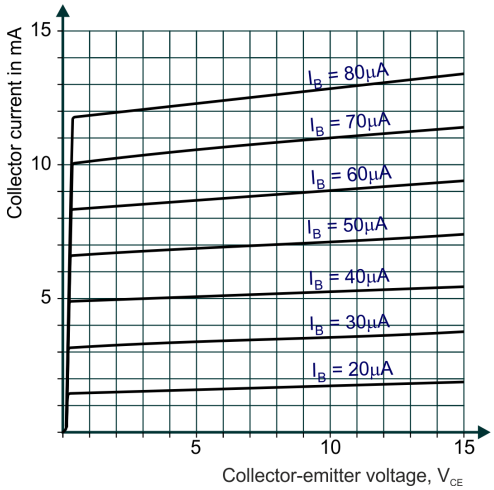


V_{CE}	I_C in mA	
	R=200k	R=100k
0.0 V		
1.0 V		
2.0 V		
3.0 V		
4.0 V		
5.0 V		



So What?

- Using the 200kΩ resistor, the base current was around 0.3μA. With the 100kΩresistor, it was twice as big. These small changes in base current had a huge effect on the collector current, I_C, as your graphs show.
- On the other hand, the output voltage, V_{CE}, has very little effect, once the initial 'knee'of the curve is passed. This is surprising!
- In a resistor, the current will double when we double the voltage across it. The transistor is not as simple as that!
- A more detailed investigation, using more values of base current, produces a set of curves like the ones shown in the diagram.
- Once the 'knee' is passed, the behaviour is quite linear, meaning that the output resistance does not change much with output voltage. It can be calculated by taking the inverse of the gradient of the graph, i.e. output resistance = 1 / gradient



For your records:

- Copy the circuit diagram for the circuit you set up in this investigation.
- Describe the steps taken to obtain the output characteristic for the transistor.
- Measure the gradient of the linear portion of the two graphs you plotted and hence obtain the output resistance.

Copyright © 2023 - 2026 Matrix Technology Solutions Limited

WORKSHEETS

Worksheet 4 - Transistor as a Switch

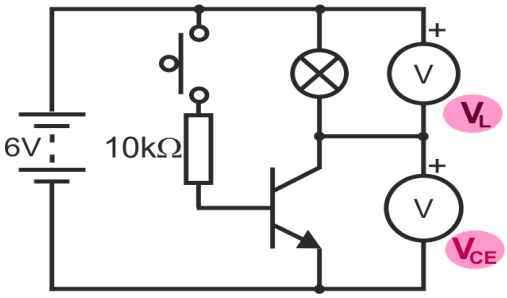


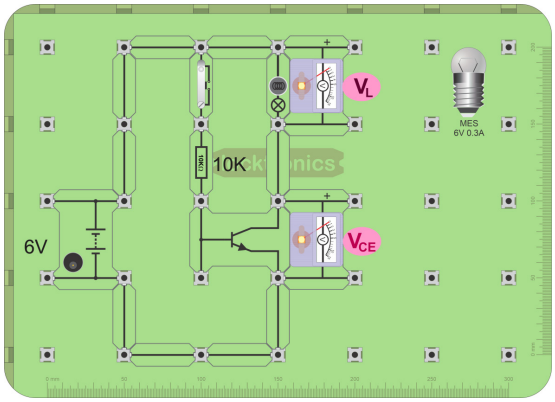
Mechanical switches operate at very low speeds. Transistors, on the other hand, can switch on and off many millions of times faster. There are no moving mechanical parts and so no friction and no 'wear-and-tear'.

In this worksheet you build and test a simple switching circuit.

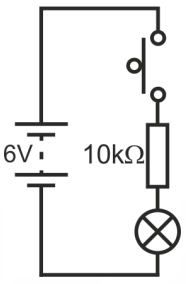
Over to you:

- Build the circuit shown opposite.
- The switch controls the MES lamp. When closed, the small base current produces a much larger collector current through the lamp.
- Set the DC power supply to output 6V.
- Measure voltages V_L, across the lamp and V_{CE}, across the transistor when the switch is open and then when closed.
- Copy the table and record your results in it.
- To see the effect of the transistor, remove it!
- Connect the lamp directly to the switch and resistor, as shown opposite. The current is too small to light the lamp. (You could remove the 10kΩ resistor. The lamp then lights perfectly well. The point is that some sensors have a high resistance and will not operate devices like the lamp without the help of a transistor.)
- A switch is a two-state device. It offers huge electrical resistance in one state and around zero in the other.





Switch	V_{CE}	V_L
Off		
On		



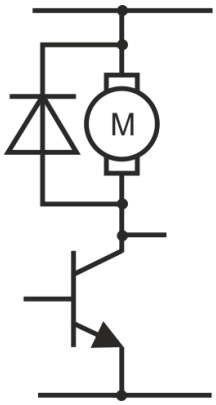
Copyright © 2023 - 2026 Matrix Technology Solutions Limited

So What?

- Look at the results for the investigation.
- Add together V_{CE} and V_L. What do you notice?
- What do you expect, bearing in mind that the transistor and lamp are a voltage divider across the power supply?
- The behaviour is the same as that described earlier for a mechanical switch. The transistor takes virtually all the supply voltage, or takes none. It is **saturated,** meaning that the collector-emitter voltage, V_{CE}, is either as high as it can be, (roughly the supply voltage - the 'off' state) or as low as it can be, (very close to 0V - the 'on' state).

A challenge or two:

- Modify the circuit so that the lamp remains **on** when the switch is open and goes **off** when it is closed. (You will have to change the position of the switch in the circuit).
- Modify the circuit so that the switch controls a motor instead of the lamp. (You will need to add a diode in reverse parallel with the motor to protect the transistor as the motor is turned off - see the diagram opposite.)



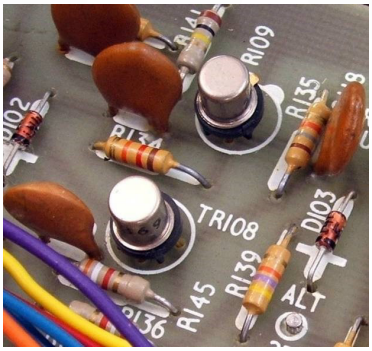
- Modify the circuit so that the switch controls both the motor and the lamp.
- The diode is needed because the motor is an electromagnetic device.
- The motor rotates because current creates a strong magnetic field in its coil.
- When the current stops, the magnetic field collapses through the coil and generates a large voltage in the opposite direction, which can damage the transistor.
- The power supply sees the diode in reverse bias. It essentially does nothing when the motor is rotating. The voltage generated by the falling current, however, sees the diode as forward biased. It conducts freely, clamping the voltage drop across it to 0.7V, (or -0.7V) as seen by the transistor). This poses no risk to the transistor.

For your records:

- Copy the circuit diagram for the transistor switch given at the start of the investigation.
- Explain why the transistor can be described as a switch in this arrangement.
- Assuming that the base-emitter voltage is 0.7V when the transistor is on, estimate the base current when the switch is closed in:
- The lamp circuit;
- The motor circuit.
- Explain why the base resistor in the motor circuit has a much lower value than that used in the lamp circuit.
- Write an explanation that a fellow student would understand as to why a diode, connected in reverse parallel, is needed when the motor is switched on and off by a transistor.

Copyright © 2023 - 2026 Matrix Technology Solutions Limited

Worksheet 5 - Transistor as an Amplifier

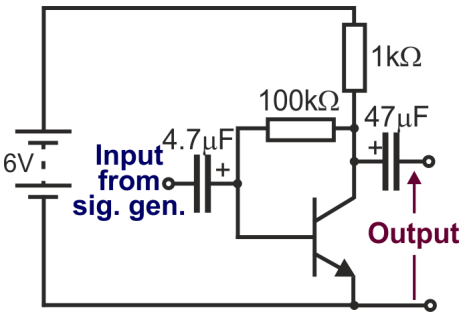


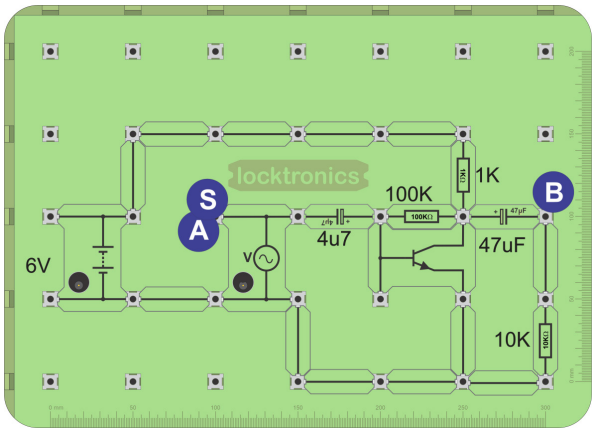
When a bipolar junction transistor is used to amplify audio signals, we need to provide a DC **bias,** a DC voltage applied to the base so that some collector current will flow even when no signal is present.

This worksheet looks at the operation of a very simple common-emitter amplifier stage that uses this technique.

Over to you:

- Build the circuit shown opposite. Add a 10kΩ resistor as a load for the amplifier.
- Use a multimeter to measure the DC voltages at the collector, base and emitter of the transistor and record your measurements in it.
- Connect the input to a signal generator at point S, with amplitude 50mV at 1kHz.
- Connect a dual-channel oscilloscope to display the input at A and output at B.
- Adjust the oscilloscope controls to display around two cycles of the input and output signals.
- Obtain a trace showing the input and output signals and copy it for your records.
- Measure the amplitude of the input and output signals, and make a note of them.
- Now, increase the input signal amplitude to 100mV. Obtain another trace showing the effect on the output.
- Replace the 10kΩ resistor with a speaker. Use the oscilloscope to observe the effect of the speaker on the output signal.
- Connect the speaker directly to the output of the signal generator. This should convince you that the circuit is amplifying that signal.



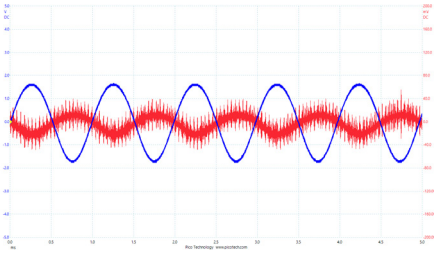


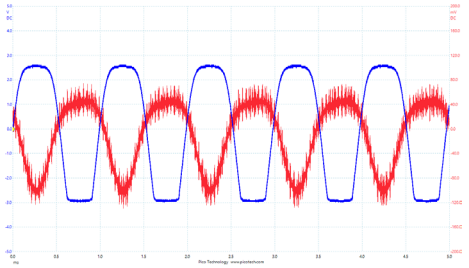
Measurement	Voltage
DC voltage at collector	
DC voltage at base	
DC voltage at emitter	
AC input amplitude	
AC output amplitude	

Copyright © 2023 - 2026 Matrix Technology Solutions Limited

So What?

The diagrams below show typical oscilloscope traces for this investigation.





Notice that:

- The amplifier inverts the input signal;
- Increasing the amplitude of the input signal eventually produces distortion - the output no longer looks like the input;
- Because the input signal is very small, the trace (red) contains a lot of electrical noise.

Transistor behaviour:

The 1kΩ resistor and transistor form a voltage divider across the power supply.

When the input voltage **increases:**

- Base current increases;
- Collector current increases;

When the input voltage **decreases:**

- Base current decreases;
- Collector current decreases;

A base current is allowed to flow all the time, through the 1kΩ and 100kΩ resistors, even when no input signal is present (the quiescent state.) This increases the collector current, creating a voltage drop across the 1kΩ resistor. The output voltage, V_{CE}, falls as a result.

The greater the base current, the greater the collector current, the greater the voltage drop across the 1kΩ resistor, and so the lower the output voltage, V_{CE}. The ideal is an output voltage of nearly half of the supply voltage when no signal is present. In that way, the output voltage can rise and fall by similar amounts when a signal is present. The signal is coupled into and out of the amplifier via capacitors to block any DC components in the signals entering and leaving the amplifier. These could otherwise affect the operation of the amplifier and anything connected to its output.

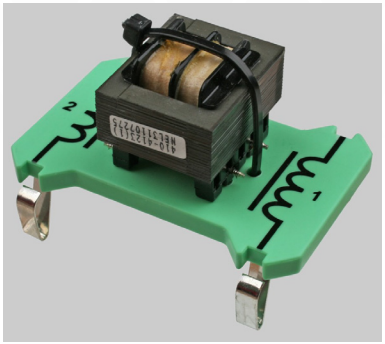
For your records:

- Copy the circuit diagram for the transistor amplifier.
- Explain what your oscilloscope traces show.
- Use them to estimate the voltage gain before distortion sets in.
- Explain why the output becomes distorted for larger input signal amplitudes.

Copyright © 2023 - 2026 Matrix Technology Solutions Limited

WORKSHEETS

Worksheet 6 - Transformer-Coupled Amplifier



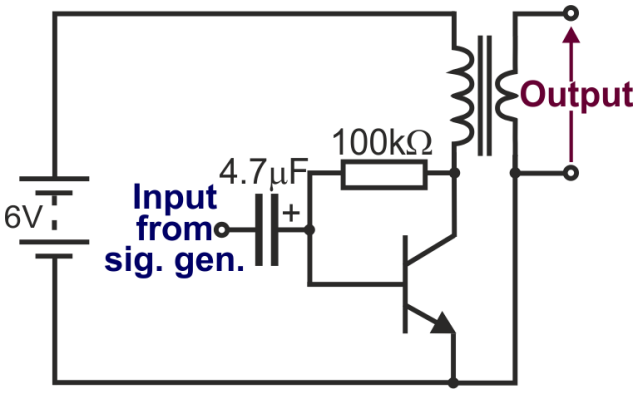
The previous amplifier circuit used a capacitor to couple the signal from the collector to the output.

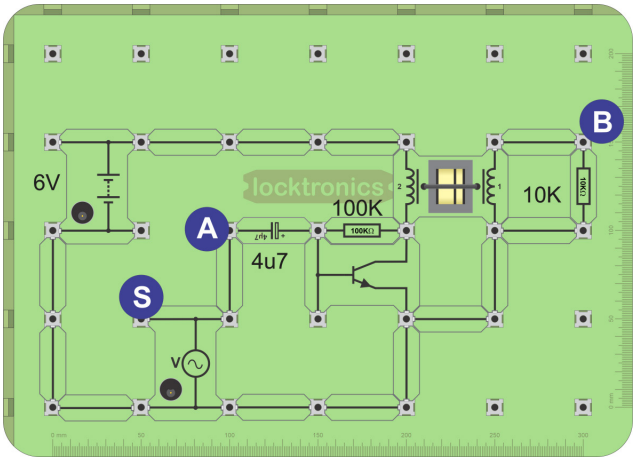
Other methods are used, based on inductors and capacitors, and on transformers. The latter has the advantage of offering accurate matching to a load, such as a speaker, ensuring efficient signal transfer.

This worksheet looks at the operation of a simple transformer-coupled common-emitter amplifier.

Over to you:

- Build the circuit shown opposite.
- A suitable layout follows underneath.
- Again, a 10kΩ resistor acts as a load for the amplifier.
- The 2:1 transformer, connected as a step-down transformer, couples the output to the load.
- Set the DC power supply to output 6V.
- Connect the input to a signal generator, set to output a signal of amplitude 50mV and a frequency of 1kHz.
- Connect a dual-channel oscilloscope to display the input and output signals.
- Adjust the oscilloscope controls to display two cycles or so of the input and output signals.
- Obtain a trace showing the two signals and copy it for your records.
- Copy the table ready to record your measurements.
- Measure the amplitudes of the input and output signals, and record them in the table.
- Use them to estimate the voltage gain of the amplifier and enter it in the table.
- Now, increase the input signal amplitude to 100mV. Obtain a new trace showing the effect on the output.



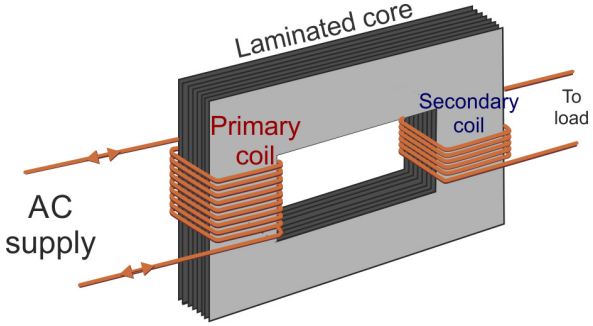


Measurement	Voltage
AC input amplitude	
AC output amplitude	
Voltage gain =	

Copyright © 2023 - 2026 Matrix Technology Solutions Limited

So What?

- In the capacitor-coupled amplifier studied earlier, the collector current flowed through the 1kΩ resistor in series with it. This generates waste heat. The aim of transformer-coupling is to reduce that energy loss.
- The diagram that follows illustrates the main features of a transformer.



- It consists of two coils wound around a magnetic core, laminated to reduce stray heating effects. The coils are electrically insulated from each other and from the core. Alternating current flowing in one coil, called the primary, produces an alternating (i.e. moving) magnetic field. This links with the other coil, called the secondary, and induces an alternating current in it. DC currents do not produce the same effect as there is no moving magnetic field.
- In a step-down transformer, the primary coil, the one supplied with AC power, has more turns of wire than the secondary, the one that generates the transformer output voltage. This transformer has a turns ratio of 2:1, meaning that one coil has twice as many turns as the other. The primary will be the '2' coil, and the secondary the '1' coil.
- As a result, the load is isolated from any DC currents flowing in the transistor, but receives the AC signal, via the transformer.
- For maximum efficiency, the transformer is chosen so that the output impedance of the transformer is equal to the load impedance. This is an example of the maximum power transfer theorem.

A challenge:

- Investigate what happens if the transformer is reversed, to act in step-up rather than step-down mode.

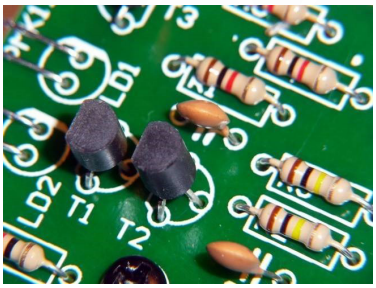
For your records:

- Copy the circuit diagram for the amplifier.
- Explain what your oscilloscope traces show.
- Use them to estimate the voltage gain when the input voltage is 50mV.
- Using resources such as the internet or text-books, distinguish between 'step-up' and 'step-down' transformers.

Copyright © 2023 - 2026 Matrix Technology Solutions Limited

WORKSHEETS

Worksheet 7 - Stabilised Common-Emitter Amplifier

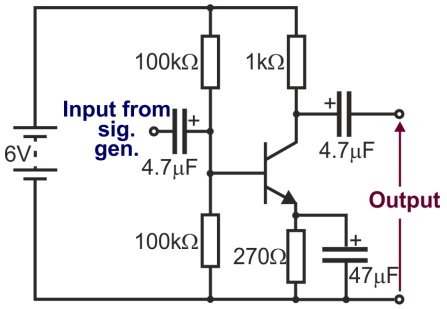


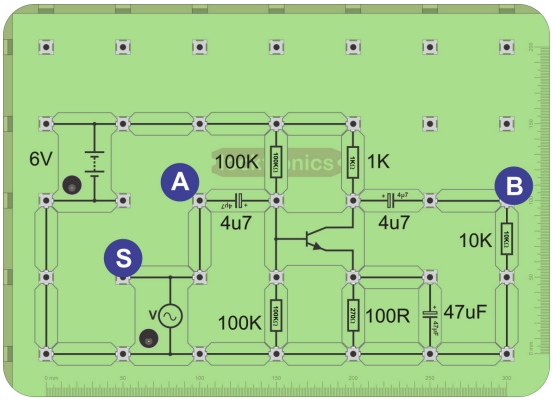
The simple common-emitter can be improved by adding DC negative feedback to stabilize it and compensate for variations in factors like transistor parameters, component tolerances and temperature changes.

This worksheet looks at the operation of a stabilised common-emitter amplifier.

Over to you:

- Build the circuit shown opposite.
- A suitable layout is given underneath, including a 10kΩ resistor, added as a load for the amplifier, once more.
- Set the DC power supply to 6V.
- Use a multimeter to measure the DC voltages at the collector, base and emitter of the transistor.
- Copy the table and record your measurements in it.
- Connect the input to a signal generator, set to generate a signal of amplitude 50mV and frequency 1kHz.
- Connect a dual-channel oscilloscope to display the input and output signals.
- Connect the ground terminals of the signal generator and oscilloscope to 0V.
- Adjust the oscilloscope controls to display two cycles or so of the input and output signals.
- Obtain a trace showing the signals and copy it for your records.
- Measure the amplitudes of the input and output signals, and record them in the table.





Measurement	Voltage
DC voltage at collector	
DC voltage at base	
DC voltage at emitter	
AC input amplitude	
AC output amplitude	

Copyright © 2023 - 2026 Matrix Technology Solutions Limited

So What?

The amplifier studied in worksheet 6 used one form of negative feedback to stabilise the amplifier, by means of the resistor connecting base and collector terminals. The control mechanism was described in the 'So what' section of the worksheet.

In this circuit, the negative feedback is provided in a different way, using an emitter resistor. This removes the need for a resistor between base and collector. However, there still needs to be a base current in the quiescent (no signal) state. Otherwise the transistor would ignore any AC voltage less than 0.7V (i.e. over half of it!) Here, the base terminal is set at a voltage determined by the voltage divider formed by the two 100kΩ resistors - no feedback involved!

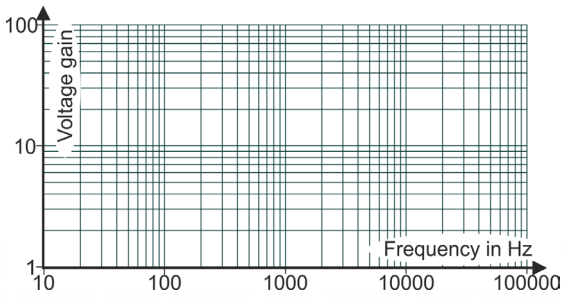
Negative feedback, provided in this circuit via the 270Ω emitter resistor, returns a signal which opposes changes at the output. If any temperature or power supply changes etc. cause the DC collector current to rise, the voltage across the 270Ω emitter resistor also rises. As a result, the voltage drop across the base-emitter junction falls, reducing the base current and, in turn, reducing the collector current - negative feedback!

A side-effect is to reduce the voltage gain of the amplifier. The emitter resistor bypass capacitor, the 47µF capacitor, does not affect **DC** currents - they see it as a gap in the circuit. However, **AC** signals can flow through this capacitor, instead of the emitter resistor.

As a result, the **AC** voltage gain is not affected as much.

A challenge:

- Investigate what happens to voltage gain when the input signal frequency changes.
- Vary the frequency over the range 50 Hz to 100 kHz and measure the voltage gain at suitable intervals.
- Use your results to plot a frequency response graph, showing voltage gain plotted against frequency.
- A 'log-log' grid is best as it allows you to cover very large ranges of frequency.



The diagram above shows a 'log-log' template. If necessary, ask your tutor for help!

For your records:

- Describe the function of the voltage divider connected to the base of the transistor.
- How does the emitter resistor provide negative feedback?
- Explain how the emitter resistor bypass capacitor affects voltage gain.
- Using resources such as the internet or text-books, explain what is meant by 'negative feedback' and describe its effects in applications like the current one.

Copyright © 2023 - 2026 Matrix Technology Solutions Limited

Worksheet 8 - Emitter Follower Behaviour



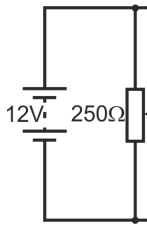
The circuits so far use the 'common-emitter' configuration, where the emitter is part of both the input and output circuits. Usually designed to produce a large output voltage signal from a small input signal, they are known as 'small signal amplifiers'.

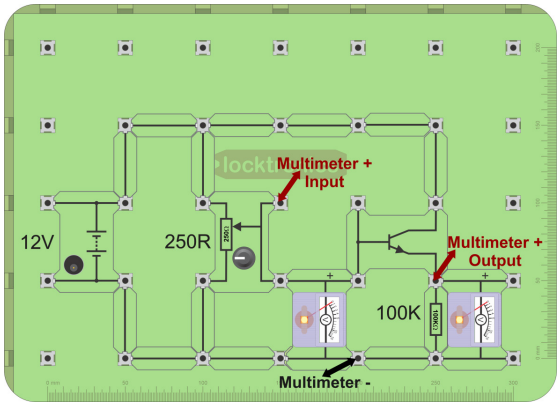
This worksheet looks at a different configuration - 'common-collector' where the collector is connected directly to the positive power supply rail, with the load connected between emitter and 0V rail.

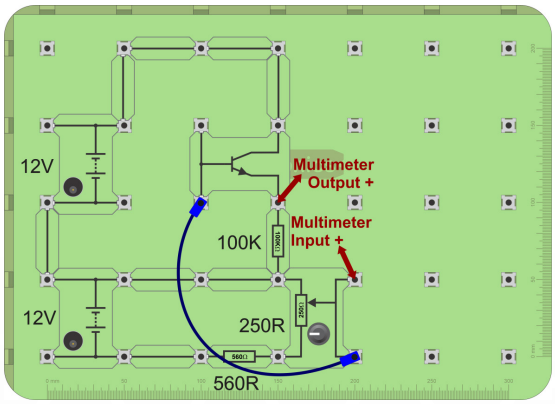
The emitter follower delivers both high signal voltage and current to a load such as a speaker. It usually uses power transistors like the one shown in the picture

Over to you:

- Build the circuit shown opposite.
- Use the 'pot' to vary the input voltage. Watch the voltmeters as you do so. The output voltage 'follows' the input - hence the name of this circuit!
- Next use a multimeter, connected as shown, to make more accurate measurements.
- Use the 'pot' to set the input voltage to 0V.
- Measure the corresponding output voltage.
- Copy the table and record your measurements in it.
- Set the input voltage to the other values in the table. Measure and record the output voltages produced.
- Modify the circuit to that shown in the second layout. This allows you to apply negative voltages.
- The 560Ω resistor prevents excessive negative input voltages.
- As before, set the input voltage to the values in the table. Measure and record the output voltages produced.







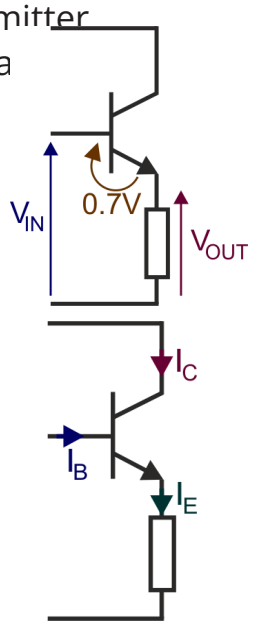
Copyright © 2023 - 2026 Matrix Technology Solutions Limited

So What?

Input voltage V_{IN}	Output voltage V_{OUT}
0	
1.0	
2.0	
3.0	
4.0	
5.0	

Input voltage V_{IN}	Output voltage V_{OUT}
1.0	
-2.0	
-3.0	

- When the input voltage V_{IN} is greater than ~0.7V, the transistor starts to conduct.
- As a result, a voltage drop of ~0.7V is created between base and emitter.
- The remainder of V_{IN} is dropped across the resistor, as output volta
- Hence, the emitter follower relationship:



$$V_{OUT} = V_{IN} - 0.7$$

Voltage gain:

$$\text{Voltage gain} = V_{OUT} / V_{IN}$$
$$= \sim 1$$

Current gain:

Output current through load = emitter current I_E

Input current = I_B

Current gain = I_E / I_B

From Kirchhoff's current law:

$$I_E = I_C + I_B$$

and $I_C >> I_B$

Hence current gain = $\sim I_C / I_B = \sim h_{FE}$ (current gain of the transistor.)

A challenge:

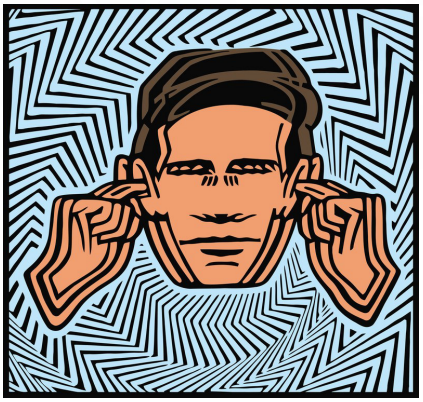
- Carry out the same investigation for the pnp transistor. Essentially, it means reversing all the power supply connections.
- Let your instructor see your circuit before switching it on.

For your records:

- Copy the circuit diagram for the emitter follower.
- Use your results to plot a graph of V_{OUT} against V_{IN} (i.e. the voltage transfer characteristics) for the emitter follower.
- Copy the expressions given above for the emitter follower relationship, its voltage gain, and its current gain.
- Write an explanation for one of your fellow students to show that emitter follower has an overall power gain (= voltage gain x current gain).

Copyright © 2023 - 2026 Matrix Technology Solutions Limited

Worksheet 9 - Emitter Follower - AC Behaviour



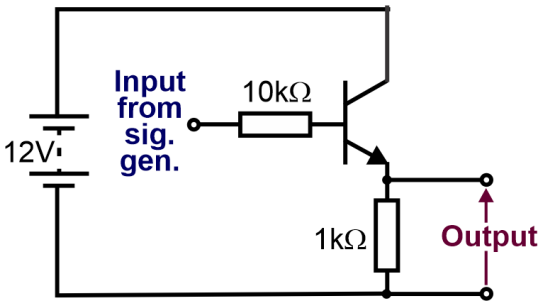
The aim of amplifier systems is to reproduce recorded sounds faithfully, but louder and with no distortion!

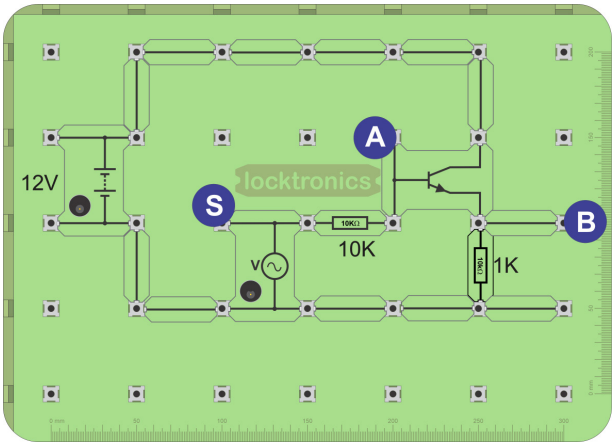
The sounds are converted into AC electrical signals, so the system must be able to amplify these AC signals faithfully.

This worksheet looks at the way in which the simple emitter follower, studied in the previous worksheet, handles AC signals.

Over to you:

- Build the circuit shown opposite.
- The diagram includes two capacitors to block any DC components in the signals, so that they do not affect the operation of the emitter follower or the circuits it is connected to.
- A suitable layout is given underneath.
- Set the DC power supply to 12V.
- Connect the input to a signal generator, at S, set to output a signal of amplitude 2V and frequency 1kHz.
- Connect a dual-channel oscilloscope to display the input and output signals at A and B.
- Set the 'Voltage sensitivity' on each channel to +/- 5V.
- Connect the ground terminals of the signal generator and oscilloscope to 0V.
- Adjust the oscilloscope controls to display a few cycles of the input and output signals.
- Obtain a trace showing the signals and copy it for your records.

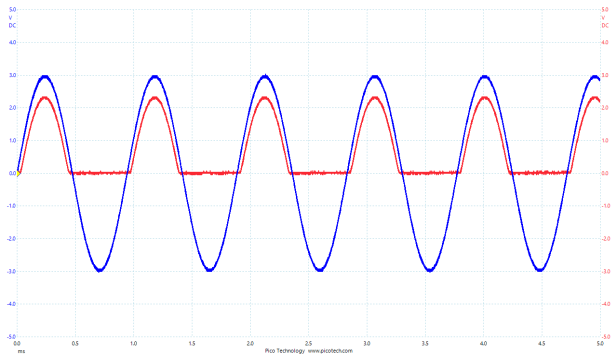




Copyright © 2023 - 2026 Matrix Technology Solutions Limited

So What?

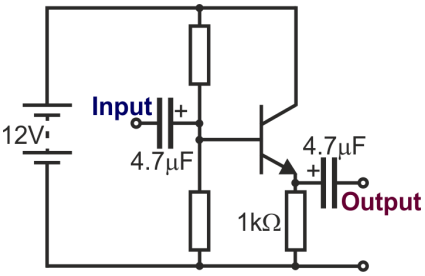
A problem:
The output signal is distorted! It is not a true copy of the input signal - half of it is missing!



In the light of the results of the previous worksheet, this is not surprising. The basic emitter follower handles only positive signals.

The diagram opposite shows a typical trace of the input (blue) and output (red) signals.

Challenges:
- Replace the 1kΩ resistor with a speaker.
- Compare the sound produced with that when the speaker is connected directly to the output of the signal generator. You should hear the distortion!
- One solution is to create a steady DC bias for the emitter.
- Experiment with the arrangement shown to try to reduce distortion by making the transistor conduct throughout the full cycle of the signal.



Design hints:
- Choose an emitter voltage of about half of the supply voltage, i.e. ~6V, to allow the output voltage to swing ~6V either way.
- Calculate the collector current (roughly the emitter current,) = 6V/1kΩ = 6mA.
- Hence estimate the base current (I_C / h_{FE}) so around 6/100 mA (0.06mA) here.
- Estimate the base voltage (= emitter voltage + 0.7V.)
- Assume a current down the resistor chain of 10 x base current (so ~0.6mA)
- Current through top resistor is greater than that through the bottom one by the base current. Choose appropriate values for the resistors.

For your records:
- Copy the circuit diagram for the emitter follower, modified to accept and output AC signals.
- Explain the purpose of the two capacitors.
- Explain why the circuit creates distortion.
- Draw the circuit diagram for the modification given in the second challenge.
- Explain why this modification should reduce the distortion.

Copyright © 2023 - 2026 Matrix Technology Solutions Limited

Worksheet 10 - Push-Pull Follower

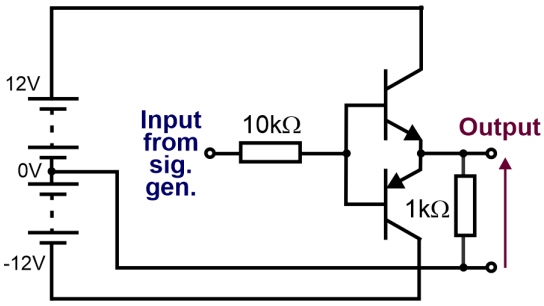


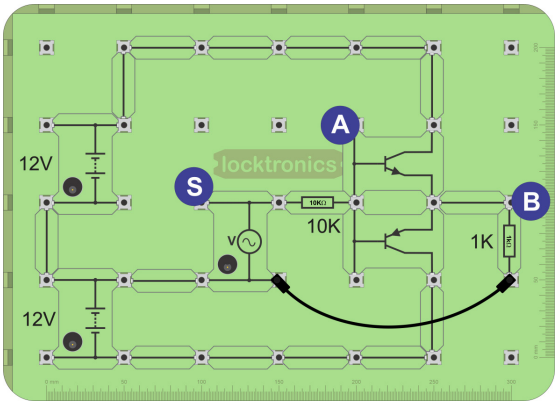
The emitter follower has a serious limitation as a power amplifier for AC signals - it only responds to half of the AC waveform. The solution is to add a steady DC voltage to the base so that the transistor is conducting all the time. The previous worksheet looked at using a voltage divider of two resistors to do this. They pass current all the time, heat up and waste energy.

This worksheet looks at a different solution which avoids this.

Over to you:

- Build the circuit shown opposite. The diagram includes two capacitors to block any DC components in the signals.
- A suitable layout is given underneath, without the two DC-blocking capacitors. When needed, they can easily be added to the layout. It uses a 1kΩ resistor as a load.
- The circuit uses a split +12/0/-12V power supply.
- Connect the input to a signal generator, set to generate a signal of amplitude 3V and frequency 1kHz.
- Connect a dual-channel oscilloscope to display the input and output signals.
- Set the 'Voltage sensitivity' on each channel to +/- 5V.
- Connect the ground terminals of the signal generator and oscilloscope to 0V.
- Adjust the oscilloscope controls to display a few cycles of the input and output signals.
- Obtain a trace showing the signals and save it for your records.
- Next, reduce the amplitude of the signal to 1V. The trace should show any distortion more clearly.
- Save this second trace for your records.

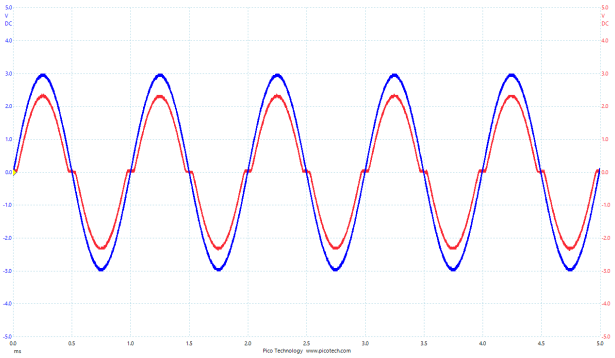




Copyright © 2023 - 2026 Matrix Technology Solutions Limited

So What?

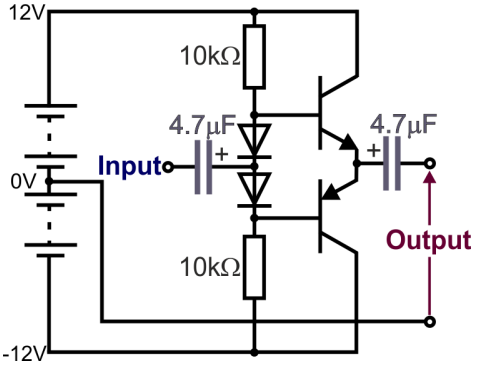
The diagram shows typical signals for this circuit. The input is shown in blue and the output in red.



Much of the distortion has gone - there is a negative portion to the output signal as well as a positive. The main distortion occurs in between the two, where the input signal is close to 0V. It appears as a 'shoulder' in the output signal. It is called cross-over distortion and occurs when the input is too small to turn on either transistor. In other words, it occurs for in-put voltages between +0.7V and -0.7V approximately.

Challenges:

- Once again, replace the 1kΩ resistor with a speaker. There is still some distortion - it sounds harsher than when the speaker is connected directly to the signal generator.
- The circuit shown can be used to eliminate cross-over distortion. The two diodes are conducting and so have a voltage drop of 0.7V across them.
- As a result, the base of the npn transistor sits at 0.7V above the signal voltage. When the signal voltage is 0V, the npn transistor base is at 0.7V and conducts.
- Equally, it conducts for any voltage greater than 0V.
- Similarly, the base of the pnp transistor sits at 0.7V below the signal voltage, and so conducts at all voltages below zero.



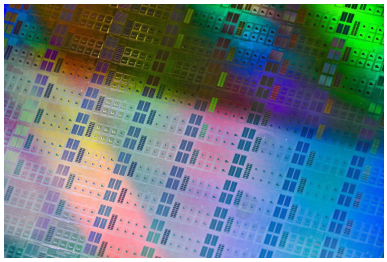
For your records:

- Copy the circuit diagram for the push-pull follower, with the DC blocking capacitors in place.
- Explain why the circuit creates cross-over distortion.
- Draw the circuit diagram for the modification given in the second challenge.
- Explain why this modification should reduce distortion.

Copyright © 2023 - 2026 Matrix Technology Solutions Limited

WORKSHEETS

Worksheet 11 - FET Transfer Characteristics



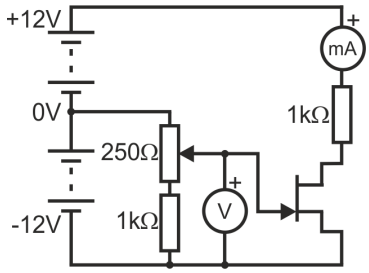
Made from the same silicon wafer, using similar techniques, the FET (field-effect transistor) has equivalent applications to the BJT but uses different principles.

The BJT family has only two members, npn and pnp. The FET family tree is much bigger.

In this worksheet, the behaviour of JFET (junction FET) and MOSFET (metal-oxide semiconductor FET) devices is studied.

Over to you:

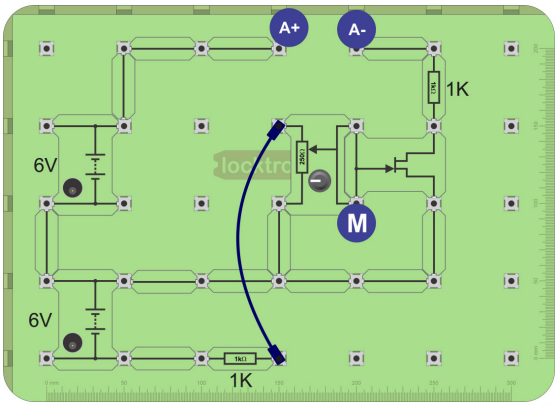
- The first part focuses on the JFET, operating in depletion mode. Build the circuit shown opposite. The 1kΩ resistor connected to the 'pot' reduces the range of voltages available, but increases the ease of adjustment.
- Use a multimeter to measure drain current, I_D (up to 5mA).
- Use a second multimeter to measure gate-source voltage (VGS) (from 0V to -5V).
- Use the 'pot' to set the input voltage (V_{GS}) to 0V, and measure the corresponding drain current, ID.
- Copy the table and record your measurements in it.
- Set the input voltage to the other values in the table. Measure and record the drain currents produced.

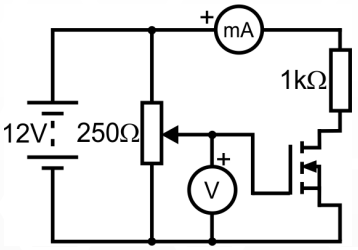


Input V_{GS}	Output I_D
0	
-0.4	
-0.6	
-0.8	
-1.0	
-1.2	
-1.4	

A challenge:

- Now carry out the exercise for the MOSFET, which operates in enhancement mode.
- The circuit diagram is given, but you should design your own layout. Use the 'pot' to input voltages from 0V to +5.0V and measure the drain current each time.
- Create a suitable table in which to record your results.



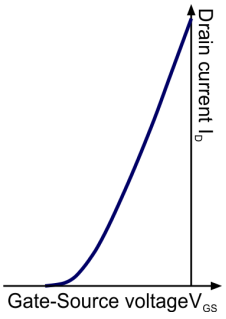


Copyright © 2023 - 2026 Matrix Technology Solutions Limited

So What?

JFET:

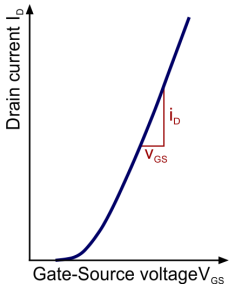
- The drain current is at a maximum when the gate-source voltage is zero.
- As V_{GS} becomes more negative, drain current decreases.
- Eventually the drain current falls to zero. The gate-source voltage that causes this is known as the pinch-off voltage.
- Use your measurements from the first circuit to plot a graph of drain current I_D against gate-source voltage V_{GS}. This is known as the transfer characteristic for the JFET. Use the graph opposite as a guide for drawing the curve.



MOSFET:

- No drain current flows until V_{GS} reaches a threshold value.
- Then, as V_{GS} increases, drain current increases almost linearly.
- Use your measurements to plot a graph of drain current I_D against gate-source voltage V_{GS}, the transfer characteristic for the MOSFET. Use the graph opposite as a guide for drawing the curve.
- The gradient of the graph is called the transconductance, g_m:

$$g_m = \frac{\text{change in drain current}}{\text{change in gate-source voltage}} = \triangle I_D / \triangle V_{GS}$$



A challenge:

- Design a circuit to test conduction in the MOSFET when the gate-source voltage is negative (up to -5V).
- Let your instructor see your circuit before switching it on.

DO NOT USE A POSITIVE VOLTAGE ON THE GATE-SOURCE TERMINAL OF THE JFET. YOU MAY DESTROY IT!

For your records:

- Explain what is meant by the term 'transfer characteristic' for a FET.
- Write an explanation of less than 100 words, for a fellow student, on the differences in the way a depletion-mode JFET and an enhancement-mode MOSFET are used in a circuit.
- Draw the circuit diagram for the investigation into the MOSFET transfer characteristic and write a simple list of instructions for a fellow student, including how to process the results.
- Copy and complete the following:
- When a MOSFET has a transconductance of 30mS, the drain current will be ..... for a gate-source voltage of 3.0V.

Copyright © 2023 - 2026 Matrix Technology Solutions Limited

Worksheet 12 - FET Output Characteristics



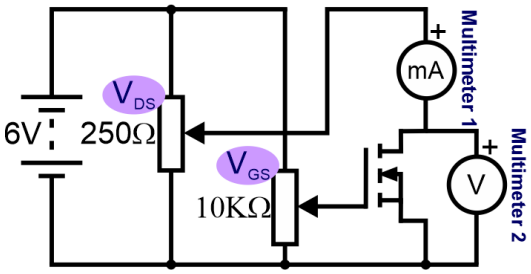
A device's output characteristics determine the way it interfaces with the following subsystem.

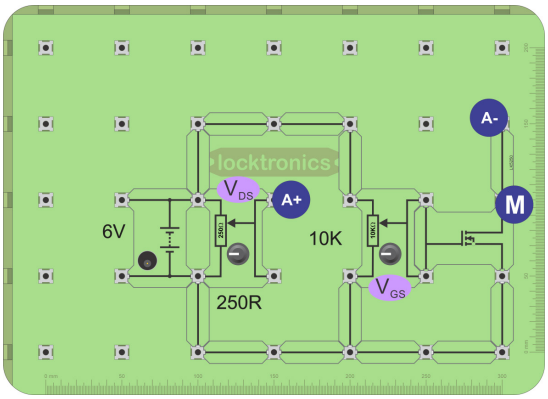
To deliver power efficiently to the next stage, output impedance ('AC resistance') should be low.

To deliver a voltage signal to the next stage, it should be high. This worksheet shows how to measure the MOSFET's output characteristics.

Over to you:

- Build the circuit shown opposite.
- The layout shows one way to do this.
- (Be careful to connect the two 'pots' correctly!)
- The multimeter, set up as an ammeter, connects the 'pot' and the MOSFET.
- Set the DC power supply to output 6V.
- Set multimeter 1 on the 200mA DC range and multimeter 2 on the 5V DC range.
- Use the 'V_{GS}' 'pot' to set the gate voltage to 2.2V.
- Use the 'V_{DS}' 'pot' to vary the drain voltage from 0V to 1V in 0.1V steps.
- At each step, measure the drain current, I_D, on multimeter 1.
- Copy the table and record your results in it.
- Use them to plot the output characteristic, I_D against V_{DS}.
- Now, set the gate voltage 'V_{GS}' to 2.4V.
- Repeat the process, recording your results in the table.
- Plot a second output characteristic curve on the same axes.



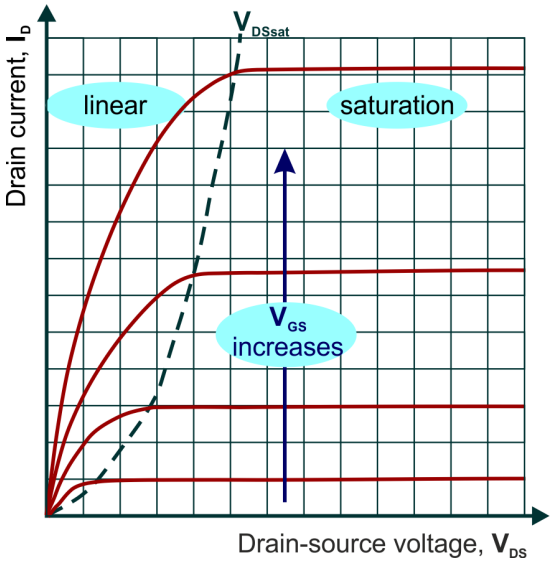


V_{DS}	V_{GS} = 2.2V	V_{GS} = 2.4V
	I_D in mA	I_D in mA
0.0 V		
0.1 V		
0.2 V		
0.3 V		
0.4 V		
0.5 V		
0.6V		
0.7V		
0.8V		
0.9V		
1.0V		

Copyright © 2023 - 2026 Matrix Technology Solutions Limited

So What?

Your graphs should resemble those opposite. The traces show the effect of four different values of VGS, the gate-source voltage.



There are two distinct regions for each curve:

- 'Linear' (or 'ohmic') region:
- For small values of drain-source voltage, (V_{DS}), the drain current, I_D, increases almost linearly with V_{DS};
- The traces are nearly straight lines through the origin - what you would expect for a resistor. However, it is a resistor with a value determined by the gate-source voltage, V_{GS}. It is known as the 'On' state resistance of the MOSFET, $R_{DS(on)}$.
- $R_{DS(on)}$ reduces as V_{GS} increases. It is usual to quote the values of V_{GS} and I_D at which $R_{DS(on)}$ is measured. For example, the **RFP30N06LE** MOSFET, used in the Locktronics carrier, has a $R_{DS(on)}$ value of 0.05Ω when V_{GS} = 5V and I_D = 30A.
- 'Saturation' region:
- Changes in V_{DS} have little effect on I_D.
- Drain current is insensitive to changes in V_{DS}, but is hugely affected by V_{GS}.

Below a threshold gate voltage, $V_{GS(th)}$, no drain current flows.

For the **RFP30N06LE** $V_{GS(th)}$ is between 1V and 2V.

The boundary between the 'linear' and 'saturation' regions is called the 'pinch-off region'.

For your records:

- Copy the circuit diagram for the circuit you set up in this investigation.
- Describe the steps taken to obtain the MOSFET output characteristic.
- Measure the gradient of the two graphs you plotted to obtain estimates of $R_{DS(on)}$.
- Copy and complete the following:
- A **2N7000** MOSFET has a value of $r_{DS(on)}$) of 5Ω. A drain current I_D of 200mA will dissipate .....mW in the device.

Copyright © 2023 - 2026 Matrix Technology Solutions Limited

WORKSHEETS

Worksheet 13 - MOSFET Switch



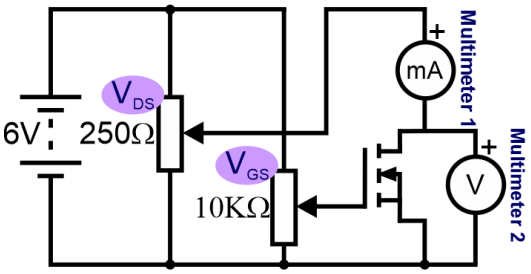
A BJT switch exists in either the 'off' state, where all the supply voltage sits across the transistor, or the 'on' state, where the voltage across the transistor is almost zero.

The reason for this is the dependence of collector-emitter resistance on the base current - the BJT is a current-controlled device.

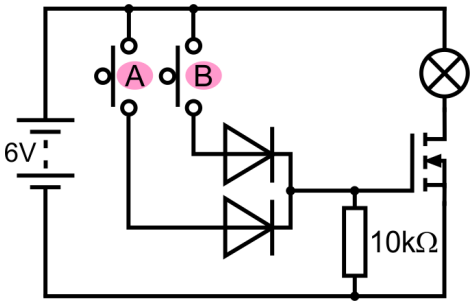
That can be the problem - some subsystems are not able to deliver sufficient current to switch the BJT on. This worksheet looks at the comparable behaviour of a MOSFET switch.

Over to you:

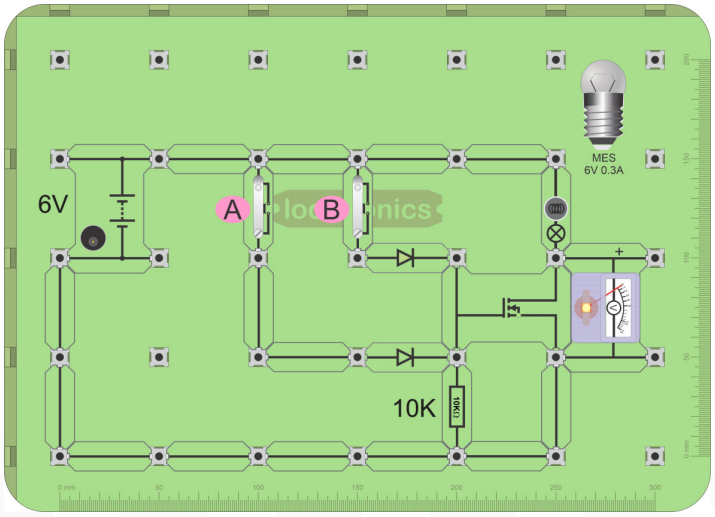
- Build the circuit shown opposite.
- Set the DC power supply to output 6V.
- Measure voltages V_L, across the lamp and V_{DS}, across the MOSFET when the switch is open and then when closed.
- Copy the table and record your results in it.
- The next circuit illustrates the use of a MOSFET as a logic gate.
- Build the circuit shown. A possible layout is given below. A voltmeter has been added to indicate the output state of the MOSFET.
- The task is to identify the logic function.
- Press switches **A and B** in all four possible combinations. These are listed in the table.
- For each combination, measure the output voltage across the MOSFET.
- Copy the following table and complete it with your results:



Switch	V_{DS}	V_L
Off		
On		



Switch A	Switch B	MOSFET output in V
Open (off)	Open (off)	
Open (off)	Closed (on)	
Closed (on)	Open (off)	
Closed (on)	Closed (on)	



Copyright © 2023 - 2026 Matrix Technology Solutions Limited

So What?

A logic function is one way of manipulating digital signals. A logic gate is a device that will carry out a particular logic function. There are not many logic functions. For example, an AND gate outputs a logic 1 signal only when all its inputs sit at logic 1. MOSFETs are widely used inside digital ICs to perform logic functions.

- Remember the rules for digital logic signals:
- A low voltage, close to 0V, represents logic 0;
- A high voltage, close to 6V, represents logic 1;
- A switch delivers a logic 1 signal when pressed.
- The next step is to convert your measurements to logic signals, and complete the truth-table for the logic function.
- Copy the table and use your results in it to complete the logic state of the output.

Input A	Input B	Output
0	0	
0	1	
1	0	
1	1	

Circuit features:

- The diodes isolate the two input devices (switches.) For example, when switch **A** is pressed, the lower diode is forward biased and conducts. As a result, the MOSFET gate terminal sits at a positive voltage. This reverse biases the upper diode, isolating switch **B** from the signal from switch **A.**
- The insulated gate terminal and source acts as a small capacitor, usually only a few nano-Farads, but this can become charged and affect the performance. The 10kΩ resistor discharges this capacitor.

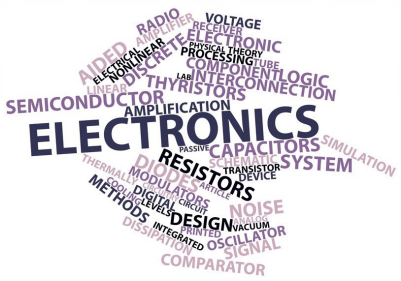
A challenge:

Modify the second circuit so that it acts as an 'AND' gate.

For your records:

- Copy the circuit diagram for the MOSFET switch.
- Write a brief explanation (no more than three sentences,) for a fellow student on why the circuit can be described as a switch.
- Use the datasheet for the **`RFP30N06LE`** to find the following information for this MOSFET:
- Maximum continuous drain current;
- Maximum power dissipation (assuming the use of a heat-sink);
- Maximum value of $R_{DS(ON)}$, (drain to source 'on' resistance).
- Use this information to work out the power dissipation in the MOSFET when it is passing maximum (continuous) drain current.

Copyright © 2023 - 2026 Matrix Technology Solutions Limited



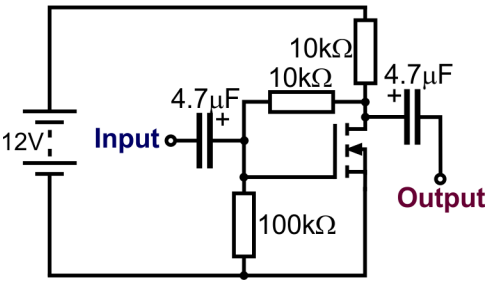
Depending on the application, MOSFETs can offer significant advantages over BJTs, including higher input impedance, smaller power loss - the effect of $R_{DS(ON)}$ is usually smaller than that of the BJT forward voltage drop V_{CE} (~ 0.3V) - faster switching and no tendency for thermal runaway.

However input capacitance can cause problems for high speed switching and it has a higher input turn-on voltage,(~3V as opposed to ~0.7V);

Over to you:

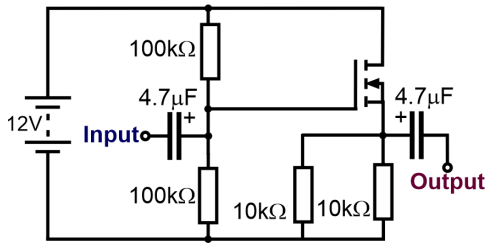
Common-source amplifier:

- Build the circuit shown opposite, using your own layout design.
- Set the DC power supply to 12V.
- Connect the input to a signal generator, set to output a signal of amplitude 50mV and frequency 1kHz.
- Connect a dual-channel oscilloscope to display the input and output signals.
- Obtain a trace showing the input and output signals and save it for your records.
- Use it to estimate the voltage gain of the amplifier.



Source follower:

- Build the circuit shown opposite, again using your own layout design
- The diagram includes two DC-blocking capacitors.
- Set the DC power supply to 12V.
- Connect the input to a signal generator, set to output a signal of amplitude 2V and frequency 1kHz.
- Connect a dual-channel oscilloscope to display the input and output signals.
- Obtain a trace showing the input and output signals and save it for your records.



Copyright © 2023 - 2026 Matrix Technology Solutions Limited

So What?

Common-source amplifier:

- The 10kΩ load resistor and the MOSFET share the 12V supply.
- The 10kΩ feedback resistor and the 100kΩ resistor bias the MOSFET in the saturation region.
- The ideal is to allow the output voltage to swing up and down, in response to the input signal, by as large an amount as possible.
- In other words, we aim to sit the drain terminal at ~ ½ supply voltage, i.e. ~6V.

Source follower:

- The output voltage follows the input voltage, but is about 2V lower.
- The current gain is enormous, because the input current is tiny. Although the voltage gain is less than unity, overall there is a big power gain.
- It provides a reasonably low output impedance to the following subsystem, though not as low as the emitter follower. A low output impedance means that the output will not drop under load.
- It has the advantage that the input impedance is huge, almost infinite.
- The MOSFET is in saturation, so the current across it is determined by the gate-source voltage.

A challenge:

- One issue for the design of MOSFET circuits is that performance parameters vary greatly from device to device. The component values given in the circuit diagrams are not necessarily optimal for the MOSFET you are using.
- Experiment with other resistor values in both circuits to try to improve the performance.

For your records:

For each circuit:

- Copy the circuit diagrams .
- Describe the steps taken to obtain the Picoscope trace and any other results.
- Write a brief explanation of the function of each resistor and capacitor in the circuit.
- Write detailed notes of any changes you made to improve the system performance and describe the resulting effect.

Copyright © 2023 - 2026 Matrix Technology Solutions Limited

STUDENT HANDOUT

Copyright © 2023 - 2026 Matrix Technology Solutions Limited

Student Handout

Worksheet 1
Testing BJT transistors

NPN

Switch	Base current I_B	Collector current I_C
Open	0	
Closed	0.5mA	

PNP

Switch	Base current IB	Collector current I_C
Open	0	
Closed	0.5mA	

- Copy the circuit diagrams for the npn and pnp transistor tests.

NPN

PNP

- Write instructions so that one of your colleagues could carry out the tests.

- Explain to your colleague why the base current is likely to be around 50µA when the switch is pressed.

- Estimate the base current if the 10kΩ resistor were swapped for a 100kΩ resistor.

- Copy the formula for current gain hFE:

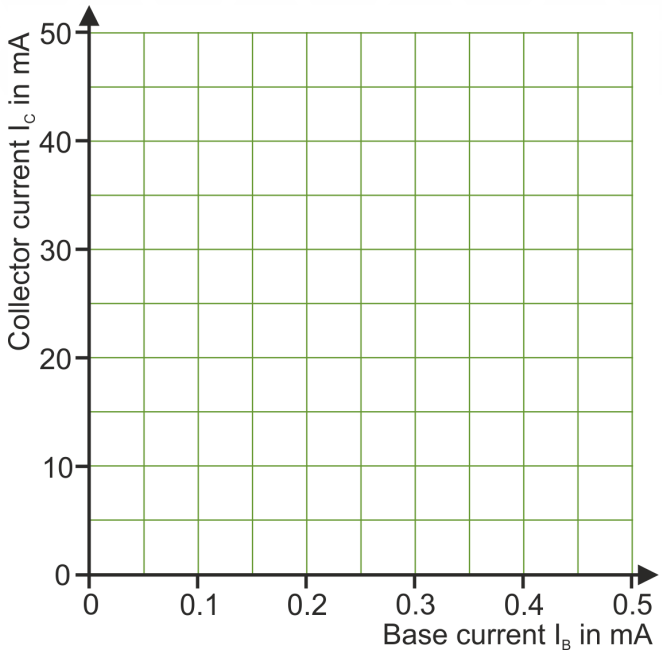
Copyright © 2023 - 2026 Matrix Technology Solutions Limited

Student Handout

Worksheet 2
BJT transfer characteristics

Current transfer characteristic

I_B in	I_C in
0	
0.1	
0.2	
0.3	
0.4	
0.5	



A challenge:
Test different BC108 transistors (or any other type available to you) with a multimeter transistor tester to see the variation in current gain.

For your records:

- Copy the circuit diagram for the circuit you set up in this investigation.

- Describe the steps taken to obtain the current transfer characteristic for the transistor.

- Measure the gradient of the graph you plotted to give you an estimate of the current gain of the transistor.

matrix
Copyright © 2023 - 2026 Matrix Technology Solutions Limited

Student Handout

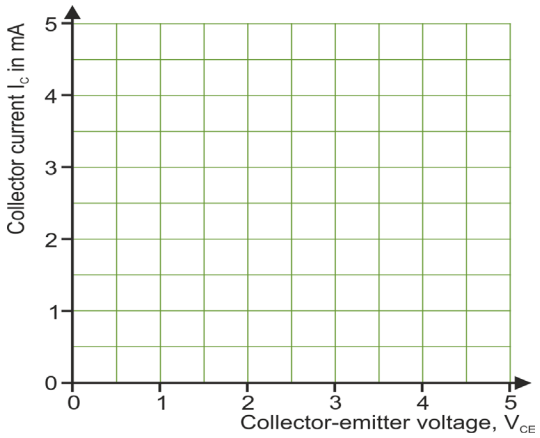
- Identify the transistor used on the transistor carrier. Look for the writing on the transistor body. It may be a ZTX 451. Use the internet to check the manufacturer's value for current gain with the one you obtained.

- Copy the following table and complete it.

Transistor type	Current gain	Base current	Collector current in mA
BC108	500	10mA	
BFY51	60		300
BD437		8mA	500
BC546	200		100
2N3904		100mA	12

Worksheet 3
BJT output characteristics

V_{CE}	I_C in mA	
	R=200k	R=100k
0.0 V		
1.0 V		
2.0 V		
3.0 V		
4.0 V		
5.0 V		



For your records:

- Copy the circuit diagram for the circuit you set up in this investigation.
- Describe the steps taken to obtain the output characteristic for the transistor.

- Measure the gradient of the linear portion of the two graphs you plotted and hence obtain the output resistance.

Copyright © 2023 - 2026 Matrix Technology Solutions Limited

Student Handout

Worksheet 4
Transistor as a switch

Switch	V_{CE}	V_L
Off		
On		

For your records:

- Copy the circuit diagram for the transistor switch given at the start of the investigation.

- Explain why the transistor can be described as a switch in this arrangement.

- Assuming that the base-emitter voltage is 0.7V when the transistor is on, estimate the base current when the switch is closed in:
- The lamp circuit;
- The motor circuit.

- Explain why the base resistor in the motor circuit has a much lower value than that used in the lamp circuit.

- Write an explanation that a fellow student would understand as to why a diode, connected in reverse parallel, is needed when the motor is switched on and off by a transistor.

Copyright © 2023 - 2026 Matrix Technology Solutions Limited

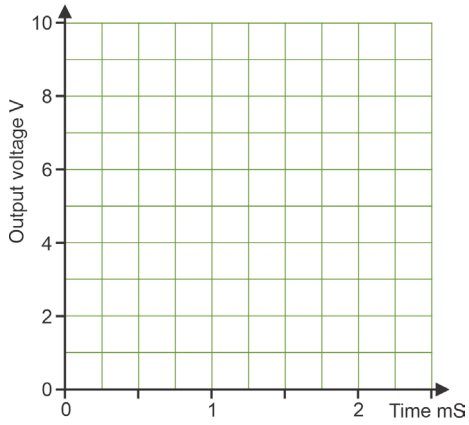
Student Handout

Worksheet 5
Transistor as an amplifier

Measurement	Voltage
DC voltage at collector	
DC voltage at base	
DC voltage at emitter	
AC input amplitude	
AC output amplitude	

For your records:

- Copy the circuit diagram for the transistor amplifier.



- Explain what your oscilloscope traces show.

- Use them to estimate the voltage gain before distortion sets in.

- Explain why the output becomes distorted for larger input signal amplitudes.

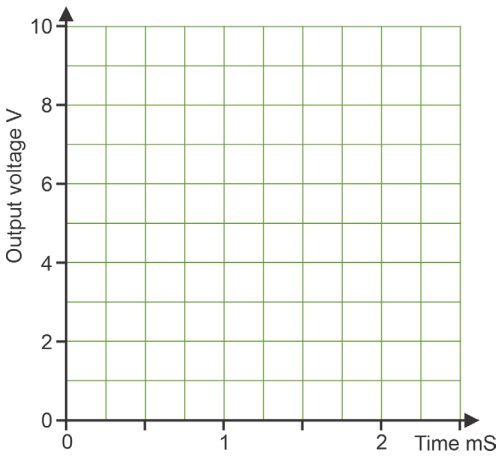
Copyright © 2023 - 2026 Matrix Technology Solutions Limited

Worksheet 6
Transformer-coupled amplifier

Measurement	Voltage
AC input amplitude	
AC output amplitude	
Voltage gain =	

For your records:

- Copy the circuit diagram for the transistor amplifier.



- Explain what your oscilloscope traces show.

- Use them to estimate the voltage gain:

Copyright © 2023 - 2026 Matrix Technology Solutions Limited

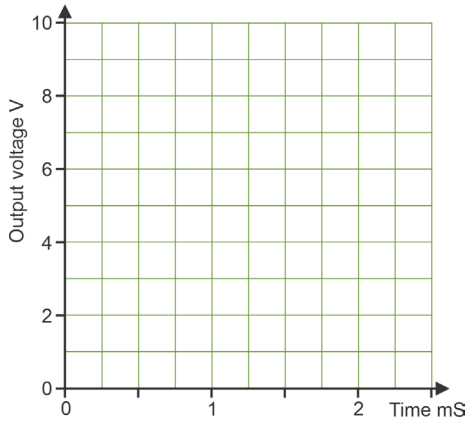
Student Handout

Worksheet 7
Stabilised common-emitter amplifier

Measurement	Voltage
DC voltage at collector	
DC voltage at base	
DC voltage at emitter	
AC input amplitude	
AC output amplitude	

For your records:

- Copy the circuit diagram for the transistor amplifier.



- Describe the function of the voltage divider connected to the base of the transistor.

- How does the emitter resistor provide negative feedback?

- Explain how the emitter resistor bypass capacitor affects voltage gain.

- Using resources such as the internet or text-books, explain what is meant by 'negative feedback' and describe its effects in applications like the current one.

Copyright © 2023 - 2026 Matrix Technology Solutions Limited

Student Handout

Worksheet 8
Emitter follower behaviour

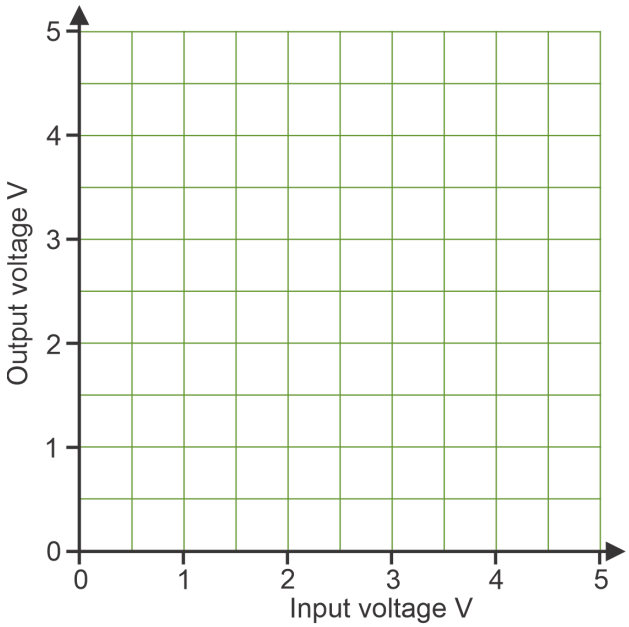
Input voltage V_{IN}	Output voltage V_{OUT}
0	
1.0	
2.0	
3.0	
4.0	
5.0	

For your records:

- Copy the circuit diagram for the transistor amplifier.

Input voltage V_{IN}	Output voltage V_{OUT}
-1.0	
-2.0	
-3.0	

- Use your results to plot a graph of V_{OUT} against V_{IN} (i.e. the voltage transfer characteristics) for the emitter follower.



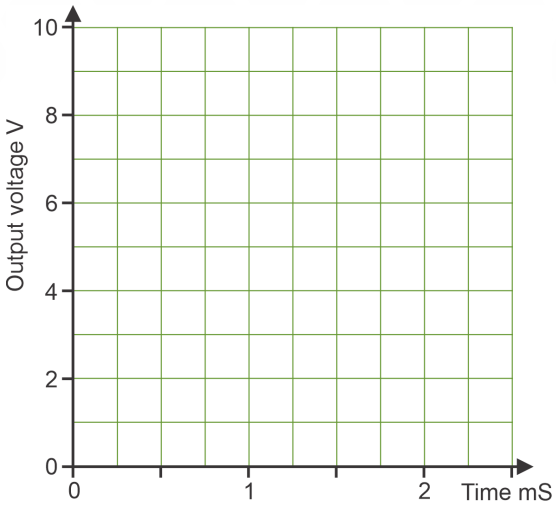
- Copy the expressions given above for the emitter follower relationship, its voltage gain, and its current gain.

- Write an explanation for one of your fellow students to show that emitter follower has an overall power gain (= voltage gain x current gain).

Copyright © 2023 - 2026 Matrix Technology Solutions Limited

Student Handout

Worksheet 9
Emitter follower - AC behaviour



For your records:

- Copy the initial circuit diagram for the emitter follower

- Explain the purpose of the two capacitors.

- Explain why the circuit creates distortion.

- Draw the circuit diagram for the modification given in the second challenge.

- Explain why this modification should reduce the distortion.

Copyright © 2023 - 2026 Matrix Technology Solutions Limited

Student Handout

Worksheet 10
Push-pull follower

For your records:

- Copy the initial circuit diagram for the push-pull follower.

- Explain why the circuit creates cross-over distortion.

- Draw the circuit diagram for the modification given in the second challenge - including DC blocking capacitors.

- Explain why this modification should reduce distortion.

Copyright © 2023 - 2026 Matrix Technology Solutions Limited

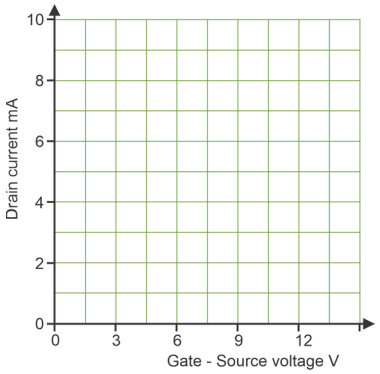
Student Handout

Worksheet 11
FET transfer characteristics

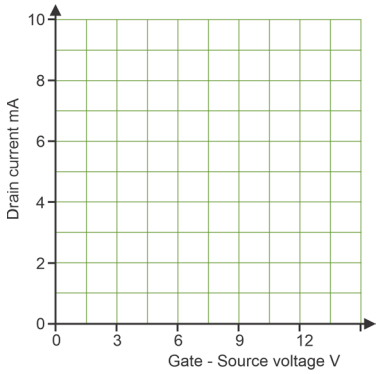
Input V_{GS}	Output I_D
0	
-0.1	
-0.2	
-0.3	
-0.4	
-0.5	

Input V_{GS}	Output I_D
-0.6	
-0.7	
-0.8	
-0.9	
-1.0	

JFET



MOSFET



For your records:

- Explain what is meant by the term 'transfer characteristic' for a FET.

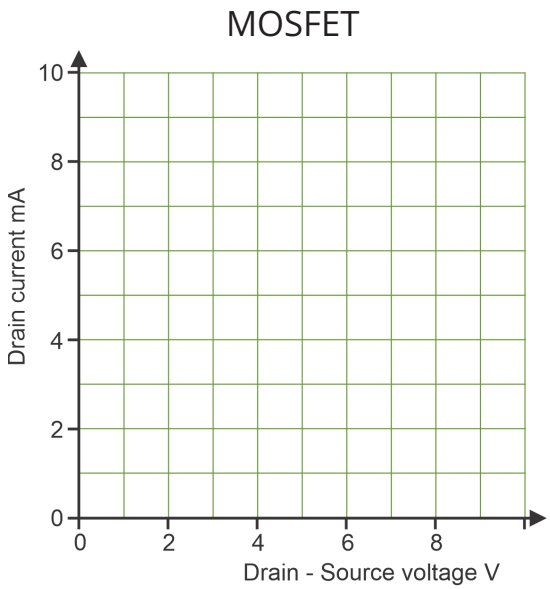
- Write an explanation of less than 100 words, for a fellow student, on the differences in the way a depletion-mode JFET and an enhancement-mode MOSFET are used in a circuit.

- Draw the circuit diagram for the investigation into the MOSFET transfer characteristic and write a simple list of instructions for a fellow student, including how to process the results.

- When a MOSFET has a transconductance of 30mS, the drain current will be ..... for a gate-source voltage of 3.0V.

Copyright © 2023 - 2026 Matrix Technology Solutions Limited

Worksheet 12
FET output characteristics



V_{DS}	V_{GS} = 2.2V	V_{GS} = 2.4V
	I_D in mA	I_D in mA
0.0 V		
0.1 V		
0.2 V		
0.3 V		
0.4 V		
0.5 V		
0.6V		
0.7V		
0.8V		
0.9V		
1.0V		

For your records:

- Copy the circuit diagram for the circuit you set up in this investigation.

- Describe the steps taken to obtain the MOSFET output characteristic.

- Measure the gradient of the two graphs you plotted to obtain estimates of $R_{DS(on)}$.

- Complete the following:
- A **2N7000** MOSFET has a value of $r_{DS(on)}$ of 5Ω. A drain current I_D of 200mA will dissipate .....mW in the device.

Copyright © 2023 - 2026 Matrix Technology Solutions Limited

Student Handout

Worksheet 13
MOSFET switch

Switch A	Switch B	MOSFET output in V
Open (off)	Open (off)	
Open (off)	Closed (on)	
Closed (on)	Open (off)	
Closed (on)	Closed (on)	

Input A	Input B	Output
0	0	
0	1	
1	0	
1	1	

For your records:

- Copy the circuit diagram for the MOSFET switch and for the OR gate:

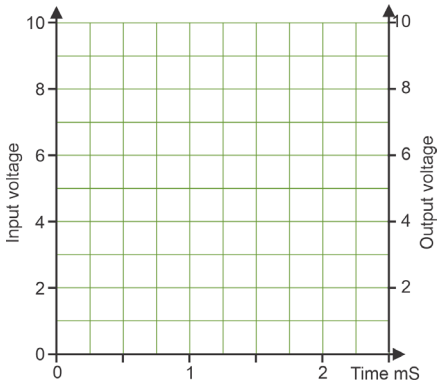
- Write a brief explanation (no more than three sentences,) for a fellow student on why the circuit can be described as a switch.

- Use the datasheet for the **RFP30N06LE** to find the following information for this MOSFET:
- Maximum continuous drain current;_____
- Maximum power dissipation (assuming the use of a heat-sink);_____
- Maximum value of $R_{DS(ON)}$, (drain to source 'on' resistance)._____
- Use this information to work out the power dissipation in the MOSFET when it is passing maximum (continuous) drain current.

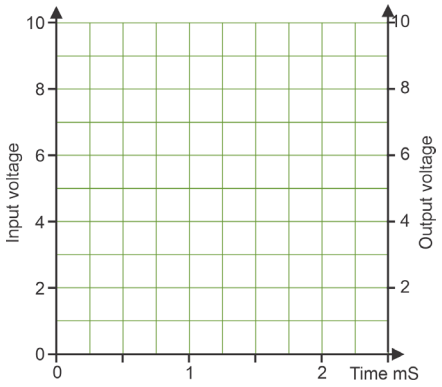
Copyright © 2023 - 2026 Matrix Technology Solutions Limited

Worksheet 14
MOSFET applications

Common source



Source follower



For your records:

- Copy the circuit diagrams.

- Describe the steps taken to obtain the Picoscope trace and any other results.

- Write a brief explanation of the function of each resistor and capacitor in the circuit.

- Write detailed notes of any changes you made to improve the system performance and describe the resulting effect.

Copyright © 2023 - 2026 Matrix Technology Solutions Limited

Notes

Copyright © 2023 - 2026 Matrix Technology Solutions Limited

Notes

Copyright © 2023 - 2026 Matrix Technology Solutions Limited

TRANSISTOR AMPLIFIERS

CP4403

www.matrixtsl.com

Matrix Technology Solutions
The Factory, 33 Gibbet Street, Halifax, HX1 5BA, United Kingdom
t: +44 (0) 1422 252380 e: sales@matrixtsl.com