locktronics

Simplifying Electricity

Battery and high voltage systems

Answers

Battery and high voltage systems

Worksheet 1 - Testing Sealed Lead-Acid batteries

Effect of load on output voltage:

Switches closed	None	1st only	1st and 2nd	1st, 2nd and 3rd
Battery voltage	6.3V	5.95V	5.75V	5.62V
Total current	0	570mA	1050mA	1480mA

Effect of discharge time on output voltage:

Time in mins	0	5	10
Battery voltage	5,74V	5.58V	5,45V
Battery current	1030mA	990mA	960mA

Worksheet 2 - Charging SLA batteries

Time in mins	0	5	10
Battery voltage while on charger	6.2V	6.45V	6.52V
Battery current	280mA	240mA	220mA
Battery voltage open-circuit	6.02V	6.2V	6.25V

Note that as the battery accepts charge its voltage increases and the current decreases.

Worksheet 3 - Testing Li-ion batteries

Effect of load on output voltage:

Switches closed	None	1st only	1st and 2nd	1st, 2nd and 3rd
Battery voltage	3.8V	3.76V	3.7V	3.67V
Total current	0	350mA	800mA	1200mA

Worksheet 4 - Charging Li-ion batteries

Time in mins	0	5	10
Battery voltage while on charger	2.8V	3.34V	3.35V
Battery current	1250mA	448mA	400mA
Battery voltage open-circuit	2.6V	3.33V	3.4V

Results will vary dramatically depending on the State Of Charge of batteries.

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Worksheet 5 - Building larger batteries

Two 6V SLA batteries in series:

Voltage (V)	Current (A)	Power delivered (W)
12V	0.35A	4.2W

Six Li-ion cells in a 2,3 battery:

Voltage (V)	Current (A)	Power delivered (W)
7.2	0.2	1.44

Challenge 1: six Li-ion cells in a 3,2 battery:

Voltage (V)	Current (A)	Power delivered (W)
10.76	0.22	2.36

Cell voltage	A	3.7	V
Individual cell current rating	B	2.6	Ah
Cells in parallel	C	2	
Groups of cells in series	D	3	
Combined power rating	A x B x C x D	57.72	Wh

Challenge 2 six Li-ion cells in a 6,1 battery:

Voltage (V)	Current (A)	Power delivered (W)
21.4	0.266	5.69

Cell voltage	A	3.7	V
Individual cell current rating	B	2.6	Ah
Cells in parallel	C	1	
Groups of cells in series	D	6	
Combined power rating	A x B x C x D	57.72	Wh

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Challenge 3: Tesla model S battery

For one brick:

Cell voltage	**A**	**3.7**	**V**
Individual cell current rating	**B**	**2.6**	**Ah**
Cells in parallel	**C**	**72**	
Cells in series	**D**	**6**	
Combined power rating	**A x B x C x D**	**4,155**	**Wh**

For 16 bricks the total power rating is 16 times this number or 66.5kWh.

Worksheet 6 - Li-ion battery faults

No load output voltage: ________21.6V________

Output voltage when connected to motor: ________21.4V   0.266A_____

Output voltage with corrosion at point A __________21.6_________

Output voltage with corrosion at point A - with load _________20.38___0.26A______

Voltage across the corrosion component ________1V__________

Battery 1 (V)	***Battery 2 (V)***	***Battery 3 (V)***	***Battery 4 (V)***	***Battery 5 (V)***	***Battery 6 (V)***

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Worksheet 7 - SLA battery faults

Part 1 - COMmon connected to node 4:

Switch	Voltage across battery (between nodes 1 and 4)
Open	10.53
Closed	9.93

Part 2 - COMmon connected to node 3:

Switch	Voltage across battery (between nodes 1 and 3)
Open	10.48
Closed	9.46

Question 1: Why are both readings the same when the switch is open?

.......There is no current flowing so there is no voltage drop across corrosion..

....

Question 2: In part 1, why does the reading change when the switch is closed?

..Batteries have an internal resistance and there is a voltage drop across this resistance........................

....

Part 3 - Voltage drop across the bulb:

Switch	Voltage across bulb (between nodes 2 and 3)
With corrosion in	9.6V
Without corrosion	9.93V

Question 3: What is the effect of corrosion in the cables and connectors on the brightness of the bulb?

................Slightly less bright as less current flows.......................................

Challenge:

Results of the investigation:

.........When little current flows the effects of corrosion are often not noticeable. When current flows there is a voltage drop across the corrosion component . If a lot of current flows then it produces a noticeable effect.

....

....

Describe how you would check whether there is corrosion on the battery.

Put a meter directly across the battery terminals and measure the voltage.

Move the COMmon lead to a part of the chassis. Check you have the same reading - if not there is a bad connection or corrosion in the 0V path.

.Measure the voltage between the battery +12V terminal and another 12V terminal in the vehicle when the headlamps are on. There should be a minimal voltage drop.

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Worksheet 8 - Battery management

Battery 1 (V)	*Battery 2 (V)*	*Battery 3 (V)*	*Battery 4 (V)*	*Battery 5 (V)*	*Battery 6 (V)*
3.49	3.59	3.65	3.6	3.8	3.55

Battery	*Initial voltage (V)*	*Charge current (A)*	*Resistor voltage (10 ohm)*	*Bypass current (A)*
1	2.9	1A	2.9V	0.29A
5	3.4	1A	3.4V	0.34A

BMS system

	Pair 1	*Pair 2*	*Pair 3*
Voltage V			
Current I			

Worksheet 9 - Voltage converters

Pot position	*Fully anti-clockwise*	*Half way*	*Fully clockwise*
Input current	0.049	0.073	0.115
Input voltage	7.5	7.5	7.5
Input power	0.37	0.55	0.86
Output current	0.014	0.019	0.025
Output voltage	14	18.51	24
Output power	0.196	0.35	0.6
Efficiency	53%	63%	69%

	Reading
Input current	0.53
Input voltage	14
Input power	7.42
Output current	0.84
Output voltage	7.15
Output power	6
Efficiency	81%

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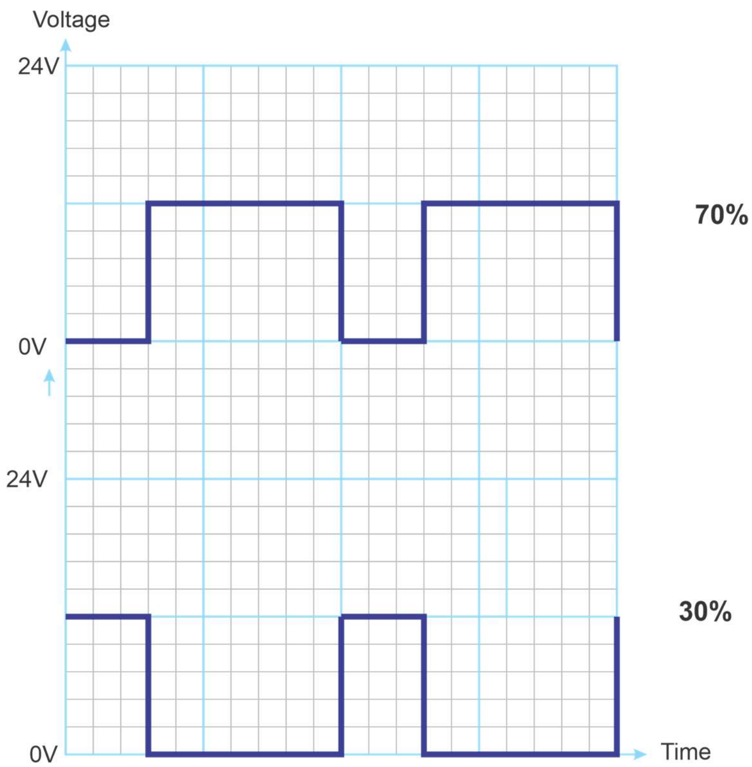
Worksheet 10 - Powering DC motors:

What happens to motor speed as you reduce the number of batteries in series?

....The motor slows down...

....

PWM signals:



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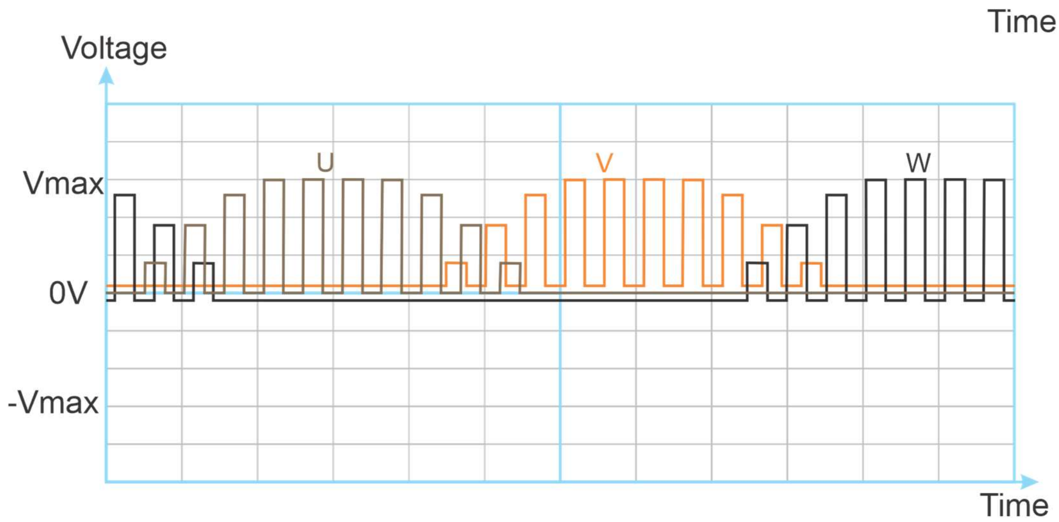
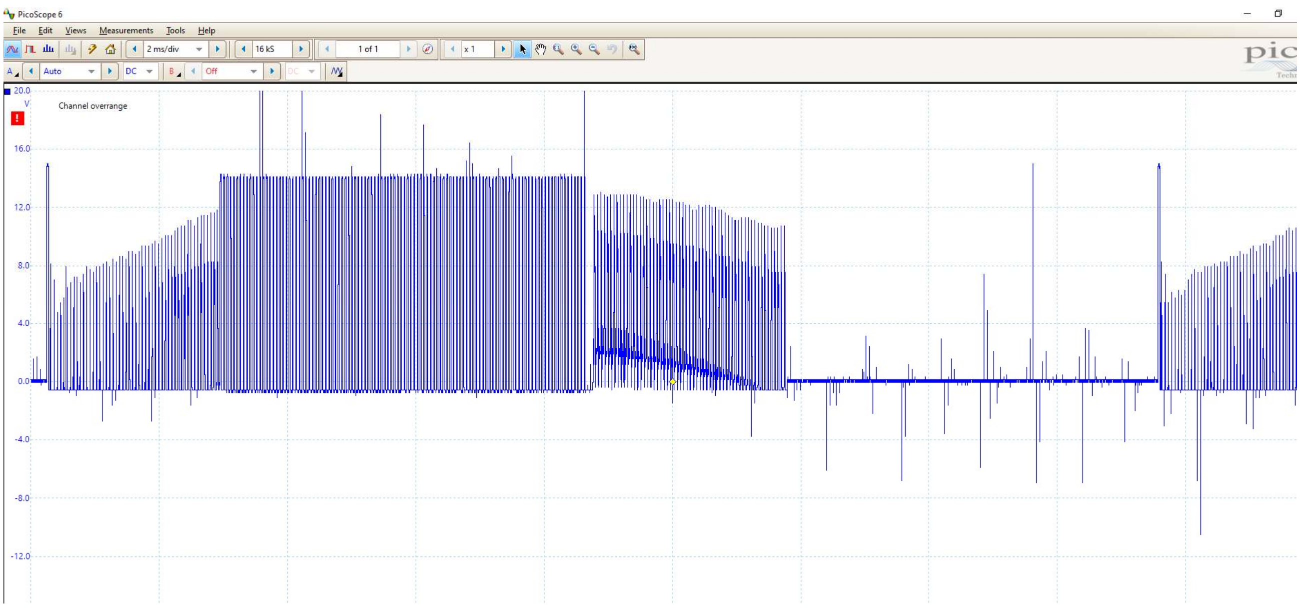
Worksheet 11 - Powering three-phase motors:

The signals at medium speed are like this:



The three signals are 120 degrees apart. They are Pseudosinusoidal. They overlap. In the drawing above we have shown the bottom of the signals at different points for clarity - but the bottom is 0V.

Here are some oscilloscope traces:



Medium

the voltage signal is not that sinusoidal. But you can see that the voltage and PWM slowly rises, peaks in the middle for quite a long time and then slowly falls.

On this trace you can also see that there is lots of noise – motors are like this. That makes triggering repeatably at a particular point in the waveform difficult.

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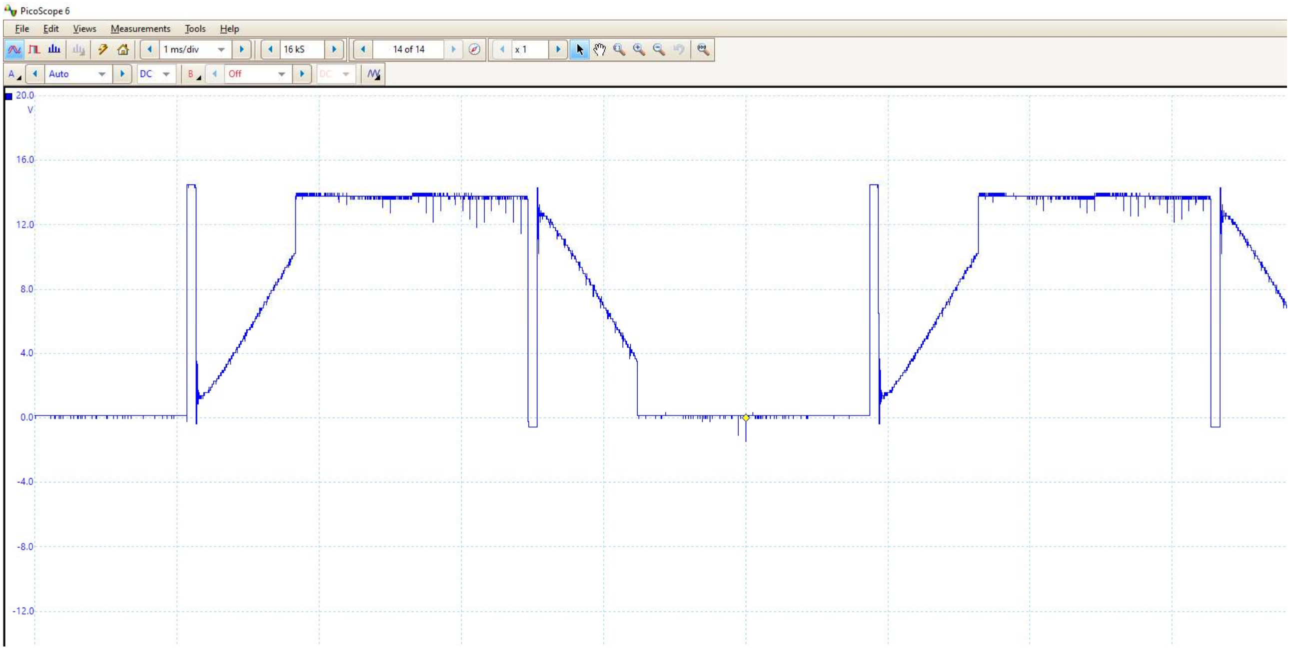
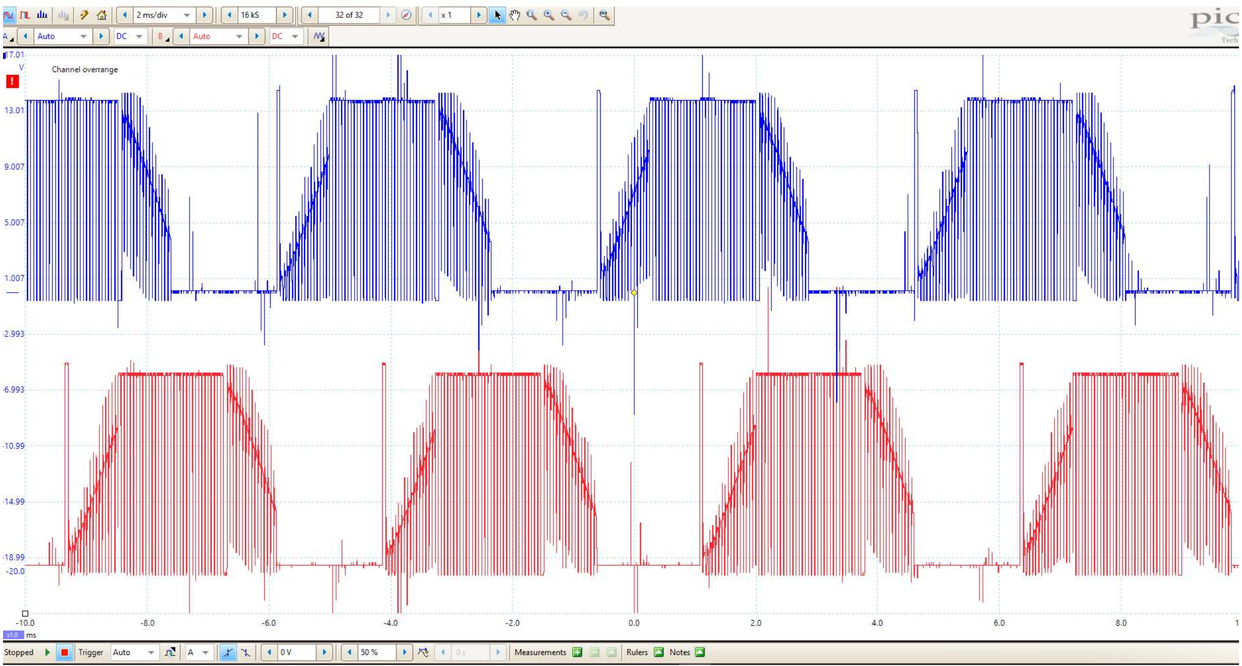


High speed

Here you can see that there is no PWM – the signal is set to maximum power. The shape is not very sinusoidal.

The two slightly strange pulses give a clue as to how the driver system works: they are used to sense the current taken and hence the position of the rotor



Two phases

Here you can see two of the phases. You can easily see the timing difference.

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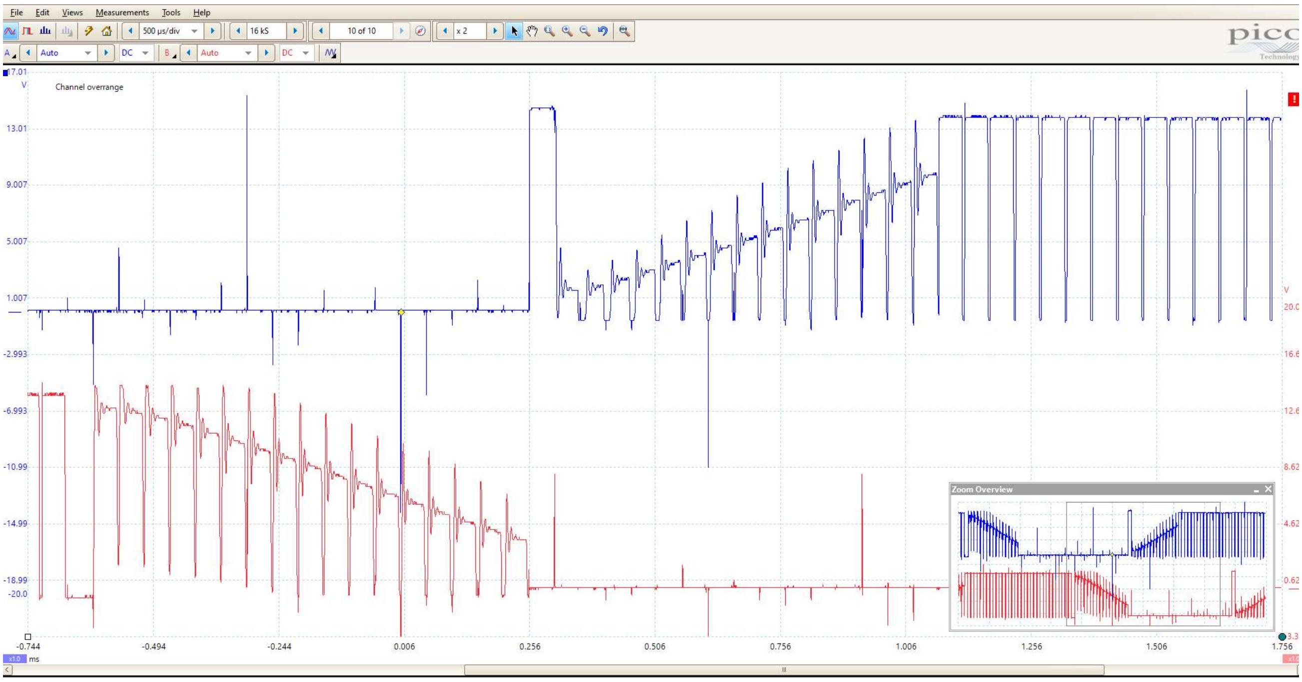
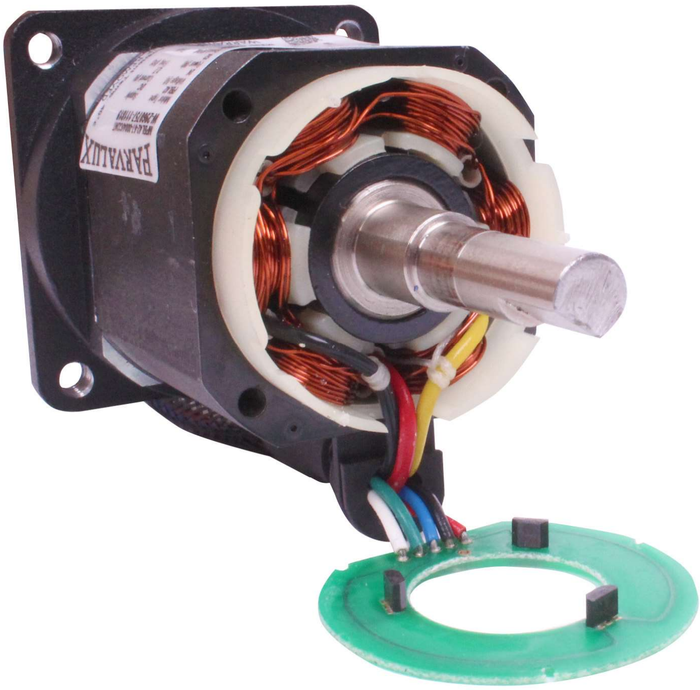


Close up

Here you can see the PWM more clearly.

Motor details



Here is a photo of the motor taken apart. There are three windings. When driving brushless DC motors a computer needs to sense the position of the rotor in relation to the stator windings. This is done in one of two ways:

Hall sensors

In the photo you can see the small black objects on the circuit board: these are Hall sensors. They sense the position of the rotor and a computer then works out how to drive the motor for a certain speed.

Back EMF sensors

An alterative is to measure the back Electro Motive force generated by the motor at certain times in the rotation period. This gives a computer the information it needs to understand where the relative position of the rotor is and when to pass current to the stator windings. The two pulses in the waveform are used for this purpose.

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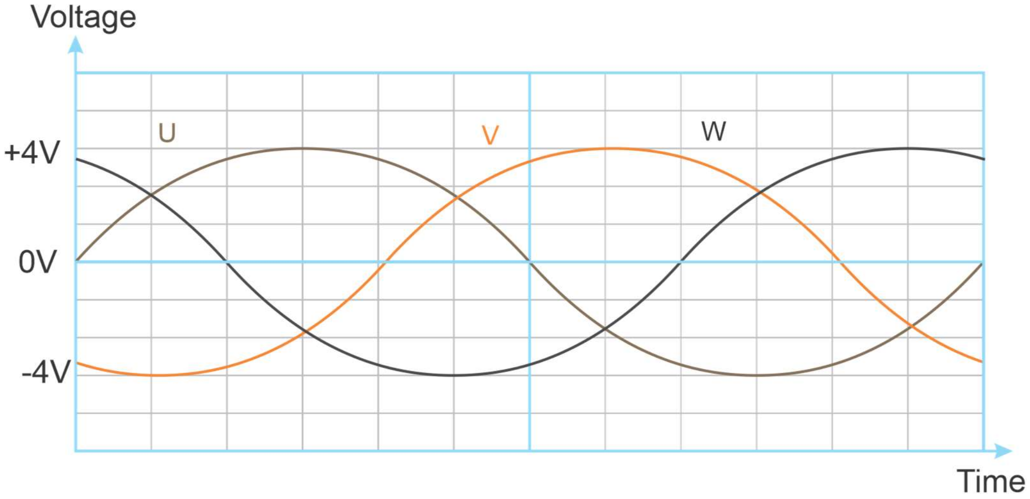
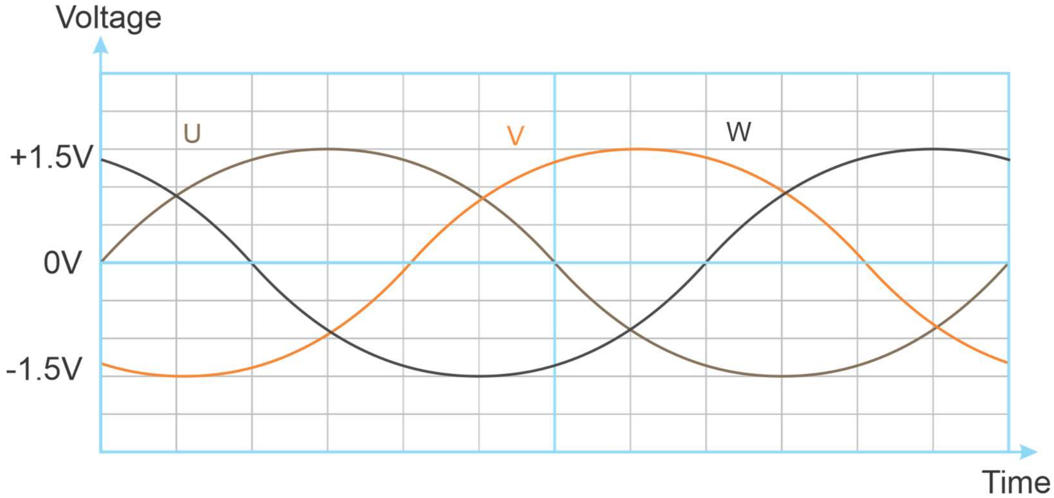
Worksheet 12 - Three phase generators

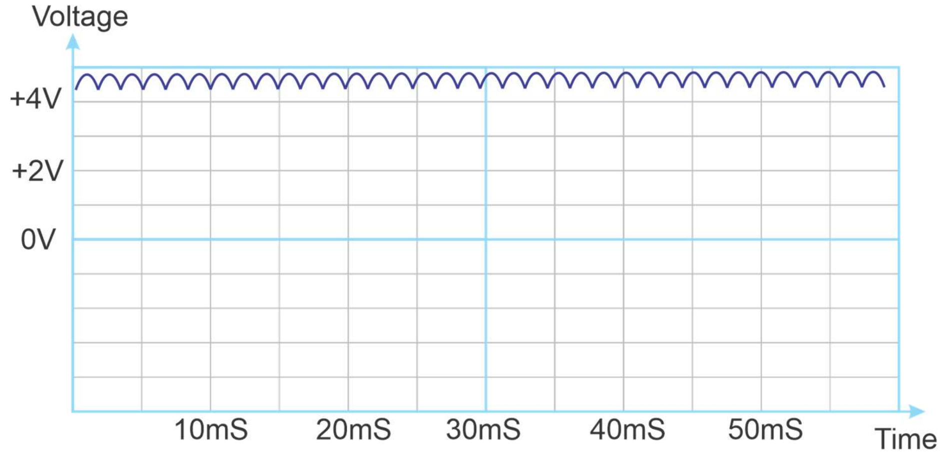
With six batteries:



With just three batteries:



Full wave rectifier:



The LED bulb stays lit for more than a minute.

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Worksheet 14 - Electric vehicle project:

What do you notice when current starts to flow to charge the SLAs?

..........When you start to charge the SLAs then the motor slows down. The reason for this is that electrical energy is being taken from the circuit and this corresponds to an increase in mechanical energy.

....

....

Worksheet 15 - Charging system faults

Note that results are different with different states of charge of SLAs. The circuit works well when the voltage of the two SLAs in series is 12.5V. As a guide:

Minimal current flowing:
All diodes in place: Voltage across the LED bulb: 4.1V
Remove any diode: Voltage across the LED bulb: 3.9V

Max current flowing:
All diodes in place: Voltage across the LED bulb: 3.5V
Remove any diode: Voltage across the LED bulb: 3.5V

Corrosion
LED voltage with minimal current, no corrosion: 4.1V
LED voltage with corrosion in place: 3.5V

LED voltage with max current, no corrosion: 3.5V
LED voltage with corrosion in place: 3.45V

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Worksheet 14 - Charging system faults

1 - Diode failure - open circuit (OC):

A. Minimum output

	No fault	*1 diode ‘OC’*	*2 diodes ‘OC’*	*3 diodes ‘OC’*
Rectifier output				

B. Increased output

	No fault	*1 diode ‘OC’*	*2 diodes ‘OC’*	*3 diodes ‘OC’*
Rectifier output				

2 - Diode failure - short circuit (SC):

A. Minimum output

	No fault	*1 diode ‘SC’*	*2 diodes ‘SC’*	*3 diodes ‘SC’*
Rectifier output				

B. Increased output

	No fault	*1 diode ‘SC’*	*2 diodes ‘SC’*	*3 diodes ‘SC’*
Rectifier output				

3 - Effect of corrosion:

A. Minimum output

	No fault	*Corrosion*
Rectifier output		

B. Increased output

	No fault	*Corrosion*
Rectifier output		

Version control

03 02 22 first release