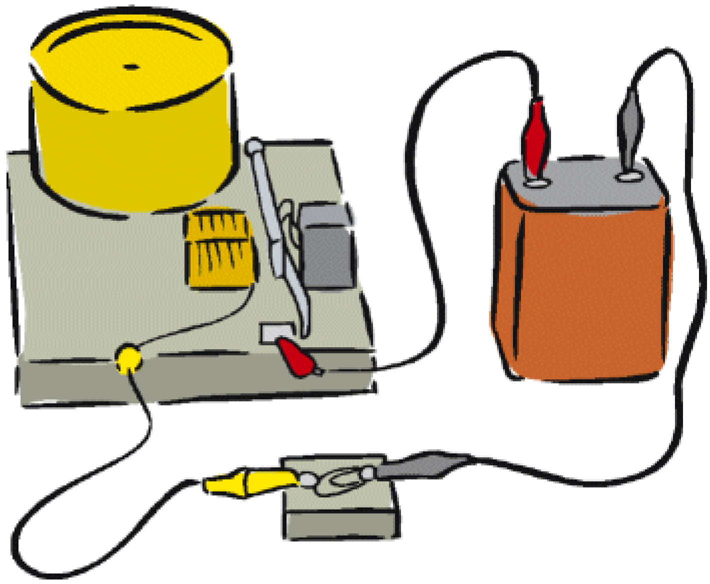
Input, output and control characteristic of a transistor



Training objectives and introduction

In this experiment we will be exploring and measuring the properties of a bipolar transistor on the basis of different characteristics.

Training content

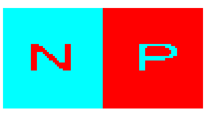
- Basic operation of a bipolar transistor
- Measuring the current control, input and output characteristics

Introduction

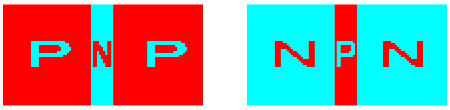
Transistors have revolutionised the world of electronics ever since they were introduced after the second World War. Their ever decreasing size and their tremendous versatility have made them into the most useful and important electronic components in existence. In the current course we will be dealing with two possible configurations of basic transistor circuits.

The first transistors, also known as bipolar transistors, comprised two semiconductor layers encapsulating a third layer. Semiconductor materials are characterised by, among other things, the property that the number of electrons which conduct electricity can be increased or decreased simply by adding impurities. This procedure is referred to as **doping**. This process is used to manufacture **n-type**, i.e. negative charged material with a surplus of electrons as well as **p-type**, i.e. positive materials featuring a relative deficiency of electrons. In the latter case, so-called holes arise which correspond to the missing electrons. These holes behave as if they were positive charge carriers similar to electrons which carry negative charges.

The two different types of material can be combined to make a single component. Here, the p-type material is arranged on one side and the n-type material is on the other so that a junction arises in the middle. This structure is a very good conductor of electricity if a positive voltage relative to the n-type's side is applied to the p-type side (constituting a forward bias). if, however, the component's n-type material connected to the positive end of the circuit (reverse bias), it is very difficult for the charge carriers (electrons and holes) to pass through the junction thus blocking the current flow. This is the basic operating principle of the **diode**, a component, which is conductive in one direction only.



Bipolar transistors feature semiconductor material of the same type on both sides with a thin layer of the opposite type in between. The two sides of the same type are designated collector and emitter zones, the layer in the middle is termed the base. At first glance, this arrangement looks like two interlinked diodes. You might expect that no current is able to flow between the collector and the emitter since a reverse voltage is always being applied to one of the two "diode junctions". The secret to this arrangement is in the thin layer of the base zone. Charge carriers can always bridge a small gap over the junction. If the base zone is supplied with additional charge carriers by applying a voltage to it, sufficient charge carriers are present to bridge the gap and current begins flowing. Due to the fact that the current flow between collector and emitter is only "switched on" when sufficient voltage and power is present at the base, these kinds of transistors can be used as electronic switches which can be switched on and off depending on the current supply to the base.

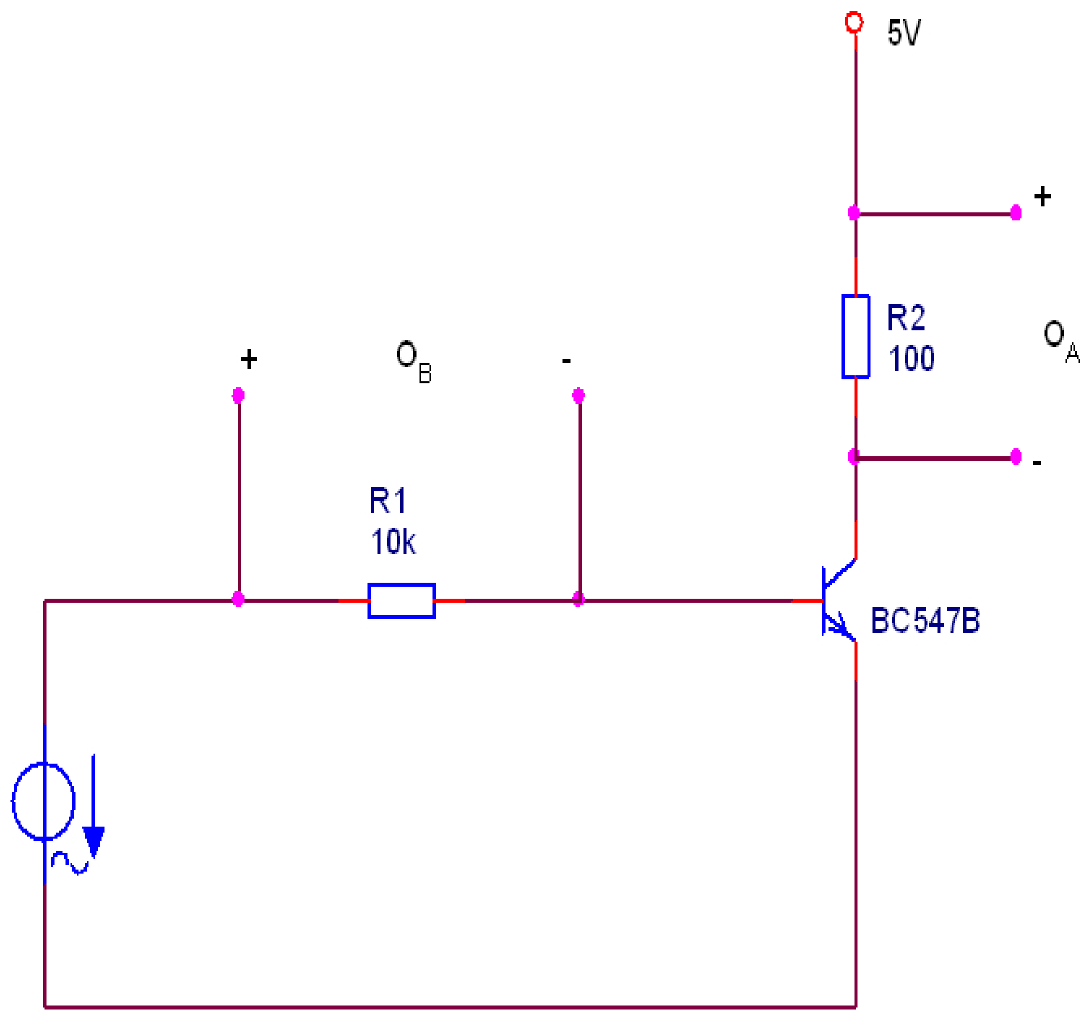


Just how much current flows between the collector and the emitter depends on the number of charge carriers in the base zone so that changes in the voltage and amperage at the base can lead to a stronger or weaker current flow between the collector and emitter. Even a slight change at the base can lead to a substantial change in voltage between collector and emitter. This relationship remains linear over a wide range: a modified voltage signal at the base is reproduced exactly between the collector and emitter but with considerable greater voltage change. Thus, the transistor serves to amplify the signal. This is the second conventional area of application for transistors.

Current control characteristic

Circuit diagram

The following circuit diagram is used for this experiment:



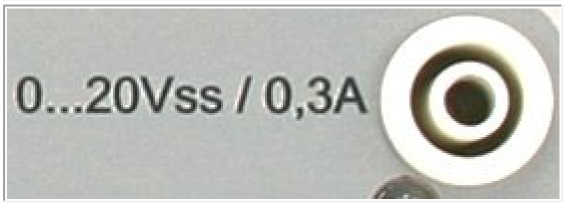
Components

The following components are using in this experiment:

Parts	Id no.	Designation
3	SO5126-5M	Cables
8	SO5124-6F	Bridges, small
1	PS4121-2N	R 100
1	PS4121-3Q	R 10k
1	PS4123-1C	NPN BC 547

Cable connections

The following cable connections are used in this experiment:

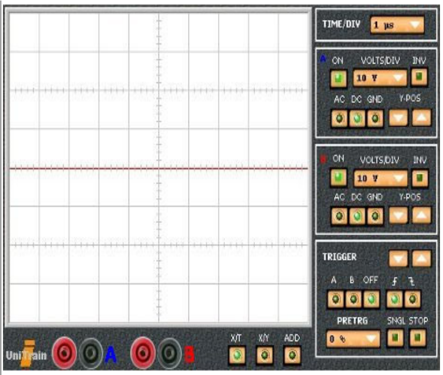
Designation	Symbol	Equipment	Sockets
FG		FUNCTION GENERATOR	
DC 5V		MULTI POWER SUPPLY 60VA / 500KHz	
GND		MULTI POWER SUPPLY 60VA / 500KHz	

Connect the specified sockets to the designated plug-in positions on the layout diagram.

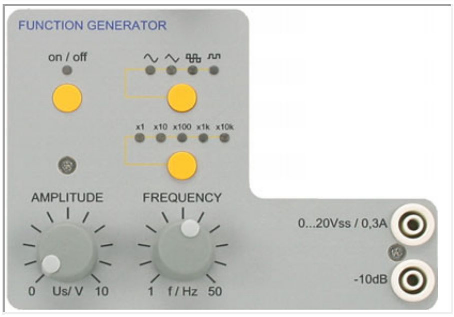
Equipment

The following equipment is required for this experiment including the corresponding settings:

Equipment	Settings



	Channel A	Channel B
Sensitivity	1 V/DIV	1 V/DIV
Coupling	DC	DC
Polarity	norm	norm
y-pos	0	0
Time base	2 msec/DIV	
Mode	X/Y	
Trigger channel	-	
Trigger edge	-	

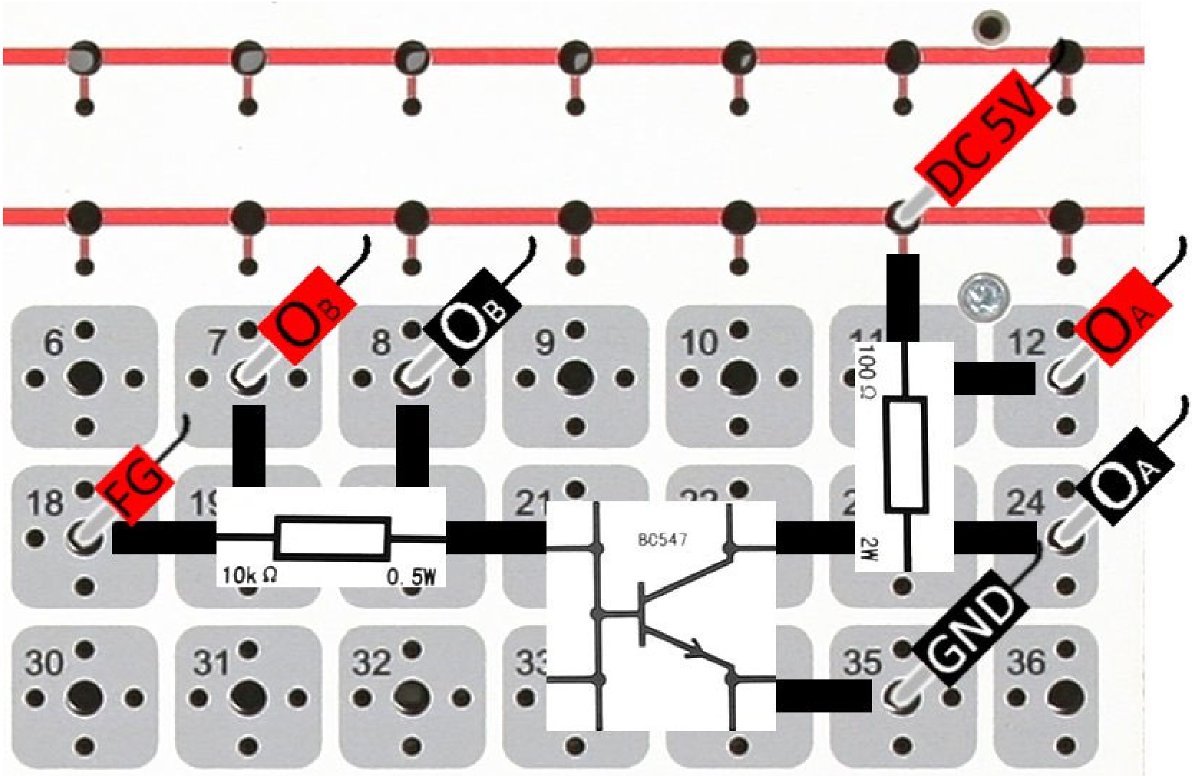


Curve shape	sinusoidal
Amplitude	3 V
Frequency factor	x1
Frequency	50 Hz

Experiment set-up

Now please set up the experiment as a testing field in the upper right hand corner of the patch panel. Begin with the following:

- Bridging plugs
- Electronic components
- Meters and cables

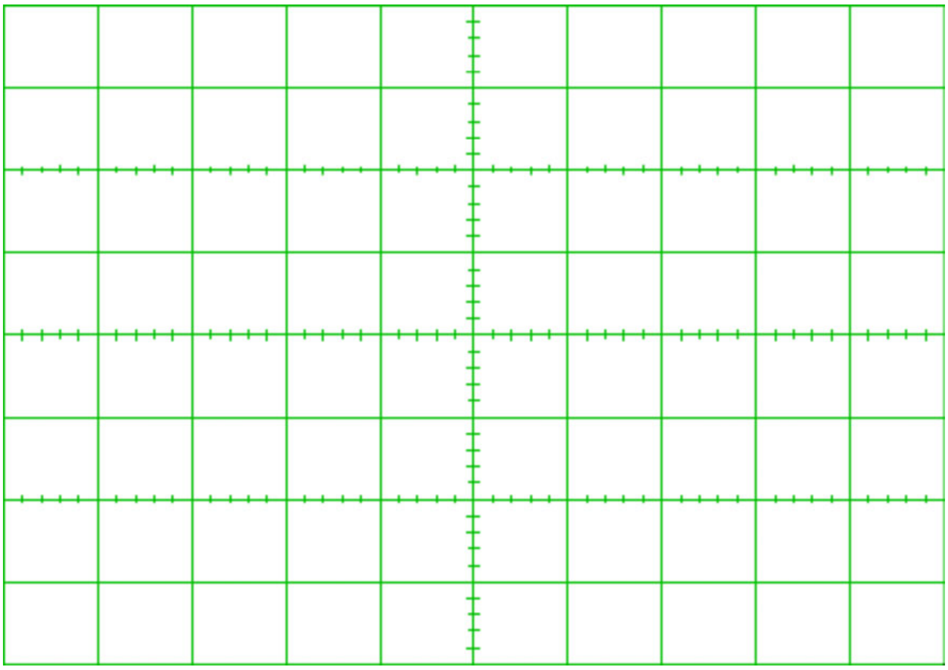


Experiment procedure and exercises

After completing the experiment the user is able to:

- measure control characteristics of a transistor
- compute the current amplification of a transistor based on the characteristic

Set the oscilloscope and function generator to the values specified above. Display the control characteristic of the transistor on the oscilloscope and enter the oscillograph trace in the diagram below.



Now compute the current amplification of the transistor. This is the relationship between the collector current the base current

$$V_I = \frac{I_{Kollektor}}{I_{Basis}}$$

The currents are calculated from the voltage drop across the resistors. Measure the voltage drop across the two resistors up to the bend in the curve and compute the currents.

Calculate the current amplification as shown above

V = ________________________________

First compute the actual currents!

Now replace the R2 resistor with a 330 Ohm resistor and repeat the previous experiment.

Compute the current amplification as specified above

V = ____________________________

First calculate the actual currents!

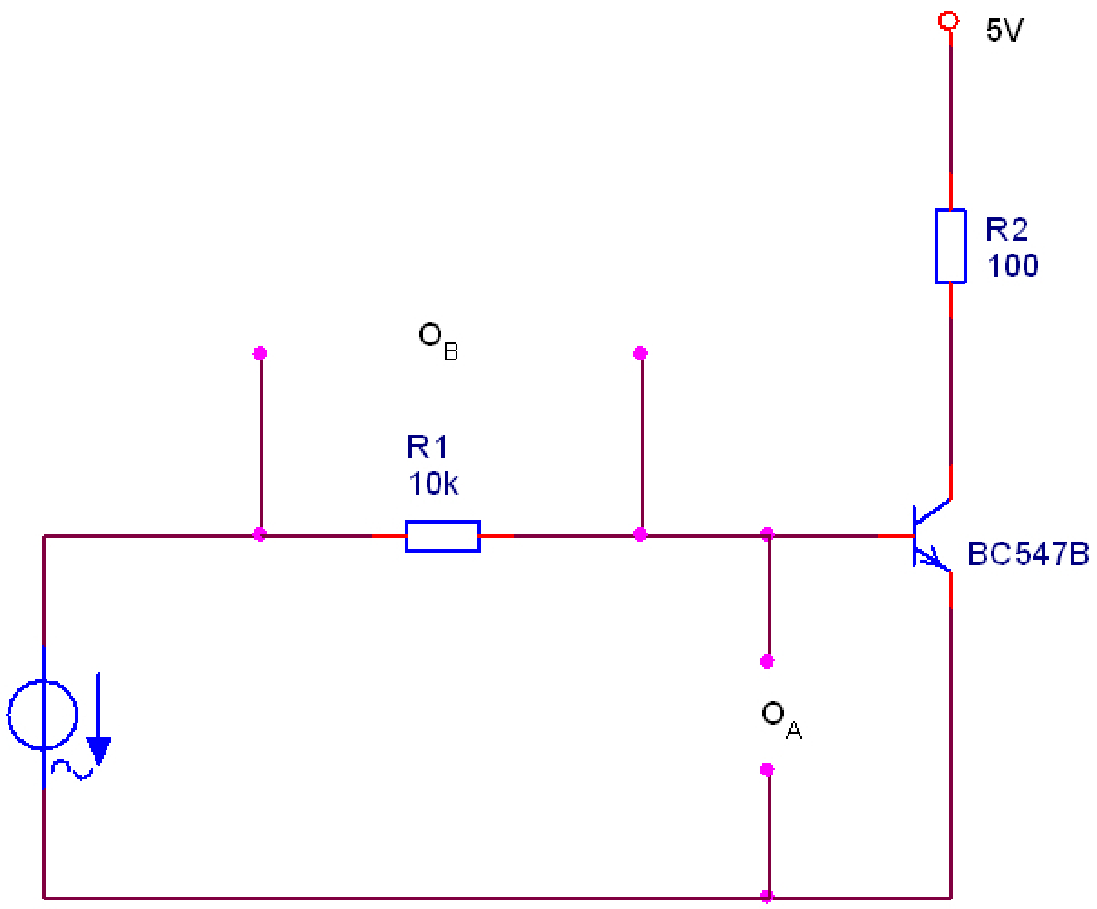
Why is the current amplification almost the same even though your have changed the collector resistance?

- The current amplification is constant due to the fact that the supply voltage has remained the same.
- The current amplification is essentially a transistor-specific value and has nothing to do with the circuit.
- It is the series resistance at the base of the transistor that determines the current amplification and thus did not change.

Input characteristic

Circuit diagram

The following circuit diagram is used for this experiment:



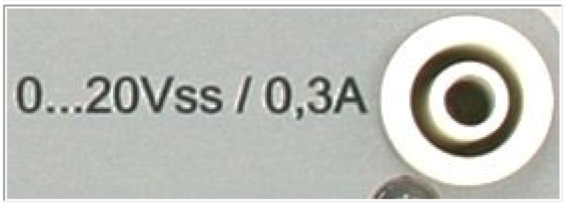
Components

The following components are needed for this experiment:

Parts	Id no.	Designation
3	SO5126-5M	Cables
13	SO5124-6F	Bridges, small
1	PS4121-2N	R 100
1	PS4121-3Q	R 10k
1	PS4123-1C	NPN BC 547

Cable connections

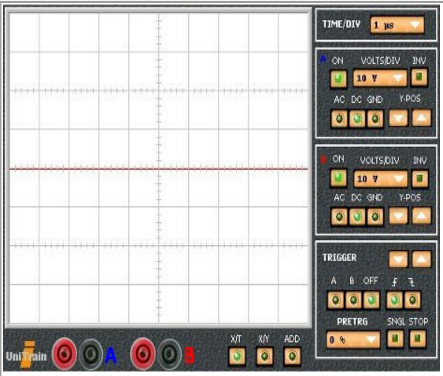
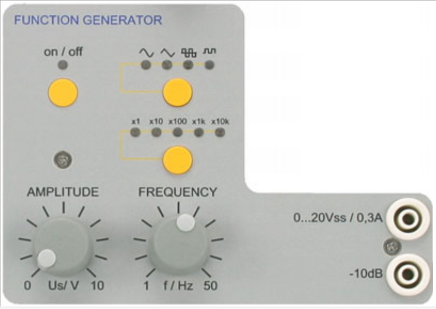
The following cable connections are used in this experiment:

Designation	Symbol	Equipment	Sockets
FG		FUNCTION GENERATOR	
DC 5V		MULTI POWER SUPPLY 60VA / 500KHz	
GND		MULTI POWER SUPPLY 60VA / 500KHz	

Connect the specified sockets to the plug connections designated in the layout diagram.

Equipment

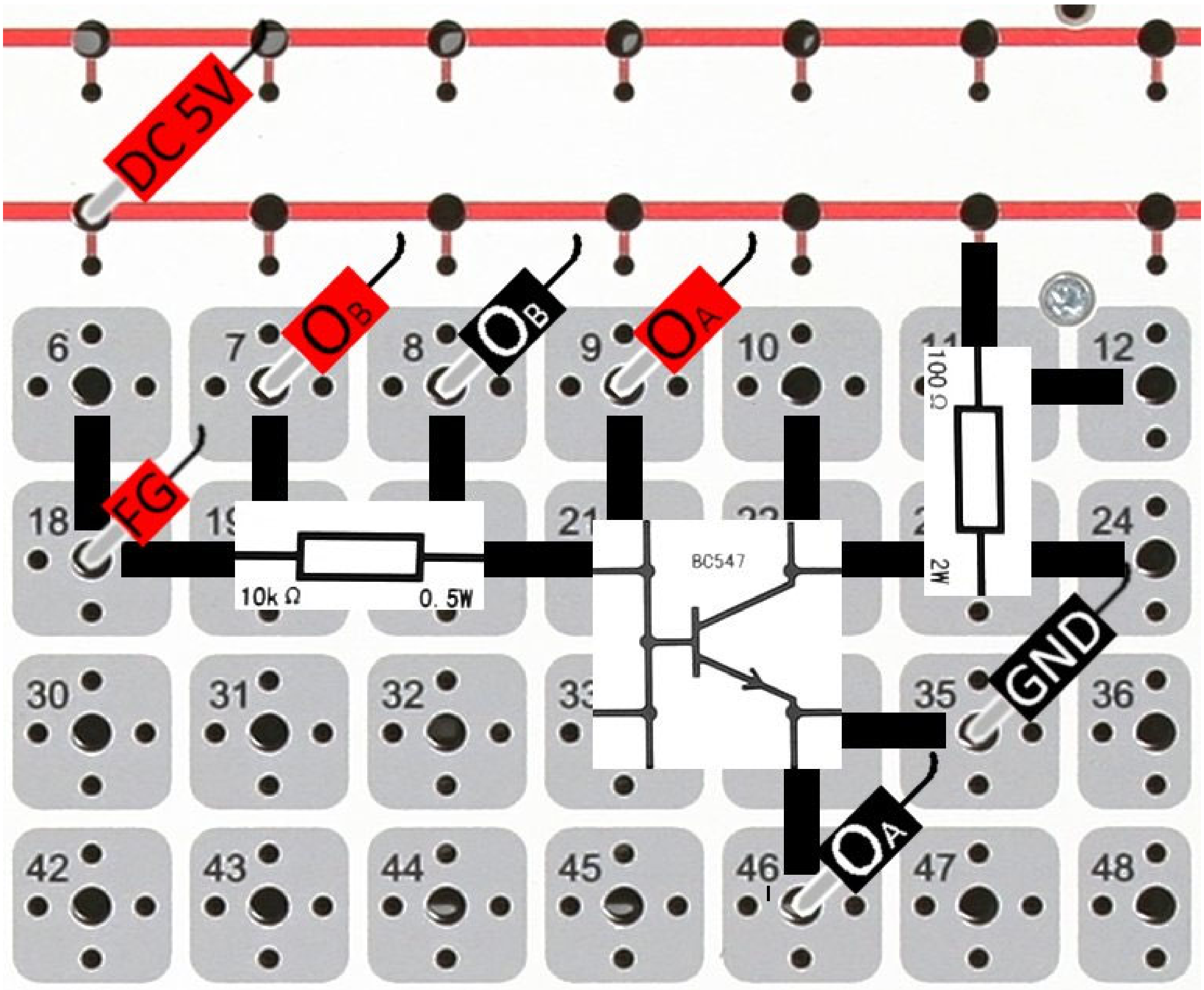
The following equipment is needed for the experiment including the corresponding settings:

<table>
<tr><th>Equipment</th><th>Settings</th></tr>
<tr><td>
</td><td>
<table>
<tr><th></th><th>Channel A</th><th>Channel B</th></tr>
<tr><td>Sensitivity</td><td>200 mV/DIV</td><td>2 V/DIV</td></tr>
<tr><td>Coupling</td><td>DC</td><td>DC</td></tr>
<tr><td>Polarity</td><td>norm</td><td>norm</td></tr>
<tr><td>y-pos</td><td>0</td><td>0</td></tr>
<tr><td>Time base</td><td colspan="2">2 msec/DIV</td></tr>
<tr><td>Mode</td><td colspan="2">X/Y</td></tr>
<tr><td>Trigger channel</td><td colspan="2">-</td></tr>
<tr><td>Trigger edge</td><td colspan="2">-</td></tr>
</table>
</td></tr>
<tr><td>
</td><td>
<table>
<tr><td>Curve shape</td><td>sinusoidal</td></tr>
<tr><td>Amplitude</td><td>7 V</td></tr>
<tr><td>Frequency Factor</td><td>x1</td></tr>
<tr><td>Frequency</td><td>50 Hz</td></tr>
</table>
</td></tr>
</table>

Experiment set-up

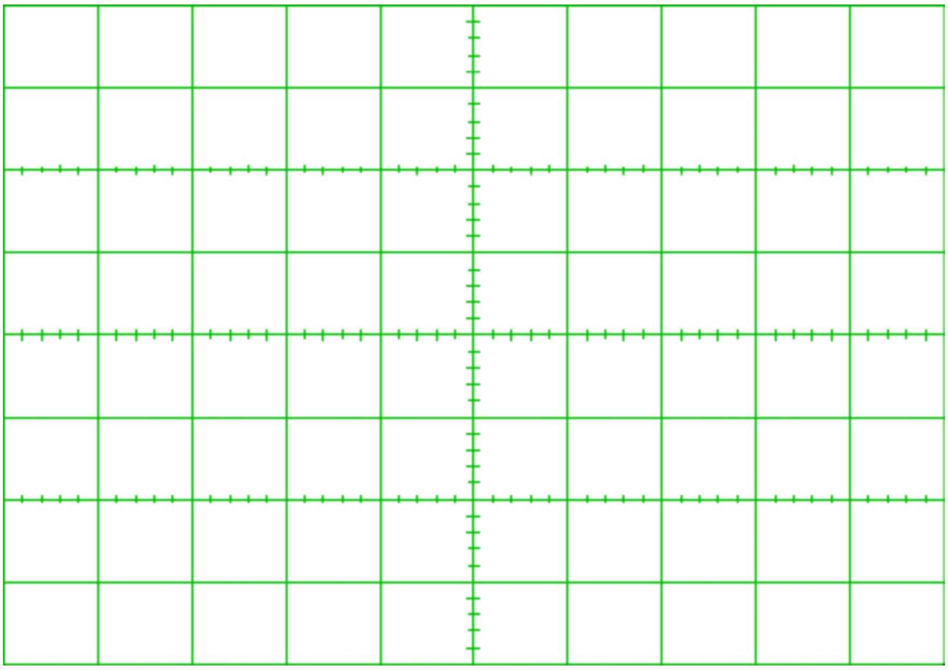
Now set up the experiment as a testing station in the top right corner of the patch panel. Begin with the following components:

- Bridging plugs
- Electronic components
- Measuring instruments and cables



Experiment procedure and exercises

Display the input characteristic of the transistor on the oscilloscope.



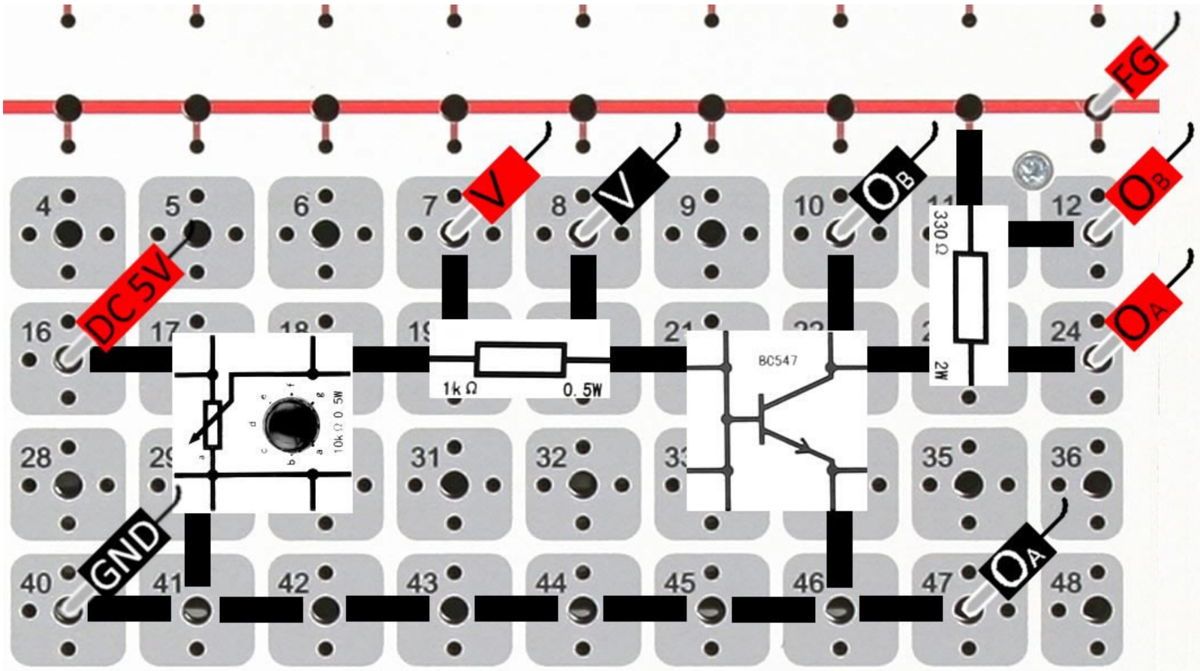
Which of the following statements about the transistor's input characteristic is correct?

- ☐ The characteristic corresponds to that of a resistor.
- ☐ The characteristic corresponds to that of a diode.
- ☐ The current through the base of the transistor initially increases very weakly and then abruptly.
- ☐ The voltage at the base is proportional to the current flowing through the resistor.
- ☐ The current flowing through the resistor is proportional to the voltage across the resistor.

Output characteristic

Circuit diagram

The following circuit diagram is used for this experiment:



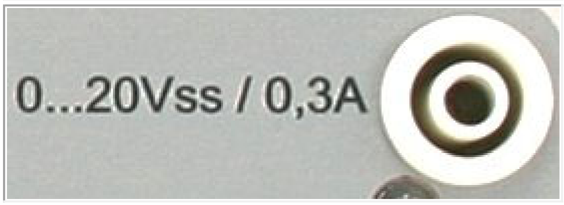
Components

The following components are used for this experiment:

Parts	Id no.	Designation
3	SO5126-5M	Cables
15	SO5124-6F	Bridges, small
1	PS4121-2U	R 330
1	PS4121-3C	R 1k
1	PS4121-8G	Potentiometer 10k
1	PS4123-1C	NPN BC 547

Cable connections

Following cable connections are used for this experiment:

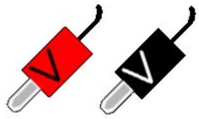
Designation	Symbol	Equipment	Socket
FG		FUNCTION GENERATOR	
DC 5V		MULTI POWER SUPPLY 60VA / 500KHz	
GND		MULTI POWER SUPPLY 60VA / 500KHz	

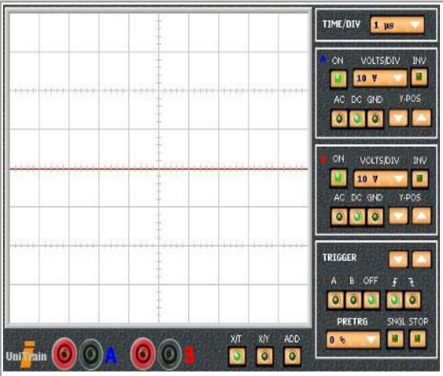
Connect the specified sockets to the plug connections shown in the layout diagram.

Equipment

The following equipment are needed for this experiment including the corresponding settings:

Equipment | **Settings**

Black cable	Ground
Red cable	V Ohm input
Control knob	V DC
	Please insert the red and black probes at the designated locations



	Channel A	Channel B
Sensitivity	200 mV/DIV	2 V/DIV
Coupling	DC	DC
Polarity	inv	inv
y-pos	0	0
Time base	2 msec/DIV	
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Trigger channel	-	
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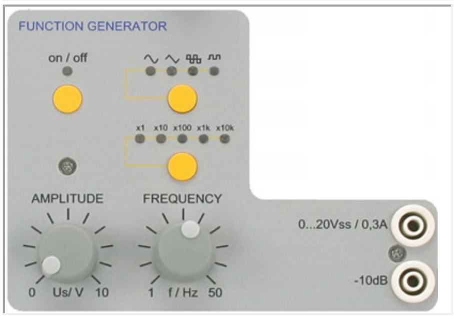


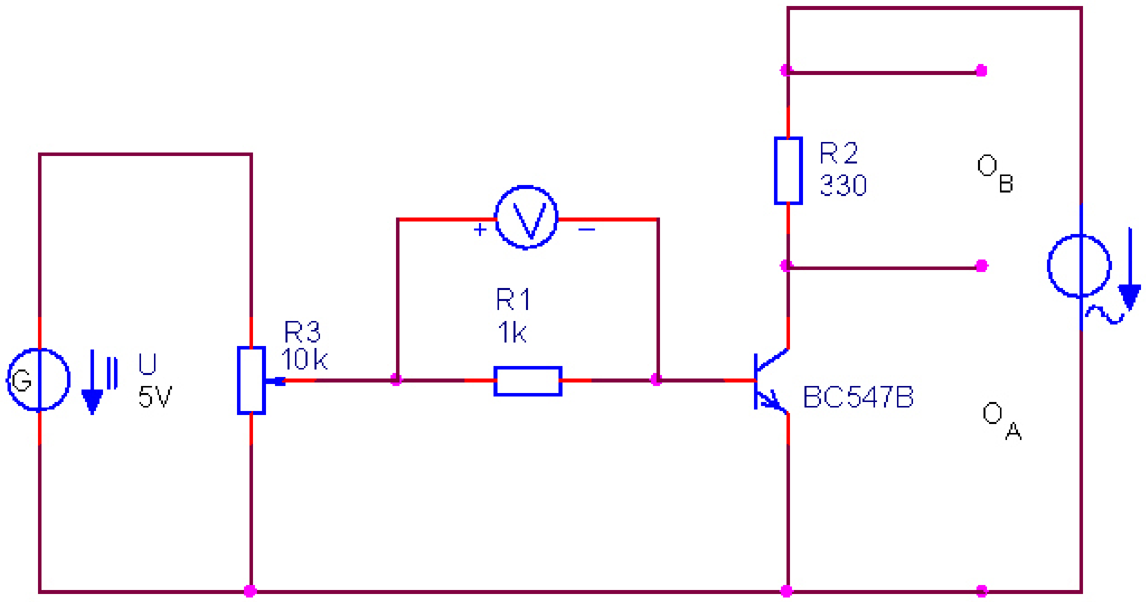
Curve shape	sinusoidal
Amplitude	4.5 V
Frequency Factor	x1
Frequency	50 Hz

Experiment set-up

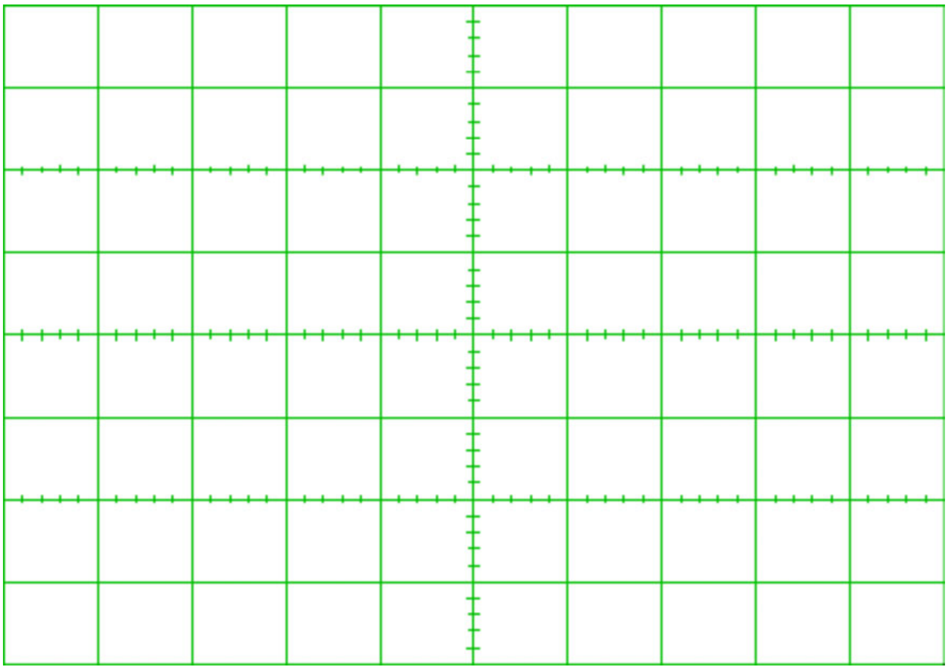
Now please set up the experiment as a testing station in the upper right hand corner of the patch panel. Start with the following:

- Bridging plugs
- Electronic components
- Measuring instruments and cables

Experiment procedure and exercises



Set the oscilloscope and the function generator as specified above. Set the potentiometer so that a voltage of 0.5 V drops across the 1kOhm resistor.



Record the output characteristic with the oscilloscope and copy the oscillograph trace into the diagram. Repeat the experiment for the voltages 0.75 Volt, 1V and 1.5 V at the base resistor. Copy this oscillograph trace into the diagram too.

How high are the current drops at the base resistor?

0.5	V across the 1kOhm resistor corresponds to	____________________ µA
0.75	V across the 1kOhm resistor corresponds to	____________________ µA
1.0	V across the 1kOhm resistor corresponds to	____________________ µA
1.5	V across the 1kOhm resistor corresponds to	____________________ µA

The current is computed from the voltage drop and teh resistance in accordance with Ohm's law!

What is the significance of the typical bend in the output characteristic?

- ○ The oscilloscope cannot display any higher values on the y-axis.
- ○ The preset base current is limited by the transistor's constant current amplfication.
- ○ The collector resistance limits the current flowing through the transistor.

The transistor has a current amplification of approx. 150 times.

How high is the maximum collector current for a base current of 1000µA? Compare the computed result to the value of the measurement curve.

The currents can be calculated from the voltage drops across the respective resistors. The current amplification factor is 150 times.

Maximum computed current	______________________________ mA
Maximum current reading	______________________________ mA