locktronics

Simplifying Electricity

EASA - Electronic Fundamentals 2

CP7422

MATRIX

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Contents

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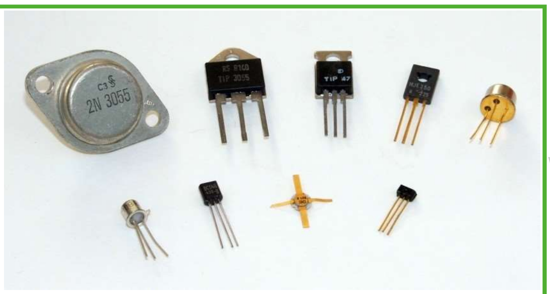
Worksheet 1

Testing 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).

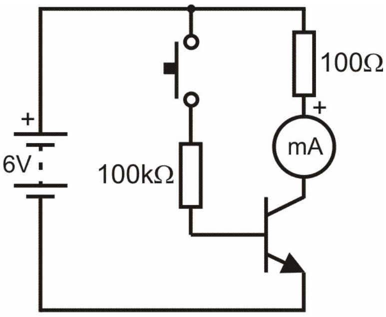


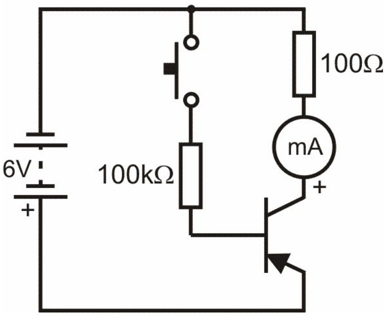
ICs contain many hundreds, thousands or even millions of transistors.

Bipolar junction transistors (BJT) come in two types, NPN or PNP, depending on the impurities used to ’dope’ the single crystal of silicon it is made from. The resulting P-N junctions are manufactured by diffusing impurities through a photographically reduced mask.

In this worksheet you will learn how to carry out basic checks on NPN and PNP transistors.

Over to you:





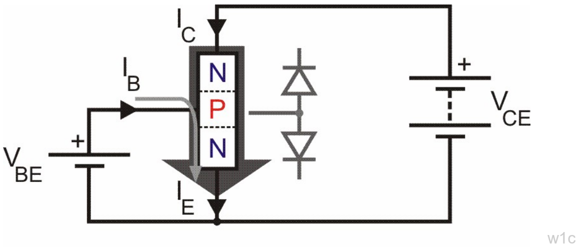
- Build the circuit shown in the upper diagram, designed to test an NPN transistor.
- Set the DC power supply to output 6V.
- Adjust the multimeter so that it reads up to 20mA DC.
- Measure the current flowing. Record it in the left-hand table below.
- Press and hold the switch closed.
- Measure and record the new current.
- Then build the lower circuit, designed to test a PNP transistor. Notice that the power supply and multimeter are now inverted.
- Repeat the same procedure as for the NPN transistor.
- Record the measurements in the appropriate table below.

NPN Transistor	
Switch	Collector current (mA)
Open (I_B = 0 μA)	
Closed (I_B ~ 54 μA.)	

PNP Transistor	
Switch	Collector current (mA)
Open (I_B = 0 μA)	
Closed (I_B ~ 54 μA.)	

So what?

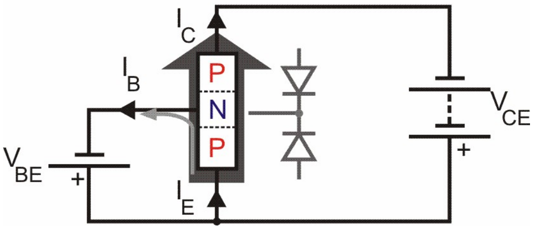
- What do the results tell you? Are the devices that you have checked functional? If not, what faults did you detect?
- The ratio of collector current (I_C) to base current (I_B) for a transistor gives the value of current gain, called h_{FE}, for the device.
  In other words,
  $$h_{FE} = I_C / I_B$$
  Calculate the current gain for each of the devices that you have checked.
- Transistors are mass-produced. The manufacturer will quote typical values for the current gain, but two individual devices may have widely different current gains.
  Given that the current gain for a small-signal transistor can vary from about 75 to 250, are your calculated values of current gain typical?



The diagrams show the direction of current flow in both NPN and PNP transistors.

- Compare them.

You can see why the PNP transistor can be considered as a mirror-image of the NPN device.



For your records:

It is often useful to be able to perform a quick functional check of a transistor.

- This can be done easily if a multimeter with a transistor-check facility is available.
- Alternatively, the forward and reverse resistance of each of the two diode junctions within the transistor (see above) can be measured using a multimeter on the Ohms range.
- A third approach is to connect a transistor to a power supply and measure the current flowing in the collector in response to the current applied to the base. A large current should flow in the collector when a much smaller current is applied to the base. This is the approach you used in this investigation.

Worksheet 2

BJT transistor characteristics

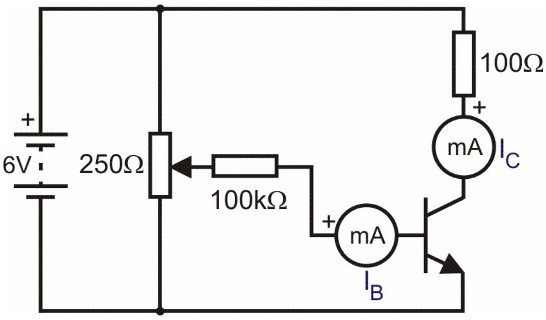
A more meaningful measure of the performance of a transistor is obtained by plotting graphs that show how the base current, collector current, and collector-emitter voltage are related.

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

In this worksheet you plot two different characteristics for a transistor. The first is known as the **transfer characteristic** whilst the second is called the **output** (or **collector**) **characteristic**.

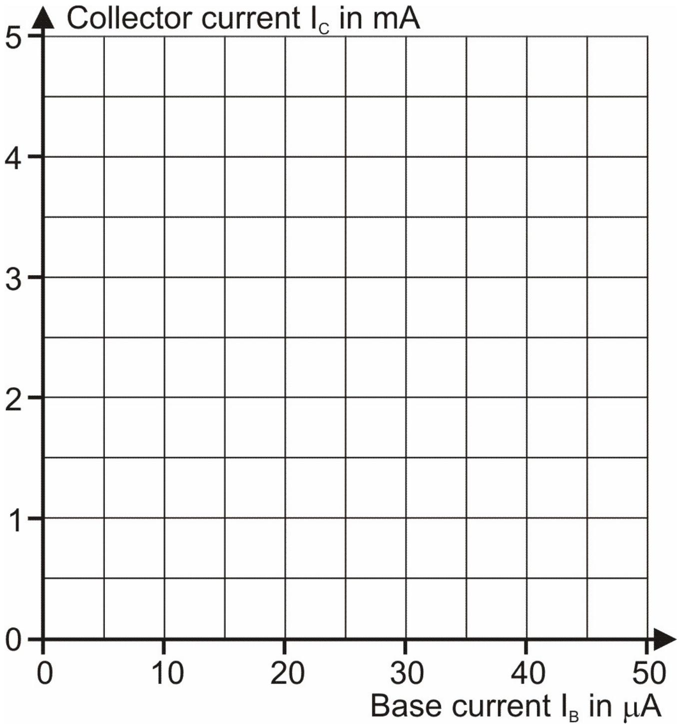
Over to you:

1. Transfer characteristic - I_C plotted against I_B



- Build the first circuit.
- Set the DC power supply to output 6V.
- Set the base current ammeter to the 2mA DC range, and the collector current ammeter to the 20mA DC range.
- Use the 'pot' to vary the base current, I_B, from 0 μA to 50 μA in steps of 10 μA. At each step, measure and record the collector current, I_C.
- Use your results to plot the transfer characteristic, I_C plotted against I_B, on the grid provided.

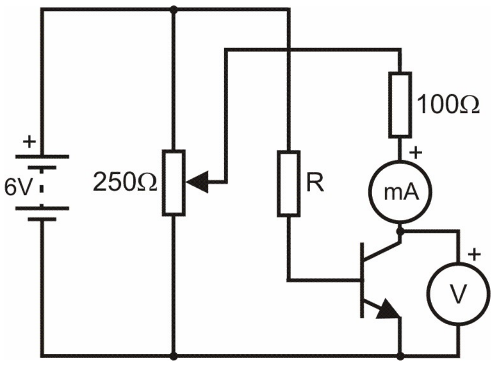
I_B in μA	I_C in mA
0	
10	
20	
30	
40	
50	



Worksheet 2
BJT transistor characteristics

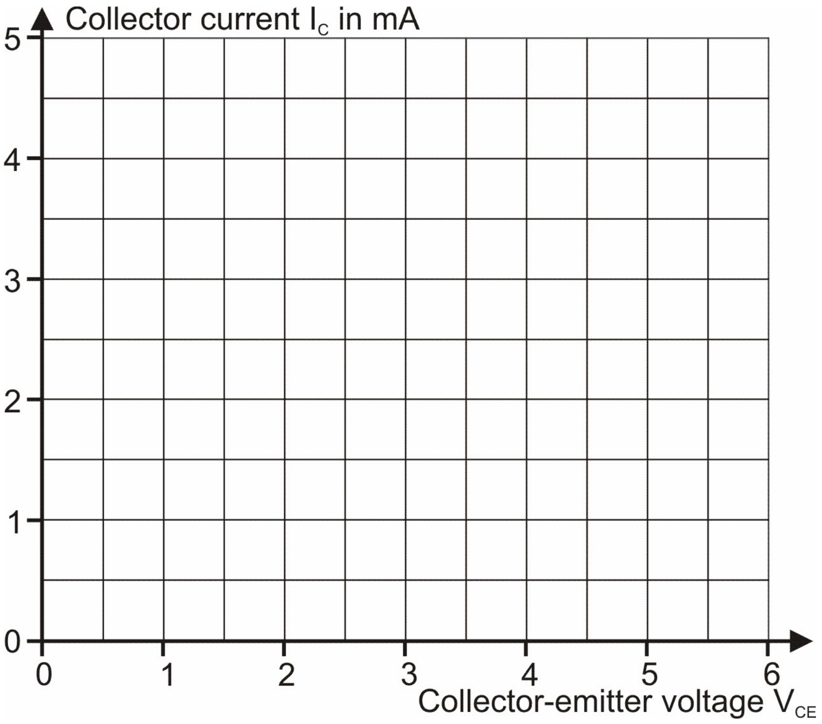
Over to you - continued:

2. Output characteristic - I_C plotted against V_{CE}



- Build the second circuit using a value of 200kΩ for R.
- Set the DC power supply to output 6V.
- Set the collector current ammeter to the 20mA DC range, and the voltmeter to the 20V DC range.
- Use the 'pot' to vary the collector voltage from 0V to 6V in 1V steps. For each, measure the collector current, I_C.
- Use your results to plot the output characteristic, I_C plotted against V_{CE}.
- Replace the 200kΩ resistor with a 100kΩ resistor, to give a bigger base current, and repeat this process.
- Plot a second characteristic curve on the same axes.

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



So what?

- What does the shape of the two graphs tell you?
- Calculate the slope of the transfer characteristic to obtain the current gain of the transistor.

Current gain =

- Calculate the slope of the output characteristic to obtain the output resistance of the transistor.

Output resistance =

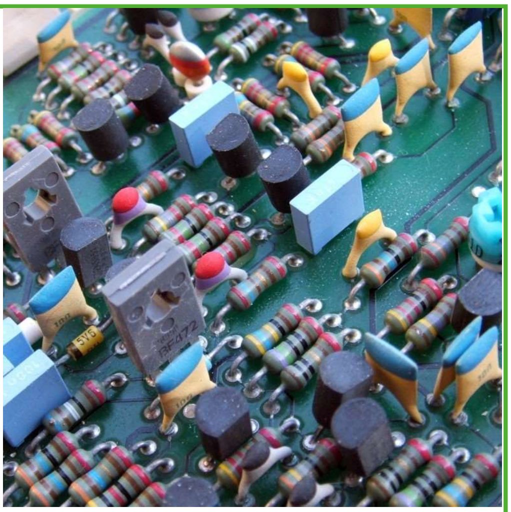
Worksheet 3

Transistor as a switch

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

Transistor switches operate under **saturated** conditions, meaning that the collector voltage will either be the same as the supply voltage (in the 'off' state) or very close to 0 V (in the 'on' state).

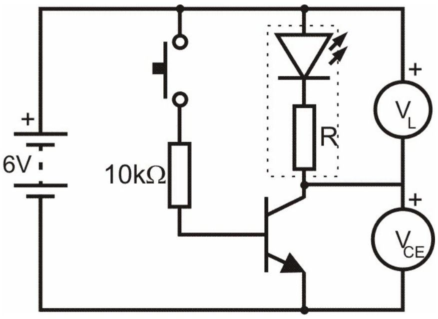
In this worksheet you build and test two simple switching circuits. The first operates a LED, the second a DC motor.



w3a

Over to you:

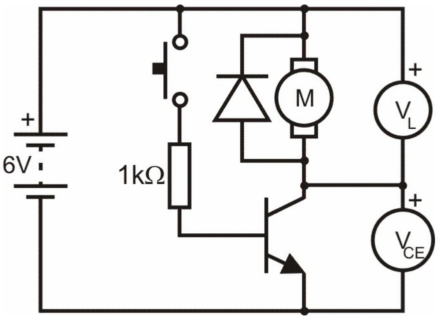
- Build the first switching circuit.
  The LED is controlled by the switch. The small base current that flows when the switch is closed produces a much larger collector current, flowing through the LED.
- Measure and record the voltages across the LED, V_L, and across the transistor, V_{CE}.



w3b

Switch	V_{CE}	V_L
Off		
On		

- Build the second switching circuit.
  The diode is a 1N4001 device. Its purpose is explained on the next page.
  The switch now controls a motor. As before, the small base current that flows when the switch is closed controls a much larger collector current, flowing through the motor.
- Measure and record the voltages across the motor, V_L, and across the transistor, V_{CE}.



w3c

Switch	V_{CE}	V_L
Off		
On		

So what?

A diode is connected across the load in the motor circuit but not in the LED circuit.
Here's why:

- The motor is an electromagnetic device. It rotates because a strong magnetic field is created in its coil when a current flows through it.
- When the current ceases to flow, that magnetic field collapses through that coil of wire, and generates a large voltage in the opposite direction - an example of Lenz's law.
- This 'back emf' can be high enough to damage the transistor.
- To avoid this, a diode is connected in reverse parallel. As far as the power supply for the circuit is concerned, the diode is reverse-biased and essentially does nothing. For the large voltage generated by the falling current, however, the diode is forward-biased, and so conducts freely. The voltage drop across it is clamped to 0.7V, or -0.7V as seen by the transistor. This causes no damage to the transistor.
- Any similar electromagnetic device, such as a relay, should be bypassed by a reverse parallel diode in similar fashion for the same reason.

- Look at the two results tables for V_{CE} and V_L.
  Add together the measurements, V_{CE} and V_L in each case.
  What do you notice?
  What do you expect the result to be, bearing in mind that the transistor and the LED / motor form a voltage divider across the power supply rails?
- Modify the LED circuit so that the LED remains **on** when the switch is open and goes **off** when it is closed
  (Hint: You will have to change the position of the switch in the circuit).
- Modify the motor circuit so that the switch controls both a LED and the motor.

For your records:

- Is the transistor operating as a saturated switch in both circuits?
  How do you know?
- Explain why the base resistor has a much lower value in the motor circuit than for the LED.
- Calculate the base current that flows when the switch is closed in:
    - the LED circuit;
    - the motor circuit.

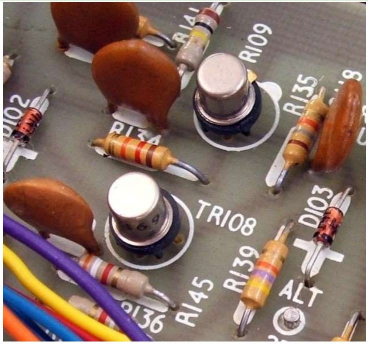
  (Assume that the base-emitter voltage is 0.7V when the transistor is conducting a current.)

Worksheet 4

Transistor as an amplifier

When a bipolar junction transistor is used to amplify audio signals, we first ensure that the transistor is **biased,** meaning that some collector current will flow even when no signal is present.

In this worksheet you will investigate the operation of a very simple common-emitter amplifier stage that uses this technique.



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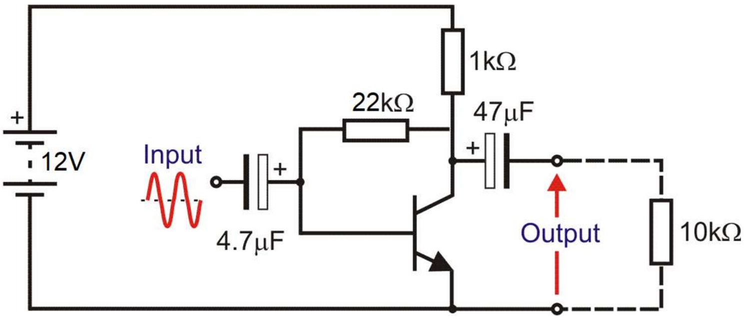
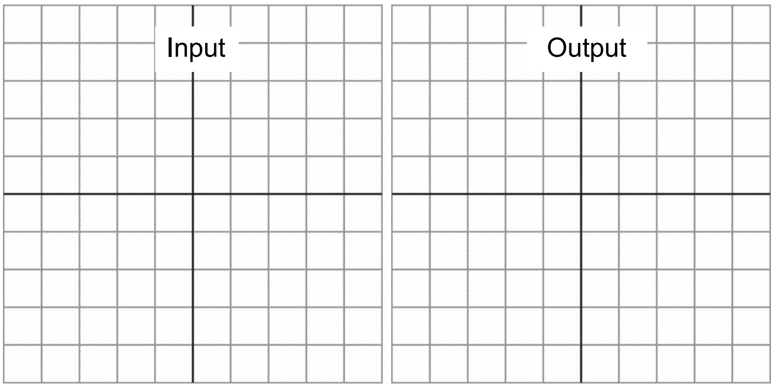
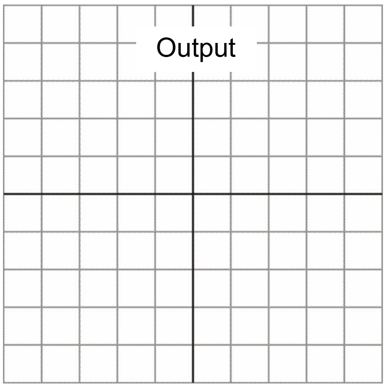


- Build the circuit shown opposite. The 10kΩ resistor acts as a load for the amplifier.
- Set the DC power supply to 6V.
- Measure and record the DC voltages present at the collector, base and emitter of the transistor.
- Connect the input to a signal generator, set to give an output of 30mV peak-to-peak at a frequency of 1kHz.
- Connect a dual-channel oscilloscope to display the input and output waveforms. The common ground connection is connected to the negative supply rail.
- Adjust the oscilloscope controls to display two cycles of the input and output waveforms.
- Sketch these on the grids provided.
- Measure the peak-to-peak voltages at the input and at the output.
- Increase the input voltage to 100mV pk-pk. Observe and sketch the effect on the output.

Measurement	**Voltage**
DC bias voltage at collector	
DC bias voltage at base	
DC bias voltage at emitter	
Input voltage, pk - pk	
Output voltage, pk - pk	



Input = 50mV pk-pk



Input = 100mV pk-pk

Worksheet 4

Transistor as an amplifier

So what?

The way the transistor behaves:

When the input voltage **in**creases:

- the base current **in**creases;
- the collector current **in**creases;
- the voltage across the 1kΩ resistor **in**creases;
- the output voltage **de**creases.

When the input voltage **de**creases:

- the base current **de**creases;
- the collector current **de**creases;
- the voltage across the 1kΩ resistor **de**creases;
- the output voltage **in**creases.

For this to happen, we allow some base current to flow all the time, even when no input signal is present. This is called DC biasing.

When no signal is present, a small base current can still flow through the 1kΩ and 100kΩ resistors. As a result, a bigger collector current flows, creating a voltage drop across the 1kΩ resistor, and leaving an output voltage less than the supply voltage.

The greater the base current, the greater the collector current, the greater the voltage drop across the 1kΩ resistor, and the lower the output voltage across the collector-emitter junction.

We aim to make the output voltage ~ half of the supply voltage when no signal is present. (called the quiescent state.) In that way, the output voltage can rise and fall by very similar amounts when a signal is present.

The signal is coupled into and out of the amplifier via capacitors that isolate the amplifier so that the DC voltages and currents inside it are unaffected by whatever is connected to the input and output terminals.

- Use your results to calculate the voltage gain of the amplifier:

Voltage gain = ...

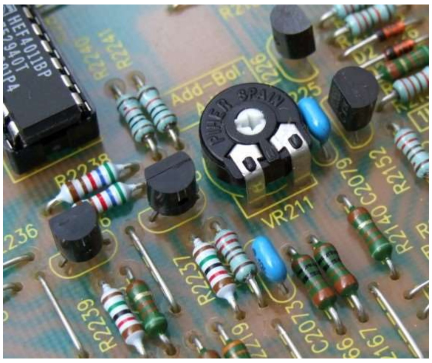
For your records:

- Explain why the output becomes distorted for larger input signal amplitudes.
- What is the maximum output signal voltage before distortion is noticeable?
- How could the output voltage be increased?

Worksheet 5

Transformer coupled amplifier

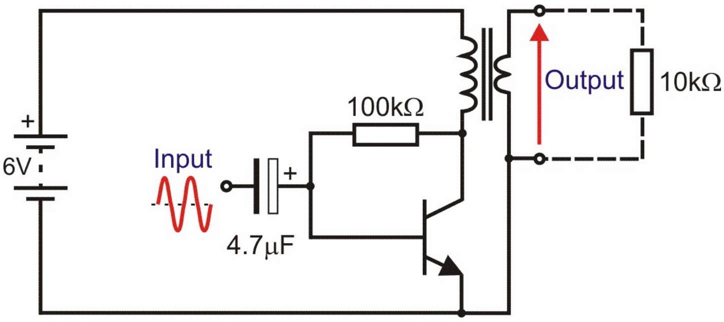
Earlier, you investigated a simple common-emitter amplifier in which a capacitor was used to couple the signal from the collector to the output.



Other inter-stage coupling arrangements are used, including those based on inductors and capacitors, and on transformers. The latter has the advantage of offering accurate impedance matching to a load, ensuring efficient signal transfer.

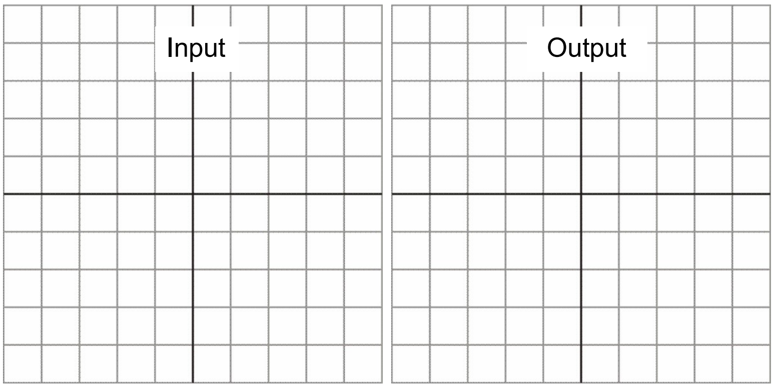
In this worksheet you investigate the operation of a simple transformer-coupled common-emitter amplifier. You should compare the results obtained here with those obtained earlier.

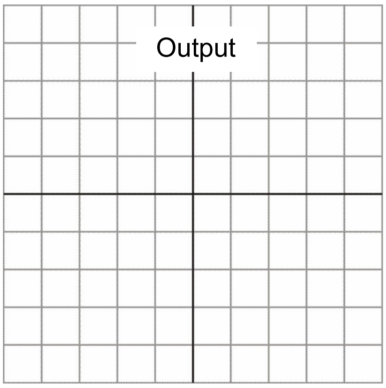
Over to you:



Measurement	Voltage
Input voltage, pk - pk	
Output voltage, pk - pk	

- Build the circuit shown. Again, a 10kΩ resistor acts as a load for the amplifier. The 2:1 transformer, connected as a step-down transformer, is used to couple the amplifier output.
- Set the DC power supply to output 6V.
- Connect the input to a signal generator, set to give an output of 20mV peak-to-peak at a frequency of 1kHz.
- Connect a dual trace oscilloscope to display input and output waveforms, with the ground connected to the negative supply rail.
- Adjust the oscilloscope controls to display two cycles of the input and output waveforms.
- Sketch these on the grids provided.
- Measure the peak-to-peak voltages at the input and at the output.





- Increase the input voltage to 100mV pk-pk.

Worksheet 5

Transformer coupled amplifier

So what?

In the capacitor coupled amplifier studied earlier, the collector current, I_C, flowed through the 1k Ω resistor in series with it. This generates waste heat. The role of the transformer is to reduce that energy loss.

Transformers respond only to AC signals. These produce an alternating magnetic field in the primary coil, which, in turn, induces an AC signal in the secondary, connected to the load.

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.

- Use your results to calculate the voltage gain of the amplifier:

Voltage gain = ...

- Compare the performance of this amplifier with the capacitor-coupled amplifier you studied earlier.
- Investigate what happens if the transformer is reversed, to act as in step-up rather than a step-down mode.

For your records:

As before, the transistor is biased, so that a current flows through the transistor even when no signal is present. Ideally, this current is adjusted to make the collector sit at a voltage mid-way between the power supply rails.

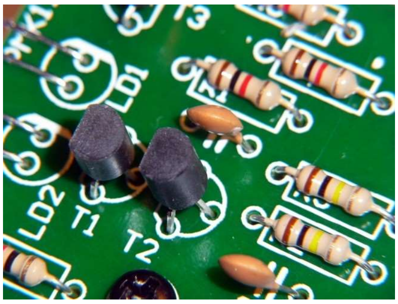
- What is the maximum output signal voltage before distortion is noticeable?
- How could the output voltage be increased?

Worksheet 6

Stabilised common-emitter amplifier

The simple common emitter can be improved by using DC negative feedback to stabilize the stage and compensate for variations in transistor parameters, component tolerances and temperature changes.

In this worksheet you investigate the operation of a common emitter amplifier incorporating DC feedback stabilisation.



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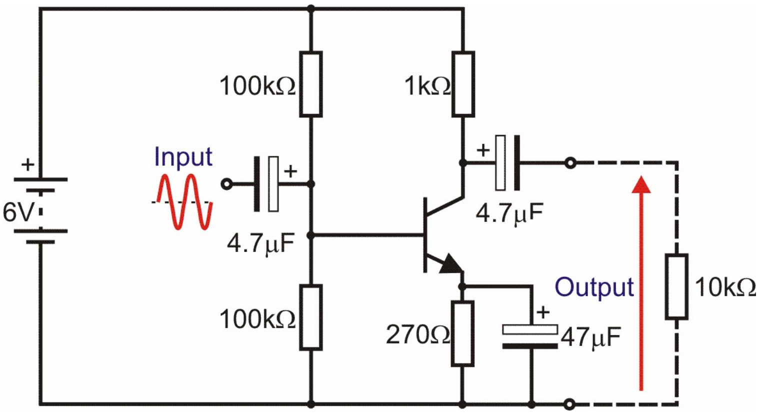
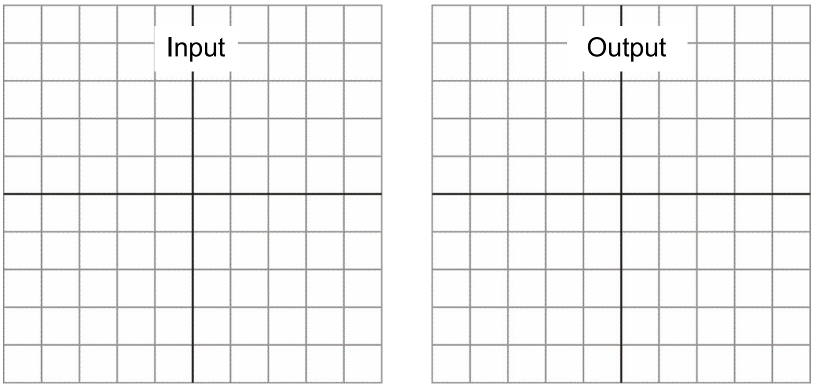


- Build the circuit shown opposite.
  Again, a 10kΩ resistor acts as a load for the amplifier.
  A 270Ω emitter resistor and parallel 47µF capacitor provide negative feedback.
  Two 100kΩ resistors provide a DC bias voltage for the base.
- Set the DC power supply to output 6V.
- Measure and record the DC voltages at the collector, base and emitter of the transistor.
- Connect the input to a signal generator, set to give an output of 20mV peak-to-peak at a frequency of 1kHz.
- Connect a dual trace oscilloscope to display input and output waveforms, with the ground connected to the negative supply rail.
- Adjust the oscilloscope controls to display two cycles of the input and output waveforms.
- Sketch these on the grids provided.
- Measure the peak-to-peak voltages at the input and at the output.

Measurement	Voltage
DC bias voltage at collector	
DC bias voltage at base	
DC bias voltage at emitter	
Input voltage, pk - pk	
Output voltage, pk - pk	



Input = 20mV pk-pk

Worksheet 6

Stabilised C-E amplifier

So what?

The quiescent (DC) base voltage is set by the two 100kΩ resistors, forming a voltage divider across the power supply rails.

- With a 6V power supply, and two equal resistors, what DC voltage do you expect at the base?

  Voltage at base = ...

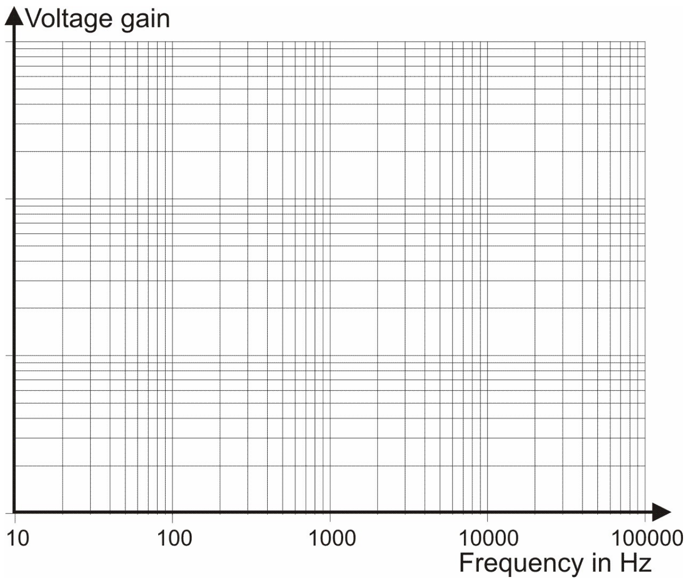
Negative feedback provides a signal which opposes changes at the output. If temperature or power supply changes etc. cause the DC collector current to rise, the voltage across the 270Ω emitter resistor also rises. As a result, the voltage drop across the base-emitter junction falls, reducing the base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

One effect of negative feedback is to reduce the voltage gain of the amplifier. The 47μF capacitor has no effect on DC currents, which see it as a gap in the circuit. However, AC signals can flow through this capacitor, bypassing the emitter resistor. As a result, the AC voltage gain is not affected as much.

- Use your results to calculate the voltage gain of the amplifier:

  Voltage gain = ...

- Vary the frequency of the signal generator over the range 10 Hz to 100 kHz and measure the output voltage at suitable intervals.
- Use this data to plot a frequency response characteristic for the amplifier that shows voltage gain plotted against frequency.
- A 'log-log' grid is provided. If you are unsure how to proceed, ask your tutor!



w6c

For your records:

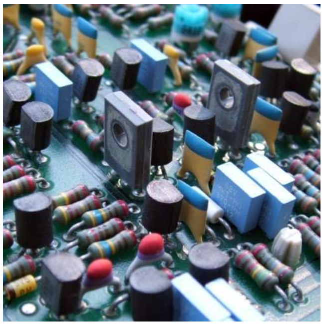
- Compare the DC voltages measured at the collector, base and emitter with those measured earlier for the capacitor coupled (uncompensated) amplifier.
- Comment on the performance of the amplifier and explain why the amplifier produces slightly less output voltage swing.

Worksheet 7

Two-stage amplifier

The voltage gain produced by a single stage transistor amplifier is insufficient for many applications. To overcome this, we can use a multi-stage arrangement where several transistors are used in cascade (as shown in the arrangement below).

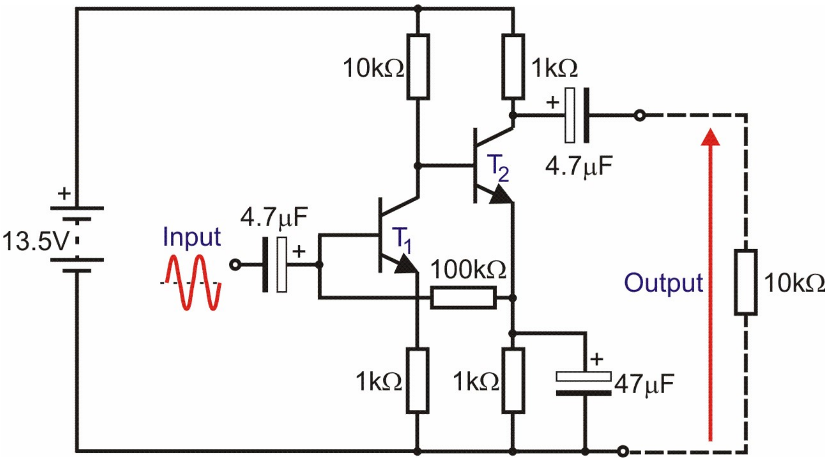
In this work sheet you construct and test a two-stage amplifier where both transistors are operated in common emitter mode.



w7a

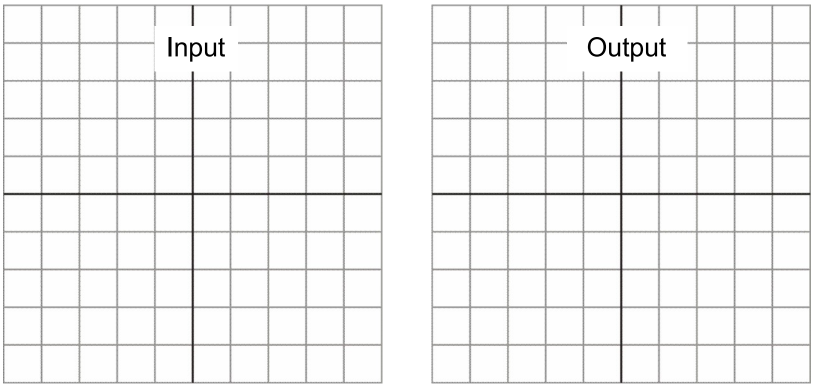
Over to you:

- Build the circuit shown opposite, which again uses a 10kΩ load resistor.
- Notice that the DC power supply is now set to output 13.5V.
- Measure and record the DC voltages at the collector, base and emitter of each transistor.
- Connect the input to a signal generator, set to give an output of 20mV peak-to-peak at a frequency of 1kHz.
- Connect a dual trace oscilloscope to display input and output waveforms, as before.
- Adjust the oscilloscope controls to display two cycles of the waveforms.
- Sketch these on the grids provided.
- Measure the peak-to-peak voltages at the input and at the output of the amplifier.



w7b

	Measurement	**Voltage**
T_1	DC collector voltage	
	DC base voltage	
	DC emitter voltage	
T_2	DC collector voltage	
	DC base voltage	
	DC emitter voltage	
Input voltage, pk - pk		
Output voltage, pk - pk		



Input = 20mV pk-pk

w4c

Worksheet 7

Two-stage amplifier

So what?

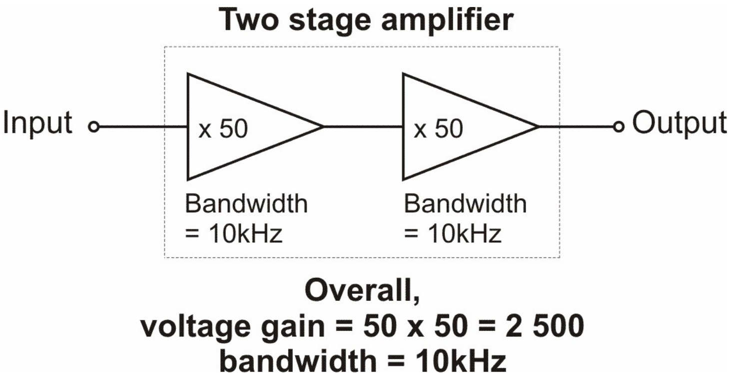
The overall voltage gain of the stage is the product of the individual stage gains. Using this technique amplifiers with voltage gains of typically between 200 and 1,000 can be produced. Essentially, there is a trade-off between voltage gain and bandwidth (range of frequencies that is amplified.)

The bigger the voltage gain, the smaller the bandwidth (and vice-versa.)

The diagram shows a two-stage amplifier made from two voltage amplifiers, each with a bandwidth of 10 kHz, cascaded together.

Each amplifier by itself has a gain of 50x. However, when they are cascaded, the overall gain is 50 x 50 (= 2 500.)

The first amplifier has a bandwidth of 10 kHz, and so amplifies successfully all frequencies up to 10kHz. So does the second amplifier. Overall, the system has a bandwidth of 10 kHz with a voltage gain of 2 500!



- Use your results to calculate the voltage gain of the amplifier:

Voltage gain = ...

- Find, by investigation, the maximum output signal voltage obtainable before distortion is noticeable? How could the output voltage be increased?

For your records:

- Compare the DC voltages measured at the collector, base and emitter with those measured earlier for the capacitor coupled (uncompensated) amplifier.
- Explain why the signal becomes distorted for larger input signal amplitudes.

Worksheet 8

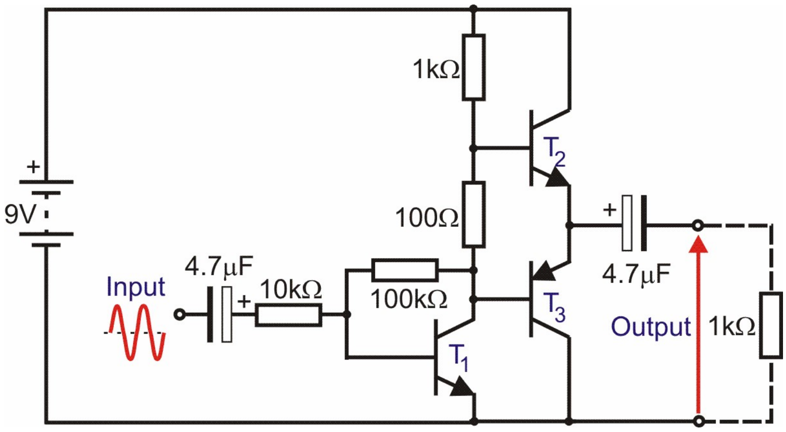
Push - pull amplifier

Amplifiers fall into two general categories, voltage amplifiers and power amplifiers. The priority for the former is to increase the voltage amplitude of the signal. For the latter, the aim is to pass on significant signal power levels to an output transducer such as a loudspeaker.

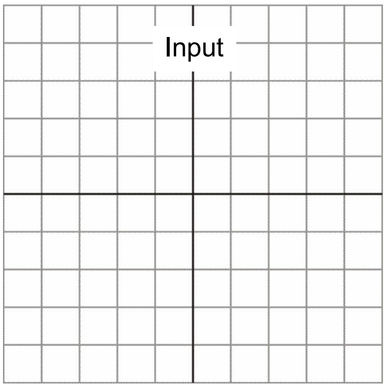
So far, the amplifiers have been of the former type. In this worksheet, you construct and test a transistor power amplifier.

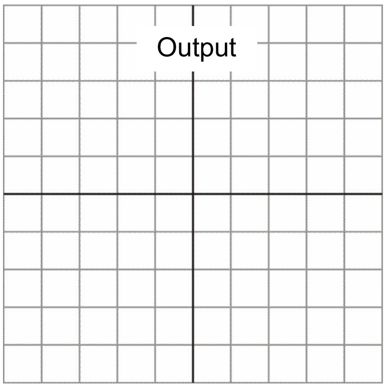
Over to you:

- Build the circuit shown opposite. This time a 1kΩ load resistor is used, though, in practice, a much lower value is likely.
- Notice that the DC power supply is set to output 9V.
- Measure and record the DC voltages at the collector, base and emitter of each transistor.
- Connect the input to a signal generator, set to give an output of 500mV peak-to-peak at 1kHz.
- Connect a dual trace oscilloscope to display input and output waveforms, as before.
- Adjust the oscilloscope controls to display two cycles of the waveforms.
- Sketch these on the grids provided.
- Measure the peak-to-peak voltages at the input and at the output of the amplifier.



	Measurement	Voltage
T_1	DC collector voltage	
	DC base voltage	
	DC emitter voltage	
T_2	DC collector voltage	
	DC base voltage	
	DC emitter voltage	
T_3	DC collector voltage	
	DC base voltage	
	DC emitter voltage	
Input voltage, pk - pk		
Output voltage, pk - pk		





Worksheet 8

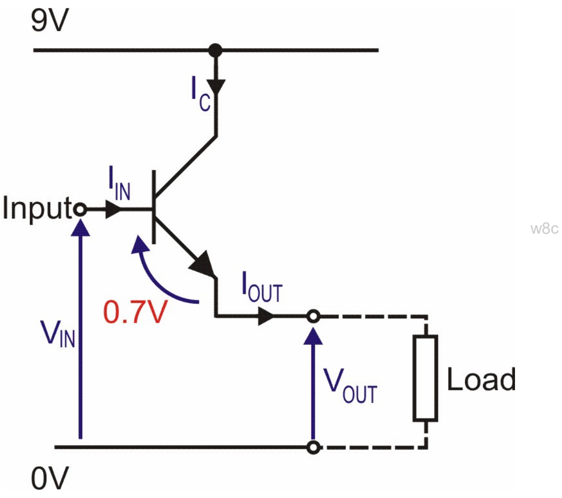
Push-pull amplifier

So what?

This circuit uses a matched **complementary pair** of transistors (T_2 is NPN and T_3 is PNP with equivalent properties.) These two transistors drive the load. T_2 conducts more heavily on positive-going half cycles of the signal, whilst T_3 conducts more heavily on negative half-cycles.

Each one is connected as an emitter-follower (or common collector amplifier.)

The emitter follower:



The circuit diagram for the simple emitter follower, using an npn transistor, is shown opposite.

When the npn transistor is conducting, there is a 0.7V drop between the base and the emitter.

As a result: $V_{OUT} = V_{IN} – 0.7$ i.e. $V_{OUT} \approx V_{IN}$

The output current, I_{OUT}, is actually the emitter current I_E of the transistor and the input current, I_{IN}, is the base current I_B.

Now $I_E = I_B + I_C$

and $I_C = h_{FE} \times I_B$ where I_C = collector current,

and h_{FE} = current gain of transistor.

As $h_{FE} >> 1$, $I_C >> I_B$ and so $I_E >> I_B$.

In other words, $I_{OUT} >> I_{IN}$

Hence P_{OUT} ($= V_{OUT} \times I_{OUT}$) $>> P_{IN}$ ($= V_{IN} \times I_{IN}$). The circuit is a power amplifier.

A third transistor (T_1) is used as a **driver**. This stage operates as a conventional common emitter amplifier - the one you investigated in Worksheet 4.

- Use your results to calculate the voltage gain of the amplifier:

  Voltage gain = ...

- Increase the input signal amplitude and observe the distortion produced when the amplifier is over-driven. How could this distortion be reduced?
- Reduce the signal amplitude to 50 mV pk-pk, or less, and observe the distortion produced at the zero voltage crossing points. Explain how this arises.

For your records:

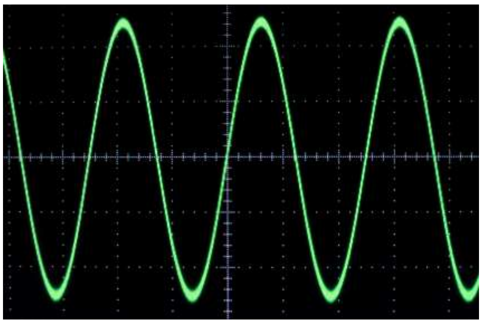
- Explain why the optimum value for the voltage at the junction of the emitters of T_2 and T_3 is half that of the supply (i.e. 4.5 V for this circuit).

Worksheet 9

Twin - T oscillator

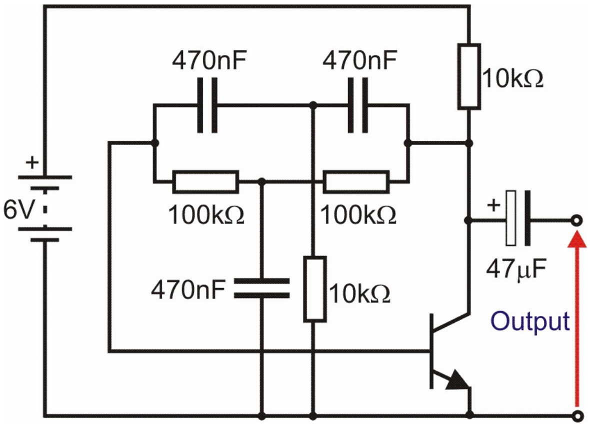
Various forms of oscillator are used in avionic systems to produce a variety of waveforms . A single stage common-emitter amplifier and a frequency selective feedback network can be used as a simple sinusoidal oscillator.

In this worksheet you investigate the operation of a simple phase-shift oscillator. The phase shift is provided by two parallel connected RC networks in a “Twin -T” arrangement.



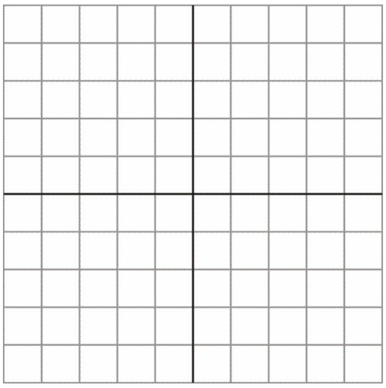
Over to you:

- Build the circuit shown opposite. This time there is no load resistor.
- Set the DC power supply to output 6V.
- Measure and record the DC voltages at the collector, base and emitter of the transistor.
- Connect a dual trace oscilloscope to display the output waveform.
- Adjust the oscilloscope controls to display two cycles of the waveform.
- Sketch this on the grid provided and label the voltage and time axes.
- Measure and record the peak-peak output voltage.
- Measure and record the time for one complete cycle of the wave (i.e. the periodic time).
- Use this measurement and the formula:
  frequency = 1 / period
  to calculate the frequency of the output signal. Record your result in the table.



Measurement	**Value**
DC bias voltage at collector	
DC bias voltage at base	
DC bias voltage at emitter	
Output voltage, pk - pk	
Periodic time	
Calculated frequency	

Output signal



Worksheet 9

Twin - T oscillator

So what?

The "Twin-T" oscillator uses two "T" RC networks.

- The R-C-R "T" acts as a low-pass filter.
- The C-R-C "T" acts as a high-pass filter.

These are connected in parallel, and provide negative feedback to the transistor. This reduces the voltage gain for all frequencies passed by the filters. The resonant frequency occurs where negative feedback is a minimum, i.e. for the centre frequency blocked by both filters.

The transistor produces a phase shift of 180° whilst the feedback network provides a further 180° thus ensuring that the signal fed back from the output to the input arrives in-phase.

Provided the transistor amplifier has a voltage gain greater than the losses associated with the feedback network, oscillation will build up at the resonant frequency, and a continuous sine wave output will be produced.

For your records:

- Investigate how the output frequency can be controlled by changing the values of the components in the RC networks. Document your findings.

Worksheet 10

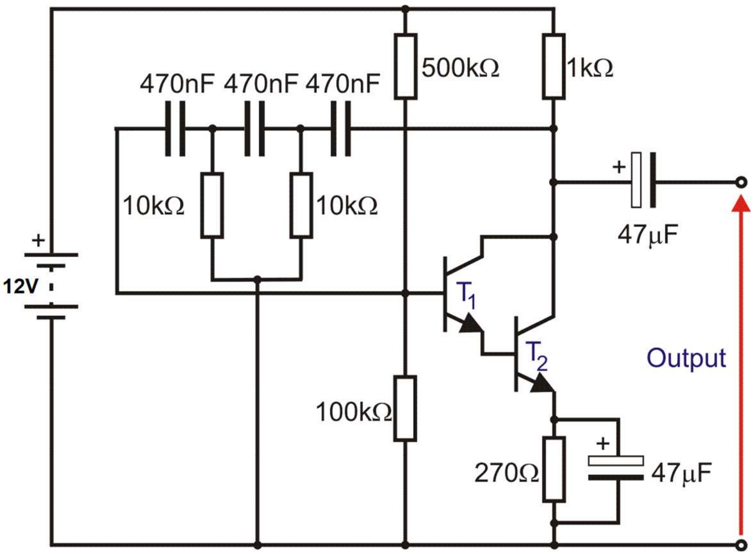
Ladder oscillator

The ladder oscillator, also called the phase shift oscillator is another example of a sinusoidal oscillator in which a feedback network provides the necessary phase shift.

In this worksheet you investigate the operation of a simple three-section ladder oscillator.

Over to you:

- Build the circuit shown opposite. Again, there is no load resistor.
- Set the DC power supply to output 12V.
- Measure and record the DC voltages at the collector, base and emitter of the transistor.
- Connect a dual trace oscilloscope to display the output waveform.
- Adjust the oscilloscope controls to display two cycles of the waveform.
- Sketch this on the grid provided and label the voltage and time axes.
- Measure and record the peak-peak output voltage.
- Measure and record the period of the wave.
- Use this measurement and the formula:
  frequency = 1 / period
  to calculate the frequency of the output signal. Record your result in the table.



Measurement	Value
DC bias voltage at collector	
DC bias voltage at base	
DC bias voltage at emitter	
Output voltage, pk - pk	
Periodic time	
Calculated frequency	

Output signal

w4c

Worksheet 10

Ladder oscillator

So what?

This circuit uses two NPN transistors in an arrangement known as a Darlington pair. The aim is to increase the overall current gain. A Darlington pair behaves like a single transistor with a high current gain, approximately equal to the product of the gains of the two transistors.

Transistors act as inverting amplifiers, as you saw earlier. In other words, they introduce a phase shift of 180^0 between the signal at the base and the signal at the collector.

A single RC network also produces a phase shift, but this depends on the frequency of the signal. The maximum value of phase shift for a single RC combination is 90^0.

In this case, at one particular frequency, the three-section RC ladder produces a 180° phase shift. Each RC stage provides a phase shift of 60° giving a total phase shift of 180°.

The total phase shift, of RC ladder plus transistor, is therefore 360^0 but only at that one particular frequency. This amounts to positive feedback. Positive feedback means that the input (base) receives a fed back signal which is in phase with the applied signal and which therefore adds to it. That combined signal is then amplified and a fraction of that fed back to the input, to augment it still further, and so on. Positive feedback causes the circuit to oscillate at that frequency.

As before, the transistor amplifier is needed to cancel out losses caused by the components of the RC network and hence maintain the oscillations .

A disadvantage of this and similar circuits is that it is not practicable to have a variable frequency output. That would require altering all three capacitors in step with each other.

For your records:

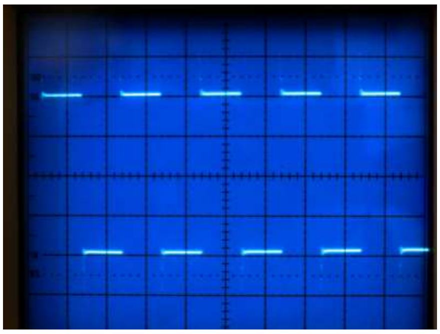
- What type of waveform does this circuit generate?
- Investigate how the output frequency can be controlled by changing the values of the components in the RC networks. Document your findings.

Worksheet 11

Astable multivibrator

The astable multivibrator provides us with a convenient way of generating a square wave.

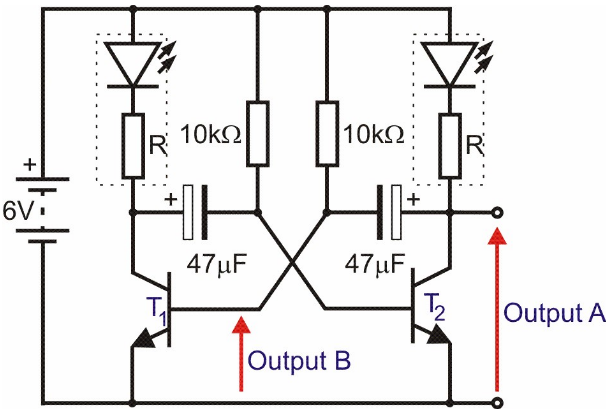
In this work sheet you will construct and test an astable multivibrator circuit. The frequency of oscillation is so low that we can observe the behaviour on the LEDs used as loads for the circuit. In practice, this circuit can be made to generate much higher frequencies.



w11a

Over to you:

- Build the circuit shown opposite. The protective resistor R is included in the LED carrier.
- Set the DC power supply to output 6V.
- Observe the two LEDs - they should flash alternately.
- Now replace the 47µF capacitors with 470nF capacitors and observe the effect.
- Connect a dual trace oscilloscope to display the output waveform. Connect channel A to the collector of transistor T_2, and channel B to the base of T_1. The common ground connection is taken to the negative supply rail.
- Adjust the oscilloscope controls to display two cycles of the waveforms.
- Sketch them on the grid provided and label the voltage and time axes.



w11b

Measurement	Value
Output voltage -Ch A	
Output voltage -Ch B	
Periodic time	
Calculated frequency	

- Measure and record the peak-peak output voltage on channels A and B.
- Measure and record the period of the wave. Use this to calculate the frequency of the output signal. Record your result in the table.

w4c

Channel A

Channel B

Worksheet 11

Astable multivibrator

So what?

This oscillator serves a different purpose to those studied earlier. They had a single resonant frequency. That meant that they produced an output at a single frequency i.e. a sine wave.

In this circuit, the transistors are alternately driven into saturation (switched on) and then turned off. As a result, the output is a square wave. In frequency terms, this is an endless series of higher and higher frequencies, not just the single frequency seen earlier.

The circuit has two stable states that change alternately because of the positive feedback provided by the two capacitors. These transfer voltage changes 'instantly', because the voltage across a capacitor is fixed until there has been time for charge to flow to or from its plates. The rate at which switching occurs depends on the time constant of the base resistors and coupling capacitors.

In each state, one transistor is switched on and the other is switched off. The base of one transistor is at 0.7V, while the other is at a low voltage. The capacitor connected to it charges until the base reaches around 0.7V, when the transistor turns on. Its collector drops to near 0V, and this change is transmitted to the base of the other transistor, turning it off. The process then repeats. The forward-biased base-emitter junction of the 'on' transistor provides a path for the capacitors to charge / discharge.

Square wave outputs have many applications. In digital circuits, for example, they provide clock pulses to counters. In more complex systems, they can synchronise operations across the system.

This circuit has a visual output, with LEDs as loads, but in practical circuits, with switching at a much higher frequency, we would simply use resistors.

For your records:

- Examine the two waveforms. Identify the times when T_1 is in 'on' and T_2 is 'off', and mark these on the graphs.
- Investigate how the output frequency can be controlled by changing the values of the components in the RC networks. Document your findings.
- Investigate the effect on waveform and duty cycle of using different values for the two capacitors, e.g. 470nF and 1μF.

Questions

About these questions

These questions are typical of those that you will be required to answer in the EASA Part-66 examination.

You should allow 15 minutes to answer these questions and then check your answers with those given on page 37.

Please remember that **ALL** these questions must be attempted **without** the use of a calculator and that the pass mark for all Part-66 multiple-choice examinations is 75%!

1. When testing a transistor with an ohmmeter, what resistance will be measured between base and collector?
(a) high resistance one way
(b) high resistance both ways
(c) low resistance both ways.

2. A silicon transistor has a base-emitter voltage of 0V. In this condition the transistor will be:
(a) conducting heavily
(b) conducting slightly
(c) turned off.

3. The device shown is:
(a) an NPN transistor
(b) a PNP transistor
(c) an N-channel JFET.

4. In a PNP transistor, conventional current:
(a) flows into the collector
(b) flows out of the collector
(c) there is no current flow in the collector.

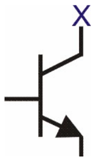
5. For a transistor to conduct, the base-emitter junction should be:
(a) forward biased
(b) reverse biased
(c) forward or reverse biased as appropriate to the input signal.

6. The typical value of common emitter current gain for a transistor is:
(a) 10 to 50
(b) 50 to 250
(c) more than 250.

7. In a common emitter amplifier, the input signal is taken to the:
(a) base
(b) collector
(c) emitter.

8. The connection marked X in the diagram is:
(a) the emitter

(b) the base
(c) the collector.



rq2

9. When a transistor amplifier uses common emitter mode:
(a) the input signal is connected to the emitter and the output is taken from the collector
(b) the input signal is connected to the base and the output is taken from the collector
(c) the input signal is connected to the collector and the output is taken from the emitter.

10. When a transistor is used in a conventional amplifier stage:
(a) both junctions are forward biased.
(b) the collector-base junction is forward biased and the base-emitter junction is reverse biased
(c) the collector-base junction is reverse biased and the base-emitter junction is forward biased

11. The collector current flowing in a transistor is 150 mA when the base current is 3 mA. Which one of the following gives the value of common emitter current gain?
(a) 15
(b) 50
(c) 150.

12. A transistor switch is saturated when there is:
(a) no current applied to the base and no current flowing in the collector
(b) no current applied to the base and maximum current flowing in the collector
(c) no increase in collector current for a further increase in base current.

13. In an NPN transistor amplifier stage:
(a) the collector is more positive than the base
(b) the emitter is more positive than the base
(c) the base is more positive than the collector.

14. The two transistors used in an astable multivibrator:
(a) conduct on alternate half-cycles of the square wave output
(b) conduct on alternate half-cycles of the sine wave output
(c) conduct on both positive and negative half-cycles of the square wave output.

15. In a sine-wave oscillator using a single transistor in common-emitter mode:
(a) no feedback is required as the transistor provides a phase shift of 360°
(b) the frequency-determining feedback circuit must provide a phase shift of 180°
(c) the transistor operates as a saturated switch and the frequency is determined by charge/discharge times.

Answers are provided on page 37

About this course

Introduction

This workbook is intended to reinforce the learning that takes place in the classroom or lecture room. It provides a series of practical activities and investigations that complement syllabus section 4.1.2 of EASA Part-66 Module 4, Electronic Fundamentals.

Locktronics equipment makes it simple and quick to construct and investigate electrical circuits. The end result can look exactly like the circuit diagram, thanks to the symbols printed on each component carrier.

Aim

The workbook aims to introduce students to the basic underpinning principles and concepts of aircraft electrical and electronic equipment. It also provides a useful introduction to electrical measurements and the use of ammeters, voltmeters and oscilloscopes.

Prior Knowledge

Students should have previously studied (or should be concurrently studying) Module 3 (Electrical Fundamentals) or should have equivalent knowledge at Level 3.

Learning Objectives

On successful completion of this course the student will have learned:

- how to carry out simple functional tests on transistors:
    - using a multimeter;
    - using a power supply and direct current measurements.
- the basic transfer and output characteristics of a silicon transistor in common-emitter mode;
- how to determine the current gain of a transistor from the transfer characteristic;
- how to determine the output resistance of a transistor from the output characteristic;
- the use of transistors in simple common-emitter amplifier stages;
- explain the use of DC biasing in a common-emitter amplifier;
- how to calculate the voltage gain of a transistor amplifier;
- the use of emitter resistor and bypass capacitor in a stabilised common-emitter amplifier;
- to recognise and remedy distortion in a transistor common-emitter amplifier;
- to compare the use of capacitors and transformers in coupling transistor voltage amplifiers to their outputs;
- to obtain the frequency spectrum for an amplifier;
- the advantages of multi-stage amplifiers;
- to distinguish between the functions of voltage amplifiers and power amplifiers;
- the use of transistors in push-pull amplifier stages;
- to explain the use of an emitter follower as a power amplifier;
- describe the role of positive feedback in oscillator circuits;
- the use of transistors in phase-shift (twin-T and ladder) sinusoidal oscillators;
- to list uses of astable circuits;
- the use of transistors in astable multivibrator oscillators.

Tutor’s notes

What students will need:

This pack is designed to work with the Locktronics Aircraft Maintenance Kit. The electrical / electronic parts required for this workbook are listed on the next page. Note that the Aircraft Maintenance Kit contains many other parts that are used in the other workbooks that together cover aspects of Module 3 and 4.

Students will also need:

- either two multimeters, such as the LK1110, capable of measuring currents in the range 0 to 200mA, and voltages in the range 0 to 200V;
- or equivalent ammeters and voltmeters.

For other modules in the series, they will need:

- a function generator, such as the LK8990, or equivalent;
- and an oscilloscope capable of monitoring the signals it produces, such as the LK6730 Pico 4000 virtual oscilloscope.

If you are missing any components, or need additional items, please contact Matrix or your local dealer.

Power sources:

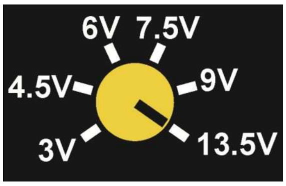
Students will need to make use of an adjustable low-voltage DC supply. The output voltage from the supplied DC power unit can be adjusted to provide outputs of either 3 V, 4.5 V, 6 V, 7.5 V, 9 V or 13.5 V, with currents typically up to 1 A. The voltage is changed by turning the selector dial just above the earth pin until the arrow points to the required voltage.

p28a

Tutors may decide to make any adjustment necessary to the power supply voltage, or may allow students to make those changes.

Each exercise includes a recommended voltage for that particular circuit.

In the example opposite, the DC power supply has been adjusted to provide an output of 13.5 V DC.



p28b

Tutor’s notes

The table below shows the parts needed for all 4 workbooks in the Electronic fundamentals series.

Qty	Code	Description
2	HP2666	12V adjustable DC power supply
1	HP3728	AC power supply, 12VAC, 1.5A, UK
1	LK2340	AC voltage source carrier
1	LK3548	Fibre optic Transmitter
1	LK3982	Voltmeter, 0V to 15V
1	LK4002	Resistor, 100 ohm, 1W, 5% (DIN)
1	LK4003	Capacitor, 1,000 uF, Electrolytic 30V
1	LK4123	Transformer, 2:1 turns ratio
1	LK4663	Low power solar motor
3	LK5202	Resistor, 1k, 1/4W, 5% (DIN)
3	LK5203	Resistor, 10k, 1/4W, 5% (DIN)
1	LK5205	Resistor, 270 ohm, 1/2W, 5% (DIN)
2	LK5207	Resistor, 180 ohm, 1/2W, 5% (DIN)
1	LK5208	Potentiometer, 250 ohm (DIN)
1	LK5209	Resistor, 5K6 ohm, 1/2W, 5% (DIN)
2	LK5214	Potentiometer, 10k (DIN)
2	LK5218	Resistor, 100k, 1/4W, 5% (DIN)
2	LK5224	Capacitor, 47uF, Electrolytic, 25V
2	LK5240	Transistor RHF, NPN
1	LK5241	Transistor LHF, NPN
1	LK5242	Diode, germanium
4	LK5243	Diode, power, 1A, 50V
1	LK5247	Zener diode, 4.7V
1	LK5248	Thyristor
24	LK5250	Connecting Link
1	LK5254	Zener diode, 8.2V
1	LK5255	Transistor RHF, PNP
1	LK5256	Transistor LHF, PNP
1	LK5266	Bridge rectifier
1	LK5402	Thermistor, 4.7k, NTC (DIN)

Qty	Code	Description
4	LK5603	Lead, red. 500mm, 4mm to 4mm stackable
4	LK5604	Lead, black, 500mm, 4mm to 4mm stackable
4	LK5607	Lead, yellow, 500mm, 4mm to 4mm stackable
4	LK5609	Lead, blue, 500mm, 4mm to 4mm stackable
1	LK6202	Capacitor, 100uF, Electrolytic, 25V
1	LK6205	Capacitor, 1uF, Polyester
3	LK6206	Capacitor. 4.7uF, electrolytic, 25V
2	LK6207	Switch, push to make, metal strip
1	LK6209	Switch, on/off, metal strip
1	LK6214	Capacitor, VARIABLE, 0-200pF
3	LK6216	Capacitor, 0.47 uF, Polyester
1	LK6218	Resistor, 2.2k, 1/4W, 5% (DIN)
1	LK6224	Switch, changeover, toggle
1	LK6224	Changeover switch
1	LK6232	Resistor, 500k, 1/4W, 5% (DIN)
1	LK6234L	Op Amp Carrier (TL081) with 2mm to 4mm Leads
1	LK6238	Resistor, 200k, 1/4W, 5% (DIN)
1	LK6239	Capacitor, 1nF, Polyester
2	LK6635	LED, red, 5V (SB)
1	LK6706	Motor 3 to 12V DC, 0.7A
1	LK6774	Fibre optic cable - 1m
1	LK6860	AND gate carrier (ANSI)
1	LK6861	OR gate carrier (ANSI)
2	LK6862	NOT gate carrier (ANSI)
1	LK7409	AA battery holder carrier
1	LK7483	1:1 transformer with retractable ferrite core
2	LK8275	Power supply carrier with battery symbol
1	LK8275	Fibre optic receiver
1	LK8492	Dual rail power supply carrier
2	LK8900	7 x 5 metric baseboard with 4mm pillars
2	LK9381	Ammeter, 0mA to 100mA

Tutor’s notes

Using this course:

It is expected that the worksheets are printed / photocopied, preferably in colour, for the students’ use. Students should retain their own copy of the entire workbook.

Worksheets usually contain:

- an introduction to the topic under investigation and its aircraft application;
- step-by-step instructions for the practical investigation that follows;
- a section headed ‘So What?’ which aims both to challenge learners by questioning their understanding of a topic and also provides a useful summary of what has been learned. It can be used to develop ideas and as a trigger for class discussion.
- a section headed ‘Questions’ which provides further work for students to carry out. Answers to these questions are provided at the end of this workbook.

This format encourages self-study, with students working at a rate that suits their ability. It is for the tutor to monitor that students’ understanding is keeping pace with their progress through the worksheets and to provide additional work that will challenge brighter learners. One way to do this is to ‘sign off’ each worksheet, as a student completes it, and in the process have a brief chat with each learner to assess their grasp of the ideas involved in the exercises that it contains.

Finally, a set of examination ’Revision Questions’ has been provided to conclude the work on each topic. These questions are of mixed difficulty and are typical of those that students will face when they sit their Module 4 CAA examinations. It is recommended that students should attempt these questions under examination conditions and without the use of notes or calculators.

Time:

It will take most students between eight and ten hours to complete the full set of worksheets. It is expected that a similar length of time will be needed to support the learning in a class, tutorial or self-study environment.

Tutor’s notes

Worksheet	Notes for the Tutor	Timing
1	In the first worksheet, students carry out some simple functional checks on a transistor. A brief introduction to this activity could be useful and students should be reminded that a transistor comprises two P-N junctions and each can be considered to act like a diode, conducting current in one direction only. Tutors may wish to demonstrate the use of a multimeter with a transistor check facility or a dedicated transistor tester. Alternatively, where these instruments are not available, tutors could show how forward and reverse resistance readings can be used to indicate the ‘go/no-go’ status of each of the junctions within a transistor. The method that students should adopt in this worksheet involves measurement of the collector current of a transistor with and without base current applied. With no base current applied there should be no measurable amount of collector current (leakage current should be negligible). With base current applied the collector current should be measurable. With the values used, the base current should be approximately 54μA. With a typical value of common-emitter current gain (e.g. 100) this should result in a collector current of around 5.4mA. The 100 ohm resistor in series with the meter is included in order to limit the current in the event of a short-circuit device. Tutors might find it useful to provide students with some defective transistors (i.e. open-circuit and/or short-circuit devices). Students should then be able to identify ‘good’ and ‘bad’ devices by applying the procedure that they have used in this worksheet investigation.	30 - 45 minutes
2	This practical exercise involves making series of measurements that will allow students to plot the transfer and output (collector) characteristics for a transistor connected in common-emitter mode. Students should record their measured values in tables and then use their data to plot the transfer and output (collector) characteristics. Students should have access to sample characteristics for a variety of common NPN transistors (e.g. BC108 or BC548) so that they can compare these with their own graphs. Students should be invited to comment on the shape of the two graphs. They should find that the transfer characteristic is almost perfectly linear and that the output (collector) characteristic is also linear for each of the two fixed values of base current (i.e. 30μA and 60μA). Students may need assistance with the calculation of common emitter current gain and output resistance. Appropriate examples could be given and students could then be asked to replace the values used with their own measured values. It might also be useful to compare results obtained by different students.	60 - 90 minutes

Tutor’s notes

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3	In this worksheet students investigate the use of a transistor as a saturated switch. They should begin by constructing and testing the simple LED switching circuit . They should make voltage measurements in order to verify that the transistor is operating under saturated conditions when the switch is closed. Next they should connect the motor on/off control circuit . Note that, due to the increased collector current this circuit will require a much lower value of base resistor in order for the transistor to become fully saturated. In this circuit students should measure and record the voltage appearing across the load (i.e. the motor). They should find that this is either 0V (with the switch open) or 6V (with it closed).	45 - 60 minutes
4	In this worksheet students explore a practical application of transistors in the form of a simple common-emitter amplifier stage. In order to cope with the wide variation in common-emitter current gain, the base bias current is derived from the collector of the transistor rather than from the positive supply rail. Tutors should explain the need for bias and the function of the collector load resistor. Worked examples involving calculation of the voltage and current at the bas and collector of the transistor could be extremely useful and should yield typical values against which students can compare their measured results. Students will need a dual-channel oscilloscope (or equivalent virtual instrument) with which to display the input and output waveforms. Where necessary, instruction on using this test instrument should be given before students begin their own measurements. It is also important to remind students that the common ground connection to the oscilloscope should be taken to the negative supply rail. Typical voltage indications for this investigation are as follows: Collector voltage = 3.8V Base voltage = 0.67V Students should make the necessary adjustments to display at least two cycles of the input and output waveforms on a common time scale. They should then sketch the waveforms that they have observed, making sure to include labelled axes of voltage and time. Alternatively, where a virtual instrument is used, capture the screen data should be captured and transferred as an image file to hard copy. Students should measure the peak-to-peak voltage at the input and output and use this to calculate the voltage gain of the amplifier. They should typically obtain an output of 4V peak-peak for a 50mV peak-peak input at 1kHz. This infers a voltage gain of around 80. Finally, students should investigate the effect of over-driving the input of the amplifier on the output waveform. In order to do this they will need to increase the input voltage from around 50mV pk-pk to around 100mV pk-pk. They should find that the maximum output voltage obtainable (before distortion becomes observable) is around 5V pk-pk.	45 - 60 minutes

Tutor’s notes

Worksheet	Notes for the Tutor	Timing
5	This work sheet is similar to Worksheet 4, but now students construct and test a common-emitter amplifier that is transformer coupled rather than RC coupled. Once again, tutors should explain the need for bias and the function of the transformer as a collector load. A worked example involving calculation of the value of the AC collector load from the transformer’s turns ratio (i.e. 2:1) and output load (i.e. the fixed 10 kΩ resistor connected across the output) could be extremely useful. Students will need a dual-channel oscilloscope (or equivalent virtual instrument) with which to display the input and output waveforms. Where necessary, instruction on using this test instrument should be given before students begin their own measurements. It is also important to remind students that the common ground connection to the oscilloscope should be taken to the negative supply rail. Typical voltage indications for this investigation are as follows: Collector voltage = 6.2V Base voltage = 0.69V Students should make the necessary adjustments to display at least two cycles of the input and output waveforms on a common time scale. They should then sketch the waveforms that they have observed, making sure to include labelled axes of voltage and time. Alternatively, where a virtual instrument is used, capture the screen data should be captured and transferred as an image file to hard copy. Students should measure the peak-to-peak voltage at the input and output and use this to calculate the voltage gain of the amplifier. They should typically obtain an output of 5V pk-pk for a 20mV pk-pk input at 1kHz. This infers a voltage gain of around 250. (Note that, compared with Worksheet 4, this increase in gain results from the greatly increased value of AC collector load resistance). Once again, students should investigate the effect of over-driving the input of the amplifier on the output waveform. In order to do this they will need to increase the input voltage from around 20mV pk-pk to around 50mV pk-pk.	45 - 60 minutes

Worksheet	Notes for the Tutor	Timing
6	This worksheet is similar to Worksheets 4 and 5 but now students construct and test a fully-stabilised common-emitter amplifier stage. Tutors should once again provide an explanation of the circuit including the function of the base potential divider and emitter resistor. A worked example will be extremely useful and this should involve calculation of the bias voltages and currents, showing the effect of both an increase and decrease in collector current. Once again, students will need a dual-channel oscilloscope (or equivalent virtual instrument) with which to display the input and output waveforms. Where necessary, instruction on using this test instrument should be given before students begin their own measurements. It is also important to remind students that the common ground connection to the oscilloscope should be taken to the negative supply rail. Typical voltage indications for this investigation are as follows: Collector voltage = 3.55V Base voltage = 1.43V Emitter voltage = 0.76V As before, students should make the necessary adjustments to display at least two cycles of the input and output waveforms on a common time scale. They should then sketch the waveforms that they have observed, making sure to include labelled axes of voltage and time. Alternatively, where a virtual instrument is used, capture the screen data should be captured and transferred as an image file to hard copy. Students should measure the peak-to-peak voltage at the input and output and use this to calculate the voltage gain of the amplifier. They should typically obtain an output of 3V pk-pk for a 50mV pk-pk input at 1kHz. This infers a voltage gain of around 60. Students should compare this value with those obtained in Worksheet 4 and Worksheet 5.	45 - 60 minutes
7	In this worksheet students investigate the operation of a high-gain two-stage amplifier. Tutors should provide an explanation of the circuit including the function of the feedback loop that provides base bias for the first stage derived from the emitter current in the second stage. Once again, a worked example could be extremely useful and this should yield typical values that students can compare with their measured values. Typical voltage indications for this investigation are as follows: T_1: Collector voltage = 3.54V Base voltage = 1.62V Emitter voltage = 0.98V T_2: Collector voltage = 10.75V Base voltage = 3.54V Emitter voltage = 2.89V	45 - 60 minutes

Tutor's notes

Worksheet	Notes for the Tutor	Timing
8	This worksheet is similar to Worksheet 7 but students will investigate the operation of a push-pull amplifier based on a pair of complementary transistors. Tutors should provide an explanation of the circuit including the operation of the complementary output stage (T_2 and T_3) and the driver stage (T_1). Once again, a worked example of bias current and voltage calculation could be extremely useful as this will yield typical values that students can compare with their measured results. Once again, students will once again need a dual-channel oscilloscope (or equivalent virtual instrument) with which to display the input and output waveforms. Where necessary, instruction on using this test instrument should be given before students begin their own measurements. It is also important to remind students that the common ground connection to the oscilloscope should be taken to the negative supply rail. Typical voltage indications for this investigation are as follows: T_1: Collector voltage = 5.08V Base voltage = 0.63V Emitter voltage = 0V T_2: Collector voltage = 9.18V Base voltage = 5.46V Emitter voltage = 4.92V T_3: Collector voltage = 0V Base voltage = 5.08V Emitter voltage = 4.92V As before, students should make the necessary adjustments to display at least two cycles of the input and output waveforms using a common time scale. They should then sketch the waveforms that they have observed, making sure to include labelled axes of voltage and time. Alternatively, where a virtual instrument is used, it should be possible to capture the screen data and transfer this as an image file to hard copy. Once again, students should measure the peak-to-peak voltage at the input and output and use this to calculate the voltage gain of the amplifier. More able students could be asked to determine the maximum undistorted output power that can be delivered to the load and compare this with theoretical calculation.	45 - 60 minutes

Tutor's notes

Worksheet	Notes for the Tutor	Timing
9	This practical task involves investigating the output waveform produced by a Twin-T oscillator. Tutors should provide an explanation of the operation of the circuit, including the phase shift produced by the feedback network. Students should also be reminded of the conditions necessary for oscillation, in terms of overall phase-shift, feedback network loss and the voltage gain provided by the transistor amplifier. As before, students should make the necessary adjustments to display at least two cycles of the sinusoidal output waveform. They should then sketch the waveform that they have observed, making sure to include labelled axes of voltage and time. Alternatively, where a virtual instrument is used, it should be possible to capture the screen data and transfer this as an image file to hard copy. Finally, students should measure the periodic time of the waveform from the display and use this to calculate the frequency of the output waveform.	45 - 60 minutes
10	This practical task involves investigating the output waveform produced by a ladder network oscillator. Tutors should provide an explanation of the operation of the circuit, including the phase shift produced by the feedback network. Students should also be reminded of the conditions necessary for operation, in terms of overall phase-shift, feedback network loss and the voltage gain provided by the transistor amplifier. As before, students should make the necessary adjustments to display at least two cycles of the sinusoidal output waveform. They should then sketch the waveform that they have observed, making sure to include labelled axes of voltage and time. Alternatively, where a virtual instrument is used, it should be possible to capture the screen data and transfer this as an image file to hard copy. Finally, students should measure the periodic time of the waveform from the display and use this to calculate the frequency of the output waveform.	45 - 60 minutes
11	This practical task involves investigating the output waveforms produced by an astable multivibrator. Tutors should provide an explanation of the operation of the circuit, including the action of the RC timing components. Tutors should introduce students to the waveforms that they should find in the circuit, including the relation between the base voltage waveform and the corresponding collector voltage waveform. Tutors should also remind students that the transistors in this circuit operate as saturated switches and this should be contrasted with the linear (Class A) mode used in Worksheets 9 and 10. Once again, students should make the necessary adjustments to display at least two cycles of the collector and base waveforms. They should then sketch the waveforms that they have observed to a common time scale, making sure to include labelled axes of voltage and time. Alternatively, where a virtual instrument is used, it should be possible to capture the screen data and transfer this as an image file to hard copy. Finally, students should measure the periodic time of the waveform from the display and use this to calculate the frequency of the output waveform.	45 - 60 minutes

Answers

Revision question paper

1. (a)
2. (b)
3 (a)
4 (b)
5. (a)
6. (b)
7. (a)
8. (c)
9. (b)
10. (c)
11. (b)
12. (c)
13. (a)
14. (a)
15. (b)

31 07 23 Reformatted to new style

Version control

18 09 23	page 21 - 13.5V changed to 12V on diagram
	page 21 - 13.5V changed to 12V on text
	Page 28 - BOM change
10 10 23	page 9 - diagram changes (22K, 12V), bullet 4 changed to 30mV