Western Cape Government

Western Cape Education Department

Directorate: Curriculum FET

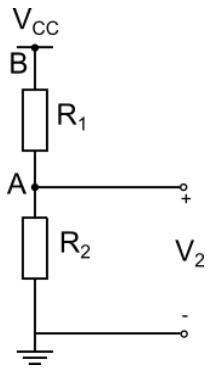
ELECTRICAL TECHNOLOGY

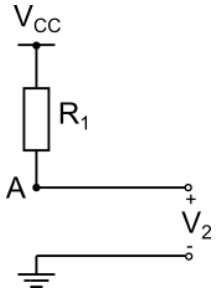
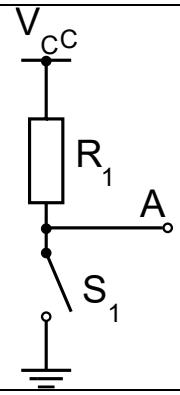
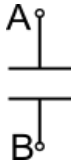
(Electronics & Digital Electronics

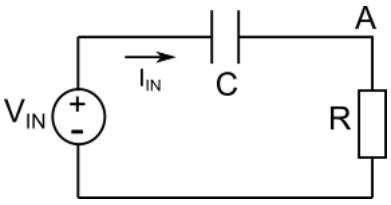
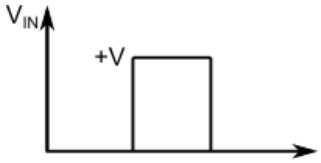
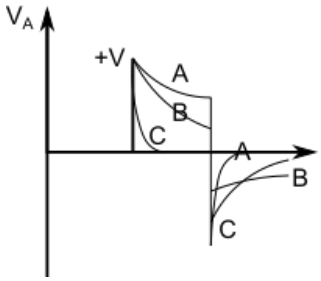
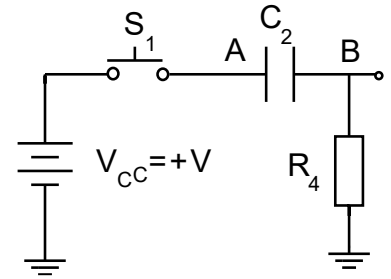
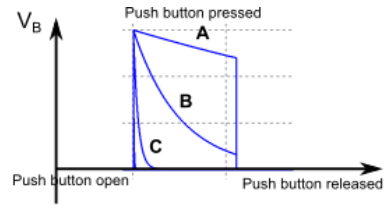
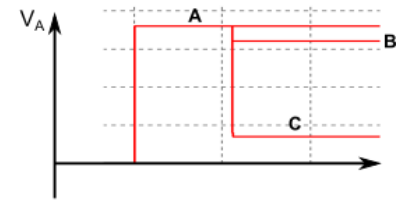
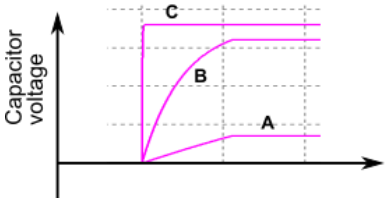
ESSENTIAL KNOWLEDGE FOR SWITCHING CIRCUITS

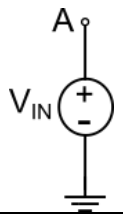
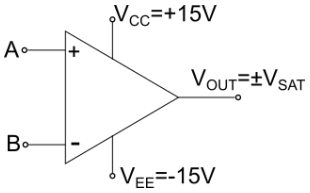
2024

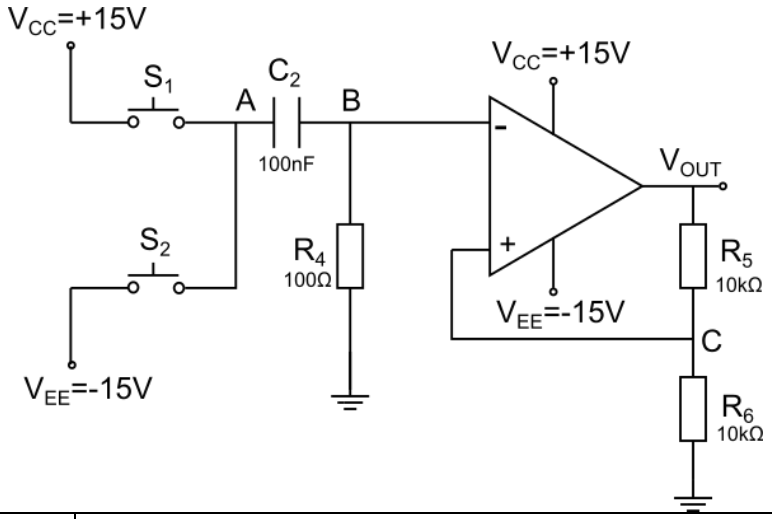
Grade 12

	SWITCHING CIRCUIT CONCEPTS		
	Bistable multivibrator	A multivibrator with two stable states and needs two external trigger signals to change the output state.	Always refer to the output states when asked to define a multivibrator, do not only state for example that it has two switches, or only one input, or no inputs.
	Monostable multivibrator	A multivibrator with only one stable output state and only need one external signal to change its output state for a certain duration..	
	Astable multivibrator	A multivibrator with no stable output states and do not require any external triggers to change its state.	
		V_{CC} indicates that a battery is connected between point B and ground. A indicates the voltage between point A and ground. The voltage at point A in this circuit is designated by V_A and at B as V_B $V_A = V_2$ $V_B = V_{CC}$	From elementary circuit analysis, $V_A = \frac{R_2}{R_1 + R_2} \times V_{CC}$ 1) When R_2 increases or R_1 decreases, V_A increases. 2) When $R_2 = 0, V_2 = 0$. In other words, point A is shorted to ground. 3) When $R_2 \to \infty, V_A = V_{CC}$ 4)

		R_1 is called a pull-up resistor. It sets $V_2 = V_{CC}$, but also allows V_2 to be changed by an externally connected voltage signal at point A.	If nothing was connected at point A, V_2 would have been floating and could jump up and down and be undefined or it may be defined by the circuit to which A is connected. Electrical noise in the environment would have been able to change its value.
		When S1 is open, $V_A = V_{CC}$ When S1 is closed, $V_A = 0$	
	Trigger voltage	The voltage at which the output of a circuit will change state.	This voltage may refer to an input voltage, or the voltage at any point of a circuit. This voltage may depend on the input voltage, or the output voltage, or the voltage across a charging capacitor.
	Resting condition	The condition of a circuit when no input voltage is applied.	A circuit such as an astable multivibrator may have no resting condition, as its output state will change constantly even though there is no input voltage.
	Zero state condition	When the power supply and all signal sources to a circuit is switched off.	
		When a voltage is applied such that $V_A = +15V$ and B is connected to ground, $V_B = 0$, the capacitor will charge to +15V. If V_A suddenly changes to -15V, V_B will drop to -30V as the capacitor voltage cannot change instantaneously.	The bottom plate of the capacitor will always change by the amount that the top plate changes at the instant that the change occurs. In this case, the top plate decrease by $\Delta V_A = +15 - (-15) = -30V$, thus the bottom plate will also decrease by 30V.

	  	Initially $V_{IN} = 0$, and $V_A = 0$. When V_{IN} suddenly changes to a value of +V, V_A will also change by the same amount +V and a current $I_{IN} = \frac{V_{IN}}{R} = \frac{V}{R}$ will flow. As the capacitor charges to +V, the current will decrease and V_A will decrease to zero. When the time constant $\tau = RC$ is short, this will happen rapidly and an impulse will be created at A. When V_{IN} changes to 0V, the left hand plate voltage decreases by +V, and the rigt hand plate also, making it -V. The capacitor discharges through R and V_{IN} until its voltage is zero.	Reminder: When the time constant $\tau = RC$ is very short, the capacitor will charge rapidly, when it is large, the capacitor will take long to charge. To generate a very sharp impulse at A, the time constant must be small. Short or long refers to in comparison with the duration of the input signal which is normally a pulse. Note that when $R \to \infty$, in other words an open circuit, A will simply follow V_{IN}, or $V_A = V_{IN}$. A: Long time constant B: Medium time constant C: Very short time constant
	   	*Note: Using a push button to provide a trigger signal is different from using a pulse such as in the previous section. The capacitor cannot discharge as there is no discharge path.* C: Short time constant When S1 is pressed, $V_A = +V$, and $V_B = +V$ the capacitor charges rapidly to +V, the current decreases and V_B decreases to zero. When the button is released, $V_A = +V$ and $V_B = 0$. B: Medium time constant When S1 is pressed, $V_A = +V$, and $V_B = +V$, the capacitor charges, but before it reaches +V, the button is released. V_B decreases, but is still above zero when the button is released. When the button is released, V_B drops to zero, and V_A drops by the same amount.	A: Long time constant When S1 is pressed, $V_A = +V$, the capacitor charges slightly, but before it reaches +V, the button is released. V_B decreases, but is still above zero when the button is released. When the button is released, V_B drops to zero, and V_A drops by the same amount. Note that when R4 is absent (open circuit from B to ground), the following will happen; When S1 is pressed, $V_A = +V$, and $V_B = +V$. As there is no path for current to flow to charge the capacitor, V_A and V_B will return to zero when the button is released.

		This is the general symbol for a voltage supply and may indicate a battery or a sine wave or any other waveform (triangular, pulse etc).	A voltage source has zero internal resistance. When the value of $V_{IN} = 0$, it means that point A is effectively connected to ground.
		An op-amp circuit has infinite gain, $A_V \rightarrow \infty$ when it is used in open-loop configuration or with positive feedback. Positive feedback means that a portion of the output voltage is fed back to the non-inverting input.	The output of the op-amp will saturate, meaning that it will attain only one of two maximum values close to V_{CC} and V_{EE}. $\pm V_{SAT} = \pm 15V$ When $V_A > V_B$, or $V_+ > V_-$, the output $V_{OUT} = +V_{SAT} = +15V.$ When $V_A < V_B$, or $V_+ < V_-$, the output $V_{OUT} = -V_{SAT} = -15V.$

	PRACTICAL BISTABLE MULTIVIBRATOR	
		
	1.	**Calculate the trigger voltages for this circuit.**
		$V_{TRIGGER} = V_C$ $= \frac{R_6}{R_5 + R_6} \times (\pm V_{SAT})$ $= \pm \frac{10\,000}{10\,000 + 1000} \times 15$ $= \pm 7{,}5V$
	2.	**Deduce the voltage at B after switch S1 is pressed for the first time.**
		As the voltage on the left plate of the capacitor C_2 immediately becomes 15V when S_1 is pressed, the voltage on the right plate must be $V_B = 15V$ as the capacitor voltage cannot change instantly. If the time constant $\tau = R_4 C_2$ is much shorter than the time that the switch is held down, the capacitor will charge very fast, V_B will decrease to 0V and V_A will be15V.

	3.	**Determine the value of V_{OUT} after S_1 is pressed for the first time.**
		As the voltage at C (at the non-inverting input of the op amp) will always be less than the voltage at B (at the inverting input of the op-amp), whether negative or positive, due to the voltage divider action of R_5 and R_6, $V_{OUT} = -V_{SAT} = -15V$.
	4.	**Deduce the voltage at B when S_2 is pressed some time after S_1 was pressed.**
		When S2 is pressed, $V_A = -15V$, the voltage on the left hand plate decreases by 30V, thus the voltage at B must also decrease by 30V, in other words, $V_B = -30V$.
	5.	**Now, determine the value of V_{OUT} after S_2 is pressed.**
		As V_B is much smaller than V_C, $V_{OUT} = +V_{SAT} = +15V$.
	6.	**Now, determine the voltage at B if S_1 is pressed again.**
		The voltage at A changes from -15V to +15V which is an increase of 30V, it means the voltage at B must also increase by 30V, thus $V_B = +30V$. As $V_B > V_C \Rightarrow V_{OUT} = -V_{SAT} = -15V$
	7.	**Draw timing diagrams for V_A, V_B and V_{OUT}.**
		