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Exploring Electronic Circuits with Breadboards, AI Circuit
Analysis, and Simulators

DAY 2: Electronic Circuit Schematic Diagrams – KiCad and Microcap

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Webinar Logistics

- Turn on your system sound to hear the streaming presentation.
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- Participate in ‘Attendee Chat’ by maximizing the chat widget in your dock.



Dr. Don Wilcher

Visit 'Lecturer Profile' in your console for more details.

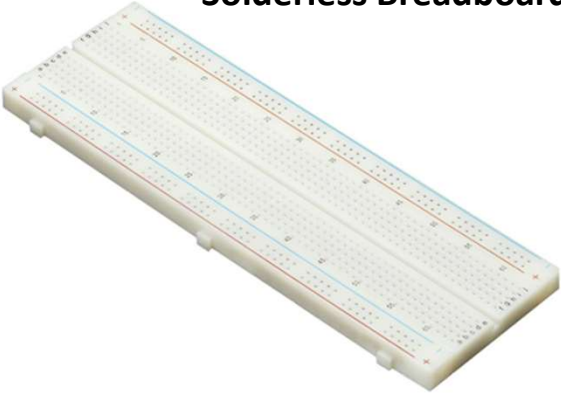
Course Kit and Materials



Adafruit Parts Pal Kit



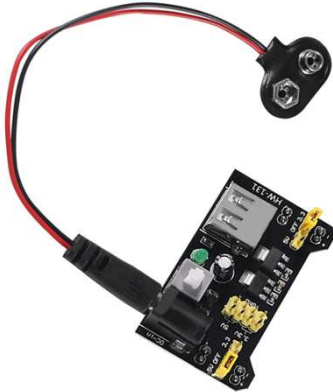
Solderless Breadboard



Jumper Wires: Male to Male



Solderless Breadboard Power Supply



Research Perspective

“Breadboards are widely used in early-stage circuit prototyping since they enable users to rapidly try out different components and to change the connections between them” (Zhu et al., 2020).

Agenda:

- The Purpose of Electronic Circuit Schematic Diagrams In Industry
- Introduction to Micro-Cap
 - a) Layout of the Micro-Cap Software Environment
 - b) Build and Simulate a 555 Timer Astable Multivibrator Circuit Activity
- Introduction to KiCAD
 - a) Layout of the KiCAD Software Environment
 - b) Drawing a 555 Timer Astable Multivibrator Electronic Circuit Schematic Diagram Activity

The Purpose of Electronic Circuit Schematic Diagrams in Industry



Due to these factors, electronic circuit schematic diagrams play an important role in the industry.

- Provide a clear visual representation of how components in a circuit are connected.
- Allowing for easier understanding of products of
 - a) design.
 - b) communication.
 - c) troubleshooting.
 - d) analysis of complex electrical systems.
- Enabling engineers and technicians to quickly grasp circuit functionality.
- Identify potential issues without needing to examine the device itself physically.

The Purpose of Electronic Circuit Schematic Diagrams in Industry...

Key benefits of Electronic Circuit Schematic Diagrams in Industry.



- Improved communication- Standardized symbols and layouts for clear communication of circuit designs.
- Design and Planning – Schematics allow engineers to visualize and plan circuit layouts before physical construction begins.
- Troubleshooting – Schematic Diagrams help technicians to identify the source of electronic circuit problems.
- Simulation and Analysis – Schematic Diagrams can be used as input for computer simulations. Allowing circuit behavior to be tested under specific conditions.
- Documentation – Schematic Diagrams preserve design details and facilitating future modifications or maintenance.

Question 1

Schematic diagrams can be used as output for computer simulations.

- a) True**
- b) False**



Introduction to Micro-Cap Software

- Is a freeware analog and digital circuit simulator that provides an interactive environment for electronic engineers to build and simulate virtual designs.
- The software was designed by Spectrum Software.
- Spectrum Software shuttered the company's domain in July 2019.
- Spectrum Software's website went offline in early 2023.
- Micro-Cap Software can be obtained from archive.org.
- Version 12 can be obtained from the following web link:
https://archive.org/details/mc12cd_202108.



Introduction to Micro-Cap Software. . .

Micro-Cap is a powerful software tool that can be used to:

- build circuits.
- explore circuit operations.
- learn about circuits.
- perform sensitivity analysis.
- worst case analysis.
- transient analysis.
- create macro-model functions of specific circuits.

Although software is no longer supported, the features listed are important in the design and analysis of electronic circuits.



Introduction to Micro-Cap Software...



What is a Macro-model?

A compact circuit that emulates the behavior of a real circuit or device without modeling each of its elements.

Question 2

Micro-Cap software was designed by

- a) Simply Software**
- b) Software Simply**
- c) Software Spectrum**
- d) Spectrum Software**



Introduction to Micro-Cap Software...



AMP

This block provides a simple linear amplifier. Its definition is:

$$V_{Out}(t) = gain V_{In}(t)$$

The function is implemented with the AMP macro:

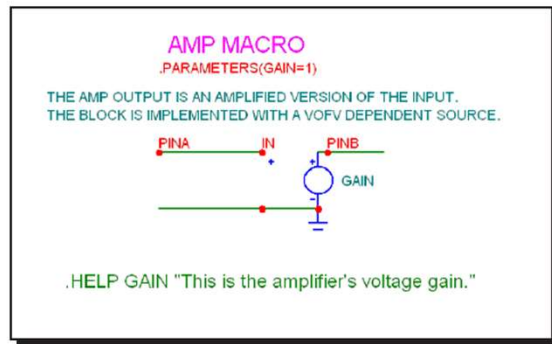


Figure 25-3 AMP macro circuit

The single input parameter, GAIN, multiplies the input to produce an amplified output. This implementation uses a simple linear dependent VOFV source. It could have been done with a Function source or a Spice poly source. In general, the simplest type of source that will perform the function is preferred.

PID Controller

The PID (Proportional-Integral-Derivative) controller is a common feedback mechanism used within closed loop control systems. The controller automatically adjusts a variable to keep a specified measurement at a set point. It can be found in temperature, flow, and position control applications. The macro employs other math function macros, SUB, AMP, INT, DIF, and SUM.

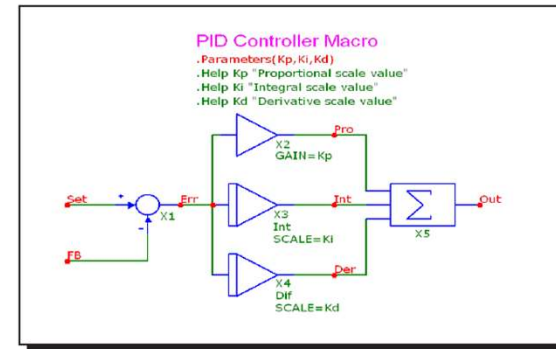


Figure 25-33 PID Controller macro circuit

Parameter	Definition
KP	Proportional scale value
KI	Integral scale value
KF	Derivative scale value

Macro-model Examples

Introduction to Micro-Cap Software...

555

The 555 is a model of the ubiquitous 555 timer circuit. Its circuit is as follows:



Macro-Model
Examples

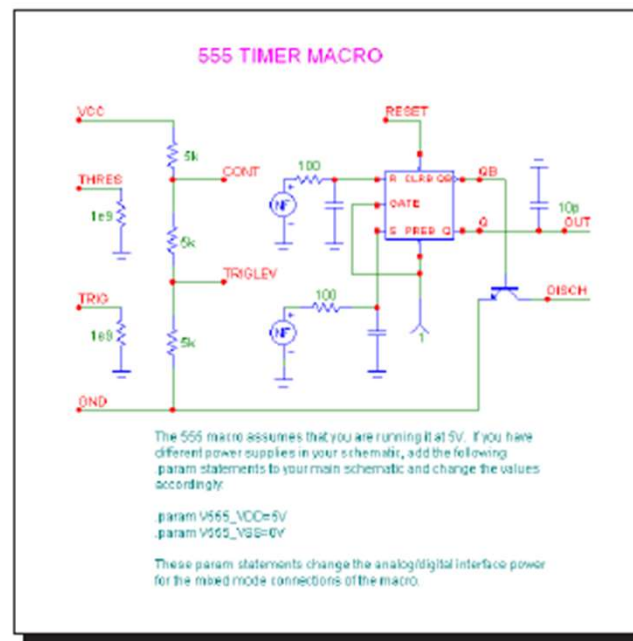


Figure 25-57 555 macro circuit

Introduction to Micro-Cap Software...

555

The 555 is a model of the ubiquitous 555 timer circuit. Its circuit is as follows:



Macro-model
Examples

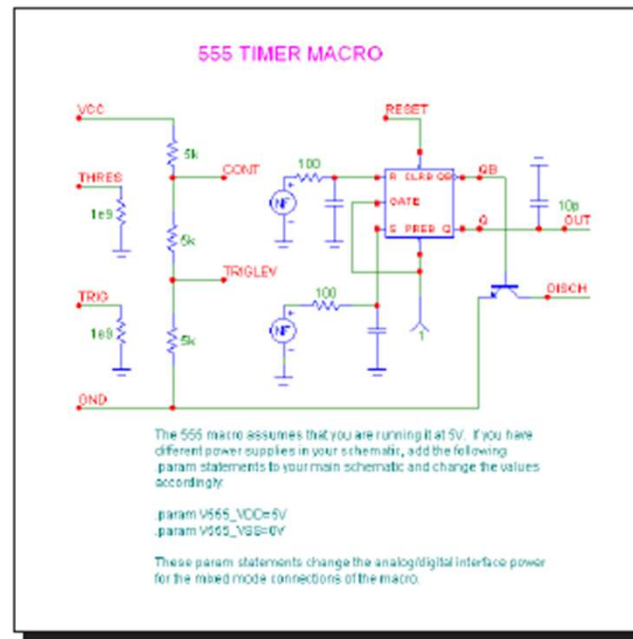
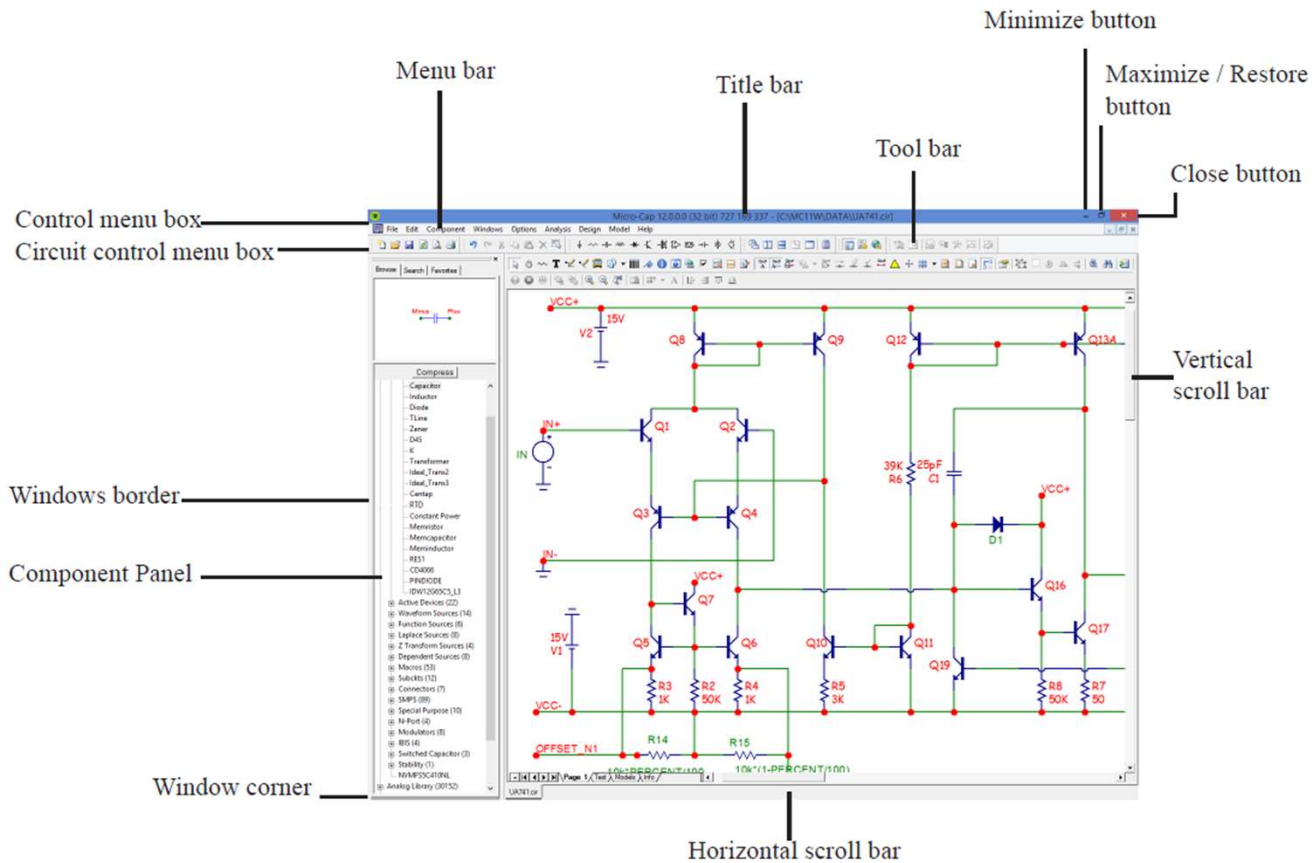


Figure 25-57 555 macro circuit

Layout of Micro-Cap Software Environment



Question 3

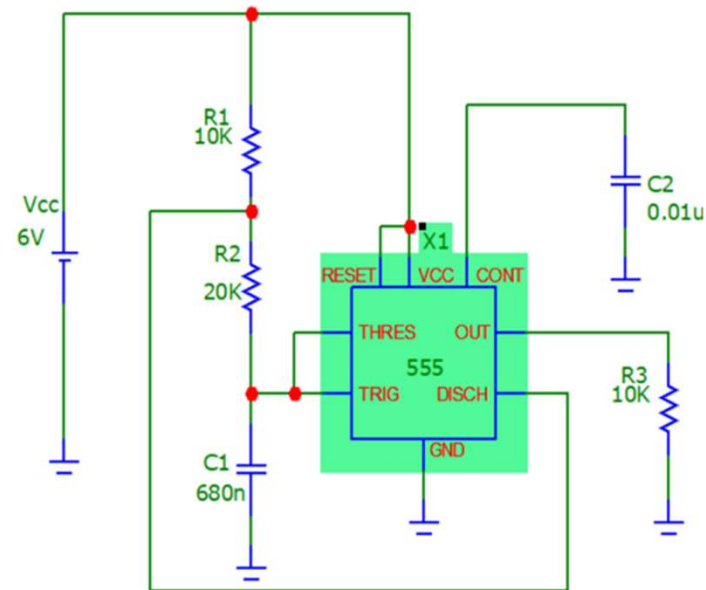
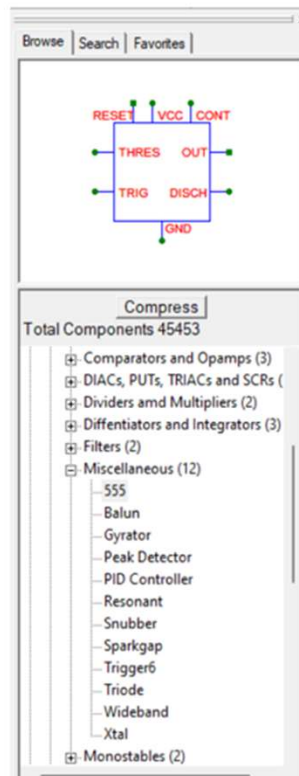
In reviewing slide 14, the AMP block provides a simple linear amplifier defined by a:

- a) picture**
- b) text**
- c) mathematical equation**
- d) none of the above**

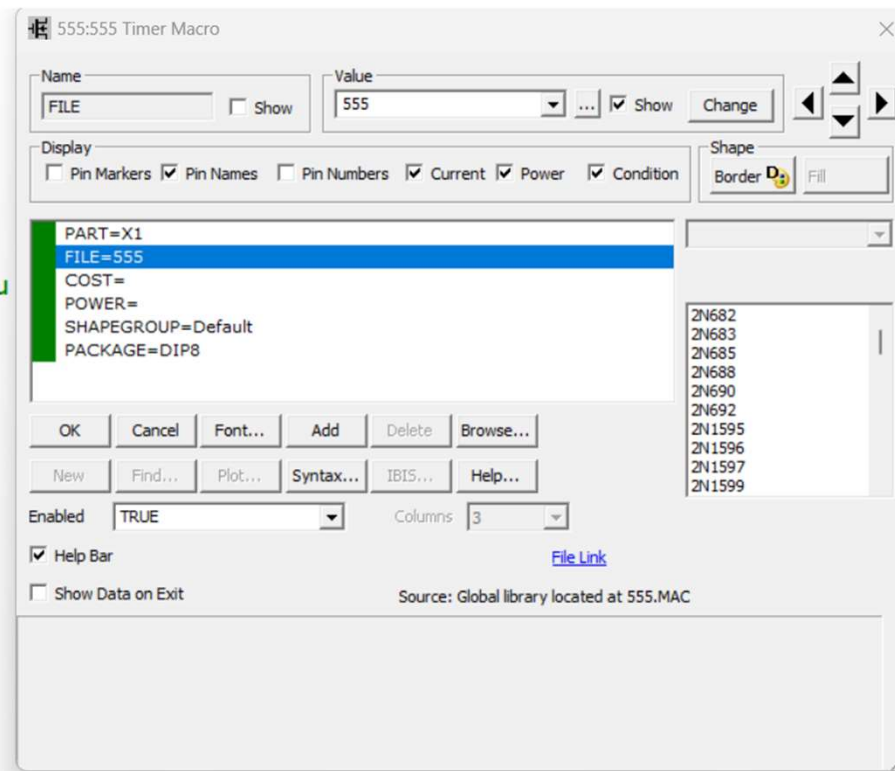
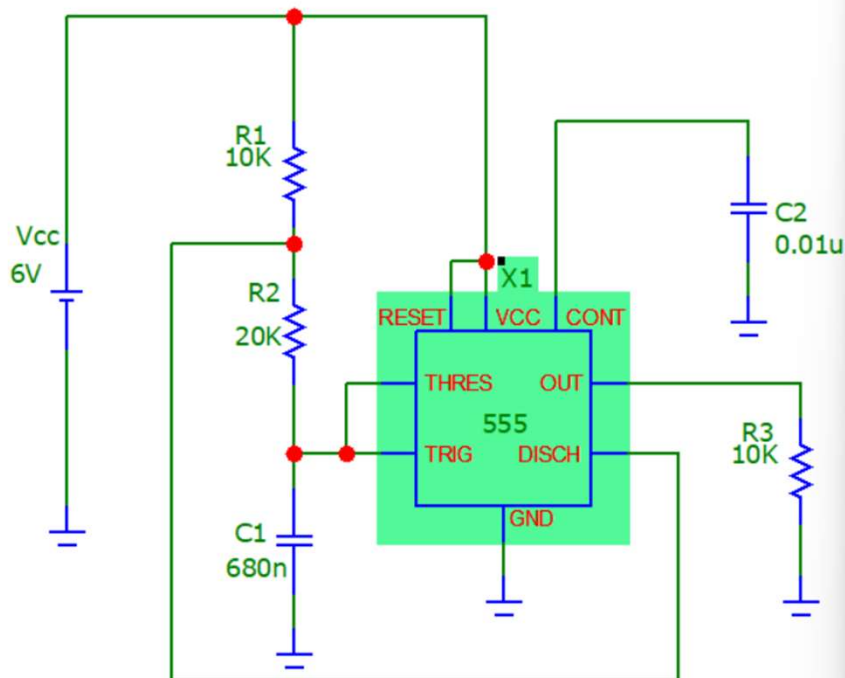


Build and Simulate a 555 Timer Astable Multivibrator Circuit Activity

Adding a 555
Timer

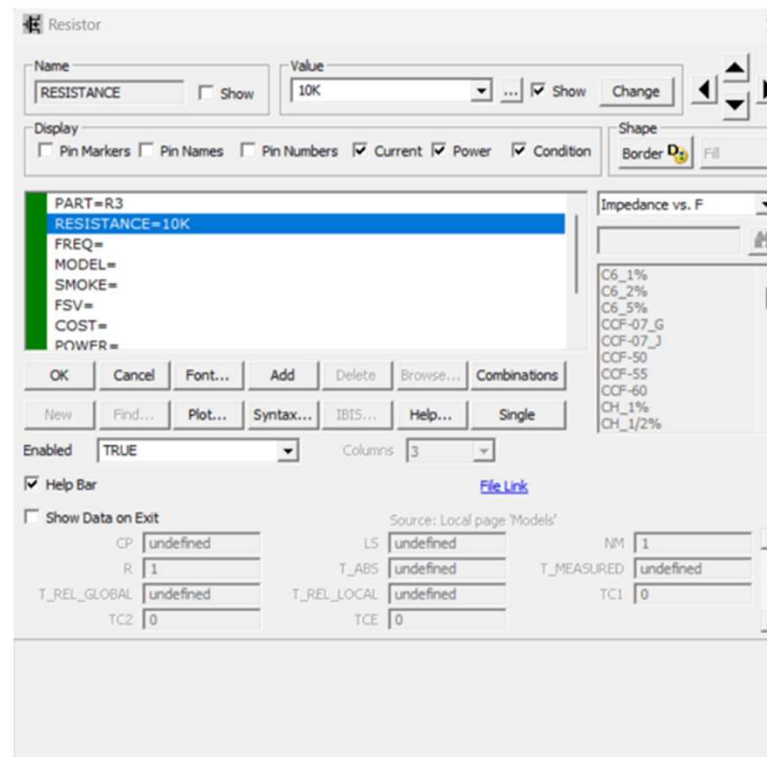
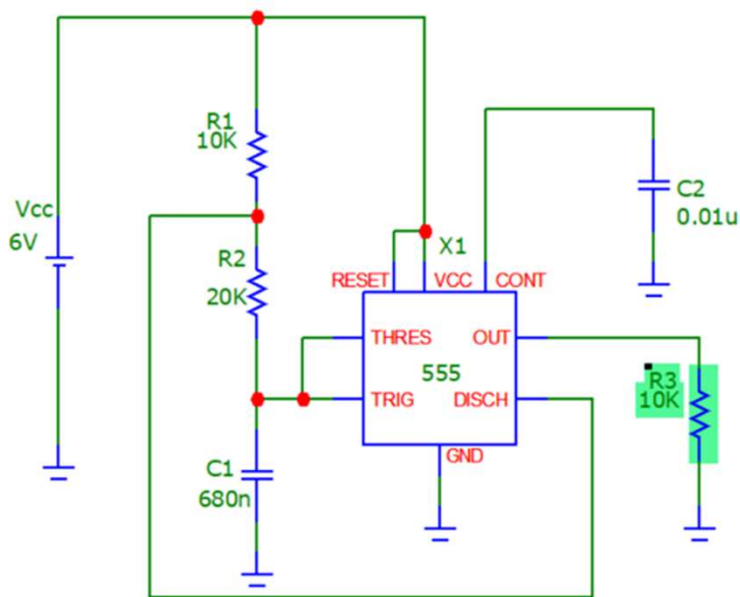


Build and Simulate a 555 Timer Astable Multivibrator Circuit Activity...



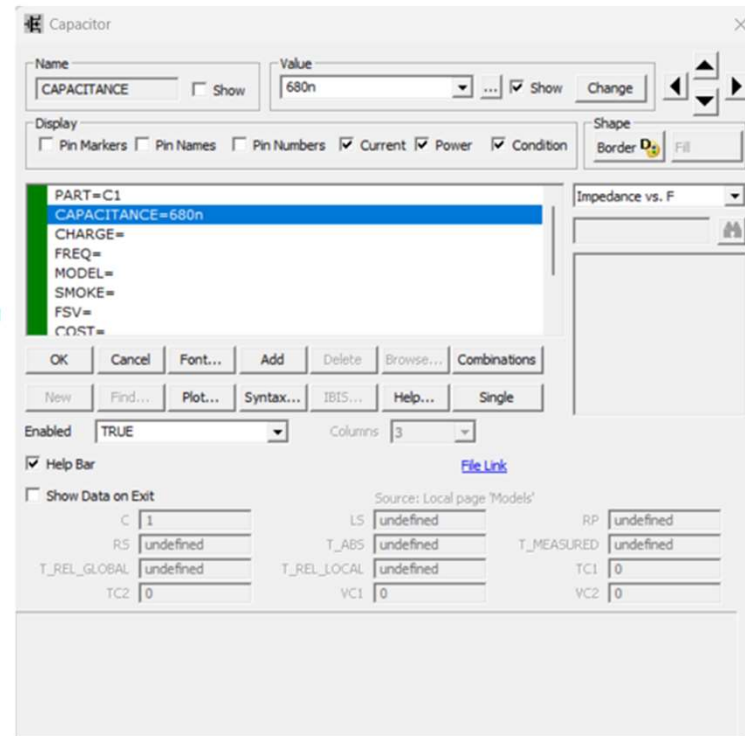
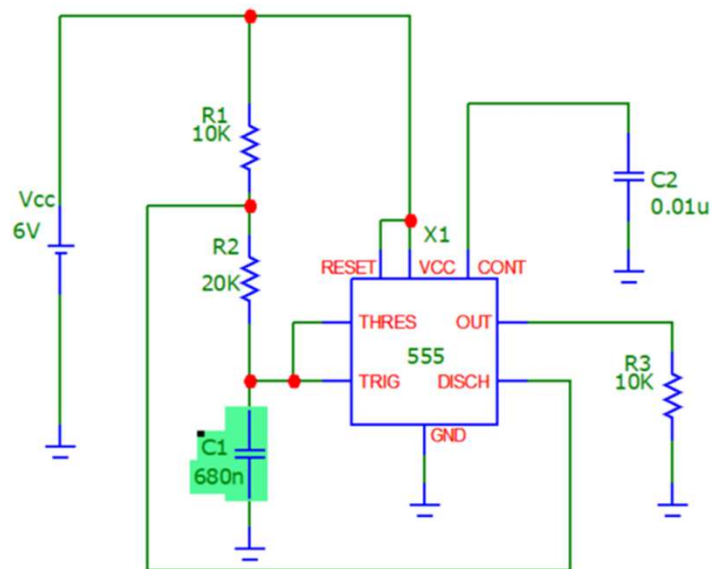
Adding
a 555
Timer...

Build and Simulate a 555 Timer Astable Multivibrator Circuit Activity



Adding an
output load
resistor

Build and Simulate a 555 Timer Astable Multivibrator Circuit Activity...



Adding the
trigger
capacitor

Build and Simulate a 555 Timer Astable Multivibrator Circuit Activity...



Before simulating the 555 Timer Astable Multivibrator circuit, perform the following analysis. Determining the output frequency (f) of the 555 Timer Astable Multivibrator circuit.

$$\begin{aligned} f &= 1/T_{\text{total}} \\ &= 1/23\text{ms} \\ &= 43.4\text{Hz} \end{aligned}$$

Where:

f is the frequency
 T_{total} is the total time

$$\begin{aligned} t_{\text{low}} &= 0.693R_2C_1 \\ &= 0.693 + (20\text{K}\Omega \times 680\text{nF}) \\ &= 9\text{ms} \end{aligned}$$

$$\begin{aligned} t_{\text{high}} &= 0.693(R_1 + R_2)C_1 \\ &= 0.693(10\text{K}\Omega + 20\text{K}\Omega)680\text{nF} \\ &= 14\text{ms} \end{aligned}$$

$$\begin{aligned} T_{\text{total}} &= t_{\text{low}} + t_{\text{high}} \\ &= (9 + 14)\text{ms} \\ &= 23\text{ms} \end{aligned}$$

Question 4

What output frequency is produced with an R2 value of $10\text{K}\Omega$ for a 555 Timer Astable Multivibrator circuit?

- a) 500Hz**
- b) 700Hz**
- c) 1.45KHz**
- d) 1.410KHz**



Build and Simulate a 555 Timer Astable Multivibrator Circuit Activity...



Set the time in simulation using 23ms as the timebase. To display 3 cycles of the squarewave output, the maximum time will be 69 ms. Go to **Analysis** (the top toolbar), and select **Transient**. **Analysis>Transient**. Click the Run button to execute the simulation.

Add 69ms
Here!



Transient Analysis Limits

Run Add Delete Expand... Stepping... PSS... Properties... Help...

Maximum Run Time: 69m
 Output Start Time (tstart): 0
 Maximum Time Step: 0
 Number of Points: 51
 Temperature: Linear 27
 Retrace Runs: 1

Run Options: Normal
 State Variables: Zero

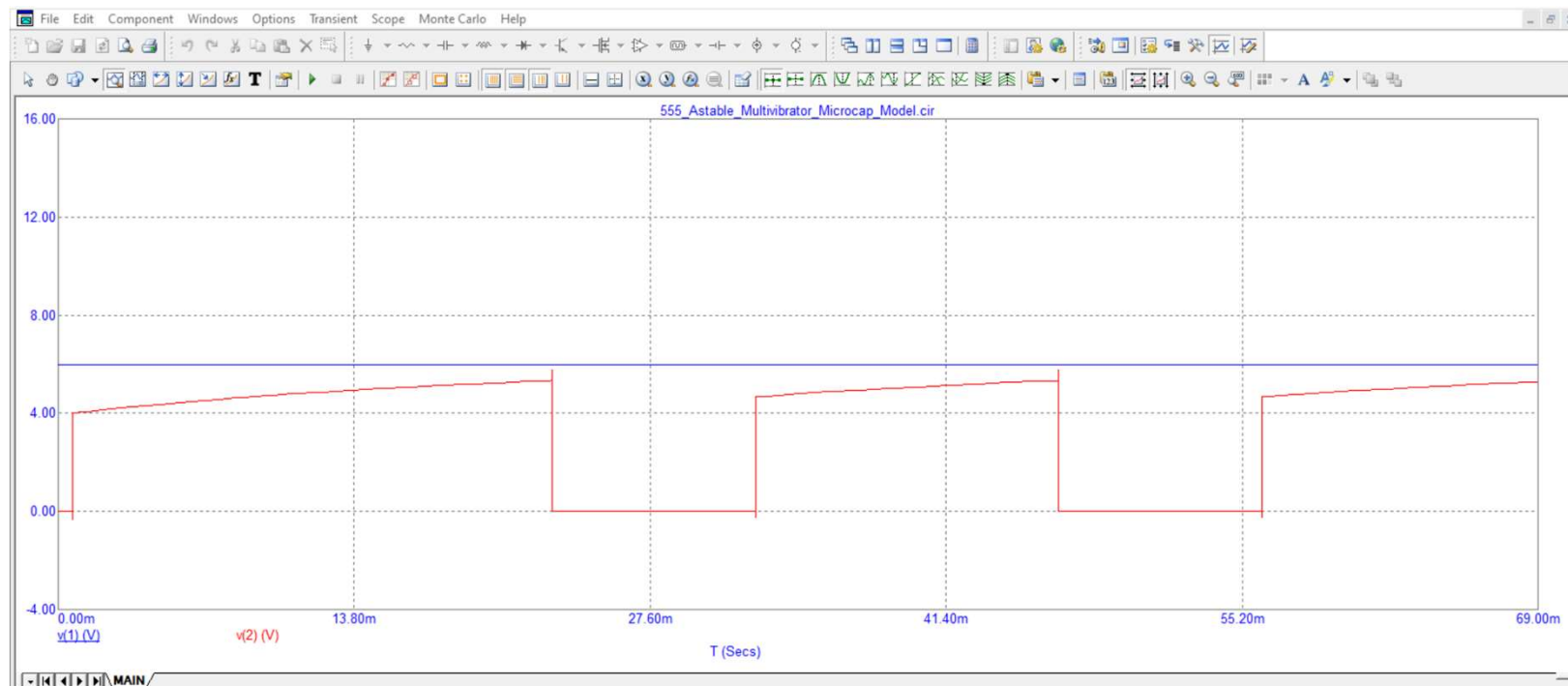
Operating Point Accumulate Plots
 Operating Point Only Fixed Time Step
 Auto Scale Ranges Periodic Steady State

<input type="checkbox"/> Ignore Expression Errors		Page	P	X Expression	Y Expression	X Range	Y Range	>
<input checked="" type="checkbox"/>			1	T	v(1)	0.072,0,0.0144	16,-4,4	
<input checked="" type="checkbox"/>			1	T	v(2)	0.072,0,0.0144	16,-4,4	
<input checked="" type="checkbox"/>								

Build and Simulate a 555 Timer Astable Multivibrator Circuit Activity...

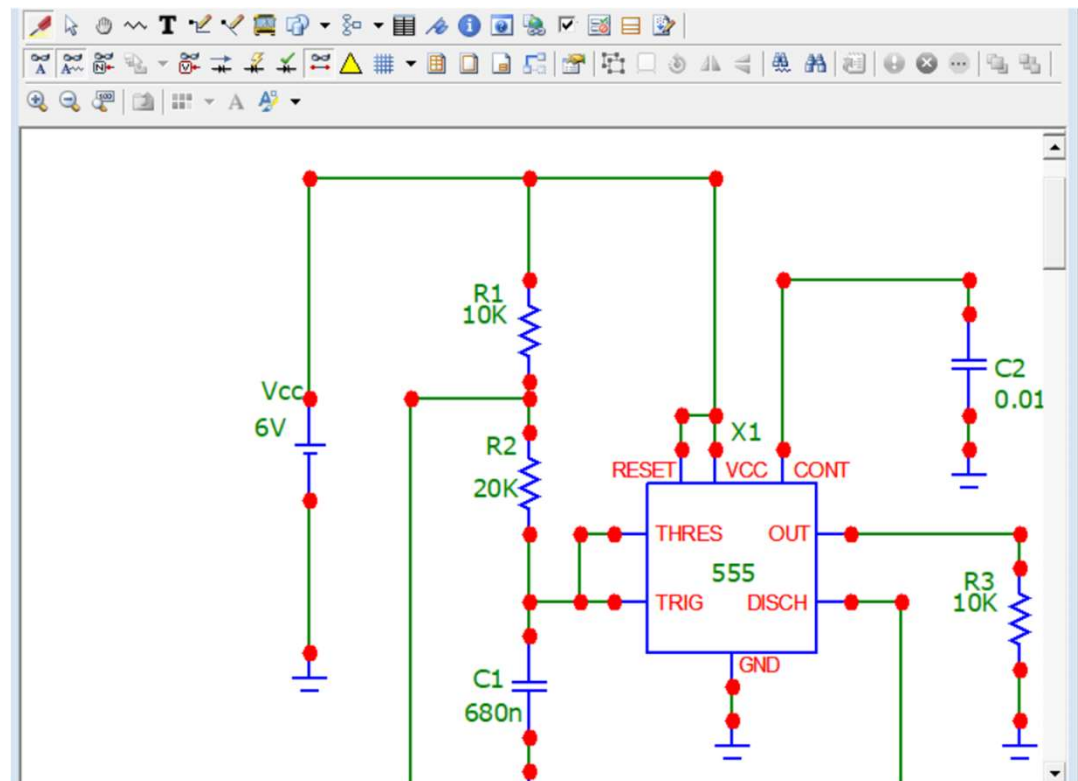


Simulation Results:
Exit out of the
simulation, Click
Transient then Exit
Simulation.
Transient>Simulation



Build and Simulate a 555 Timer Astable Multivibrator Circuit Activity...

To obtain multiple circuit points (nodes) for probing voltages use, Analysis > Probe Transient.

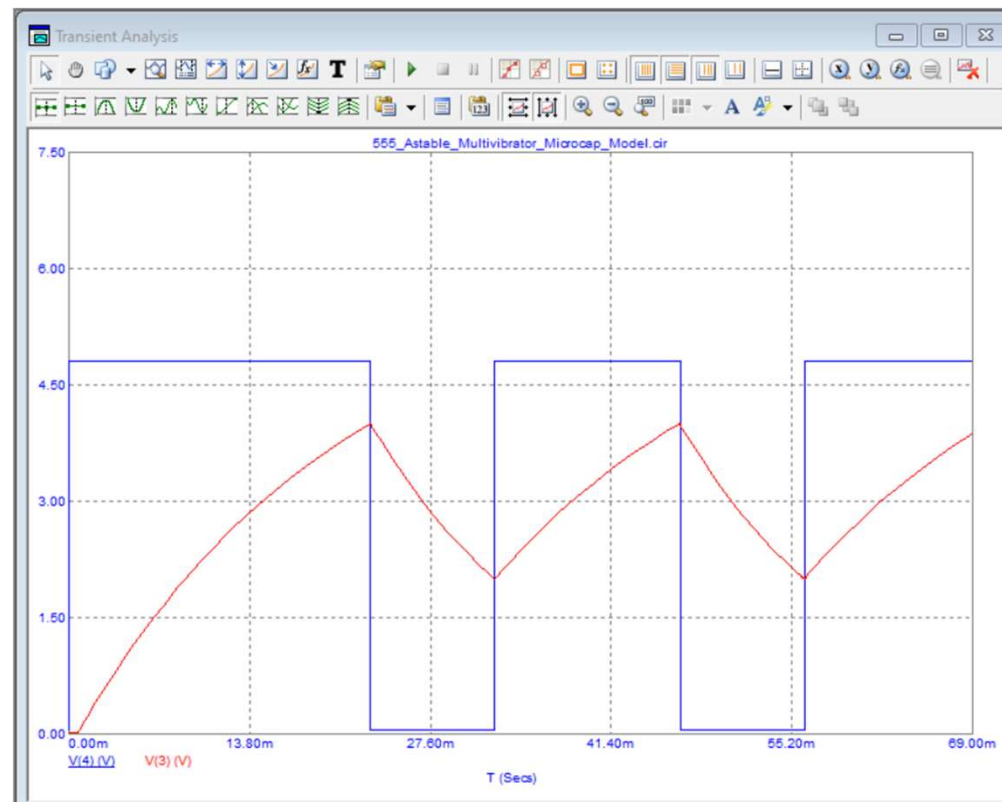


Build and Simulate a 555 Timer Astable Multivibrator Circuit Activity...



Results of Analysis >Probe
Transient.

- 555 Timer Astable Multivibrator Squarewave output
- Charging/Discharging of the 680nF (C1) capacitor



Introduction to KiCad Software

- Is a free software suite for Electronic Design Automation (EDA).
- The software facilitates the design and simulation of electronic hardware for Printed Circuit Board (PCB) manufacturing.
- The software features an integrated environment for:
 - a) schematic capture.
 - b) PCB layout.
 - c) manufacturing file viewing
 - d) ngspice (open-source SPICE) simulation
 - e) engineering calculation

Note:

SPICE is Simulation Program with Integrated Circuit Emphasis



Layout of KiCad Software Environment. . .

File > New Project

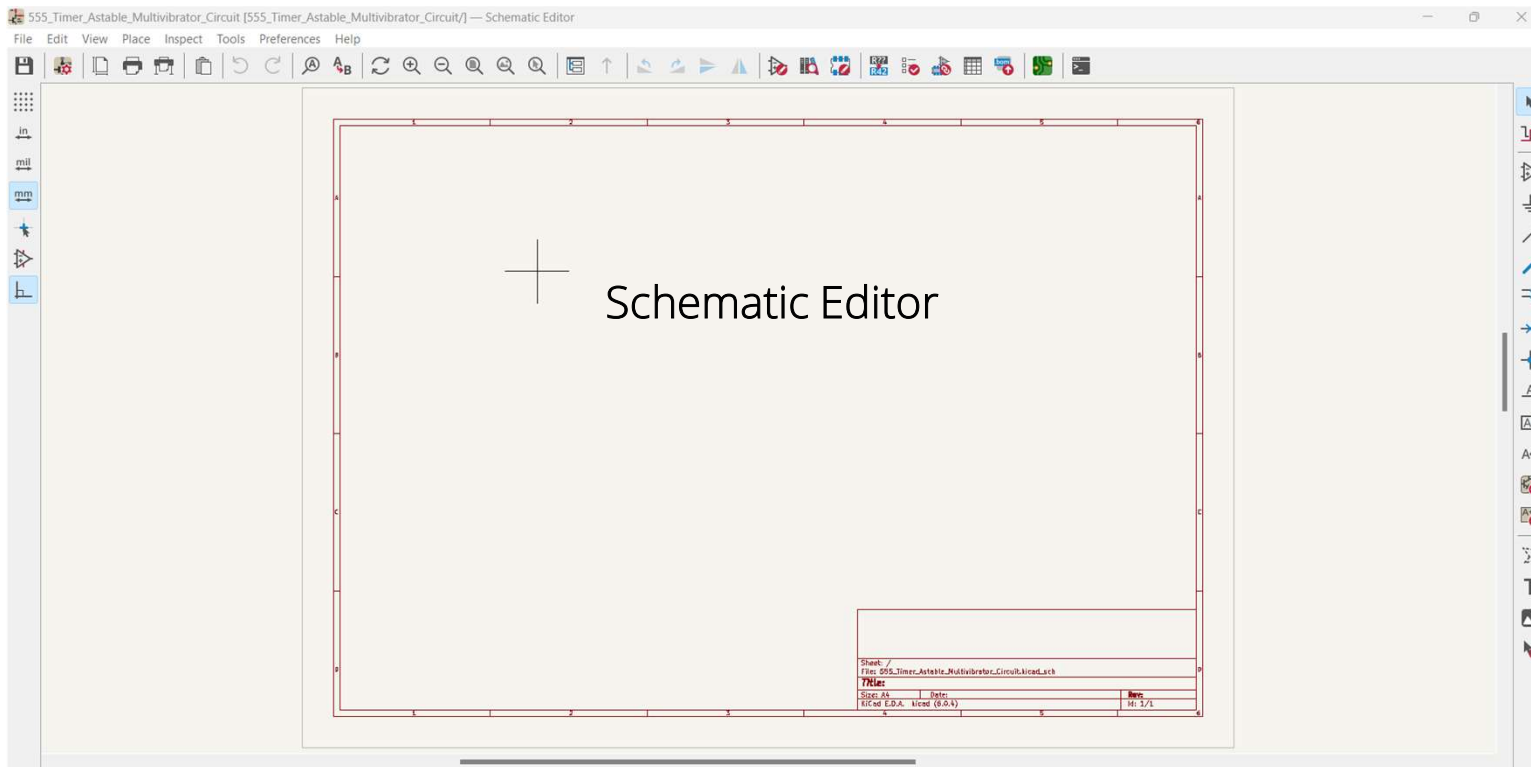


The screenshot shows the KiCad software interface. On the left, the 'Project Files' panel is visible, showing a project named '555_Timer_Astable_Multivi' with three sub-files. A hand cursor icon is positioned over the 'New Project' button in the toolbar. Below the toolbar, the text 'Click Here to go to Schematic Editor!' is displayed. On the right, the main tool palette is shown, listing various tools with their descriptions:

- Schematic Editor**
Edit the project schematic
- Symbol Editor**
Edit global and/or project schematic symbol libraries
- PCB Editor**
Edit the project PCB design
- Footprint Editor**
Edit global and/or project PCB footprint libraries
- Gerber Viewer**
Preview Gerber files
- Image Converter**
Convert bitmap images to schematic symbols or PCB footprints
- Calculator Tools**
Show tools for calculating resistance, current capacity, etc.
- Drawing Sheet Editor**
Edit drawing sheet borders and title blocks for use in schematics and PCB designs
- Plugin and Content Manager**
Manage downloadable packages from KiCad and 3rd party repositories



Layout of KiCad Software Environment. . .



Click Here to obtain the component library!

Drawing A 555 Timer Astable Multivibrator Electronic Circuit Schematic Diagram Activity ...

Adding the 555 Timer IC to the Schematic Editor



Choose Symbol (17110 items loaded)

Q 555

Item	Description
4xxx_IEEE	4xxx series IEEE symbols
> 4555	
Timer	Assorted timer devices
LM555xM	Timer, 555 compatible, SOIC-8
LM555xMM	Precision Timers, 555 compatible, VSSOP-8
LM555xN	Timer, 555 compatible, PDIP-8
NA555D	Precision Timers, 555 compatible, SOIC-8
NA555P	Precision Timers, 555 compatible, PDIP-8
NE555D	Precision Timers, 555 compatible, SOIC-8
NE555P	Precision Timers, 555 compatible, PDIP-8
SA555D	Precision Timers, 555 compatible, SOIC-8
SA555P	Precision Timers, 555 compatible, PDIP-8
SE555D	Precision Timers, 555 compatible, SOIC-8
SE555P	Precision Timers, 555 compatible, PDIP-8

LM555xN
Alias of NE555P (Precision Timers, 555 compatible, PDIP-8)
Timer, 555 compatible, PDIP-8
Keywords: single timer 555

Reference U?
Footprint Package_DIP:DIP-8_W7.62mm
Datasheet <http://www.ti.com/lit/ds/svmlink/lm555.pdf>

Select with Browser Place repeated copies Place all units

[Default] Package_DIP:DIP-8_W7.62mm

Drawing A 555 Timer Astable Multivibrator Electronic Circuit Schematic Diagram Activity ...

Adding a resistor to the schematic editor



Choose Symbol (17113 items loaded)

resistor

Item	Description
R_Potentiometer_US	Potentiometer, US symbol
Thermistor_PTC	Temperature dependent resistor, positive temperature coefficient
Thermistor_PTC_3Wire	Temperature dependent resistor, positive temperature coefficient, 3-wire interface
Thermistor_PTC_4Wire	Temperature dependent resistor, positive temperature coefficient, 4-wire interface
Thermistor_PTC_US	Temperature dependent resistor, positive temperature coefficient, US symbol
R_Small	Resistor, small symbol
R_Small_US	Resistor, small US symbol
R	Resistor
R_Trim	Trimable resistor (preset resistor)
R_US	Resistor, US symbol
R_Variable	Variable resistor
R_Variable_US	Variable resistor, US symbol
Heater	Resistive heater
R_Shunt	Shunt resistor

R_US
Resistor, US symbol
Keywords: R res resistor

Reference R?
Footprint
Datasheet ~

Select with Browser Place repeated copies Place all units

No default footprint

No footprint specified

OK Cancel

Drawing A 555 Timer Astable Multivibrator Electronic Circuit Schematic Diagram Activity ...

Adding a capacitor to the schematic editor



Choose Symbol (17112 items loaded)

Q capa

Item	Description
Device	Generic symbols for common devices
D_Capacitance	Variable capacitance diode
D_Capacitance_Filled	Variable capacitance diode, filled shape
C_Small	Unpolarized capacitor, small symbol
Microphone_Condenser	Condenser microphone
C	Unpolarized capacitor
C_Polarized	Polarized capacitor
C_Polarized_Small	Polarized capacitor, small symbol
C_Polarized_Small_US	Polarized capacitor, small US symbol
C_Polarized_US	Polarized capacitor, US symbol
C_Trim_Differential	Differential variable capacitor with two stators
C_Variable	Variable capacitor
C_Feedthrough	Feedthrough capacitor
C_Trim	Trimable capacitor

C
Unpolarized capacitor
Keywords: cap capacitor

Reference C?
Footprint
Datasheet ~

Select with Browser Place repeated copies Place all units

No default footprint

No footprint specified

OK Cancel

Drawing A 555 Timer Astable Multivibrator Electronic Circuit Schematic Diagram Activity ...

Placing a ground onto the schematic editor



Choose Power Symbol (102 items loaded)

Filter

Item	Description
-VDC	Power symbol creates a global label with name "-VDC"
-VSW	Power symbol creates a global label with name "-VSW"
AC	Power symbol creates a global label with name "AC"
Earth	Power symbol creates a global label with name "Earth"
Earth_Clean	Power symbol creates a global label with name "Earth_Clean"
Earth_Protective	Power symbol creates a global label with name "Earth_Protective"
GND	Power symbol creates a global label with name "GND", ground
GND1	Power symbol creates a global label with name "GND1", ground
GND2	Power symbol creates a global label with name "GND2", ground
GND3	Power symbol creates a global label with name "GND3", ground
GND4	Power symbol creates a global label with name "GND4", analog ground
GND5	Power symbol creates a global label with name "GND5", digital ground
GNDPWR	Power symbol creates a global label with name "GNDPWR", power ground
GNDREF	Power symbol creates a global label with name "GNDREF", reference supply ground
GND6	Power symbol creates a global label with name "GND6", signal ground
HT	Power symbol creates a global label with name "HT"
LINE	Power symbol creates a global label with name "LINE"
NEUT	Power symbol creates a global label with name "NEUT"
...	...

GNDREF
Power symbol creates a global label with name "GNDREF", reference supply ground
Keywords: power-flag

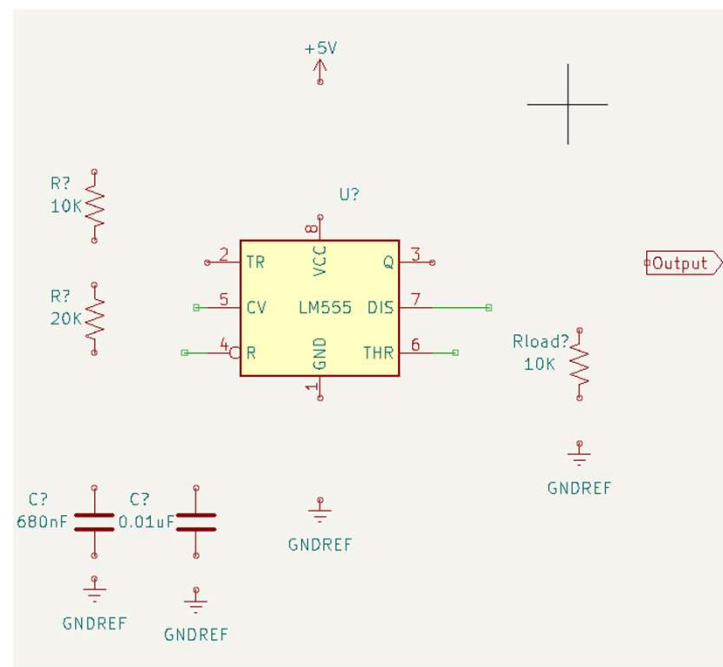
Select with Browser Place repeated copies Place all units

OK Cancel

Drawing A 555 Timer Astable Multivibrator Electronic Circuit Schematic Diagram Activity ...



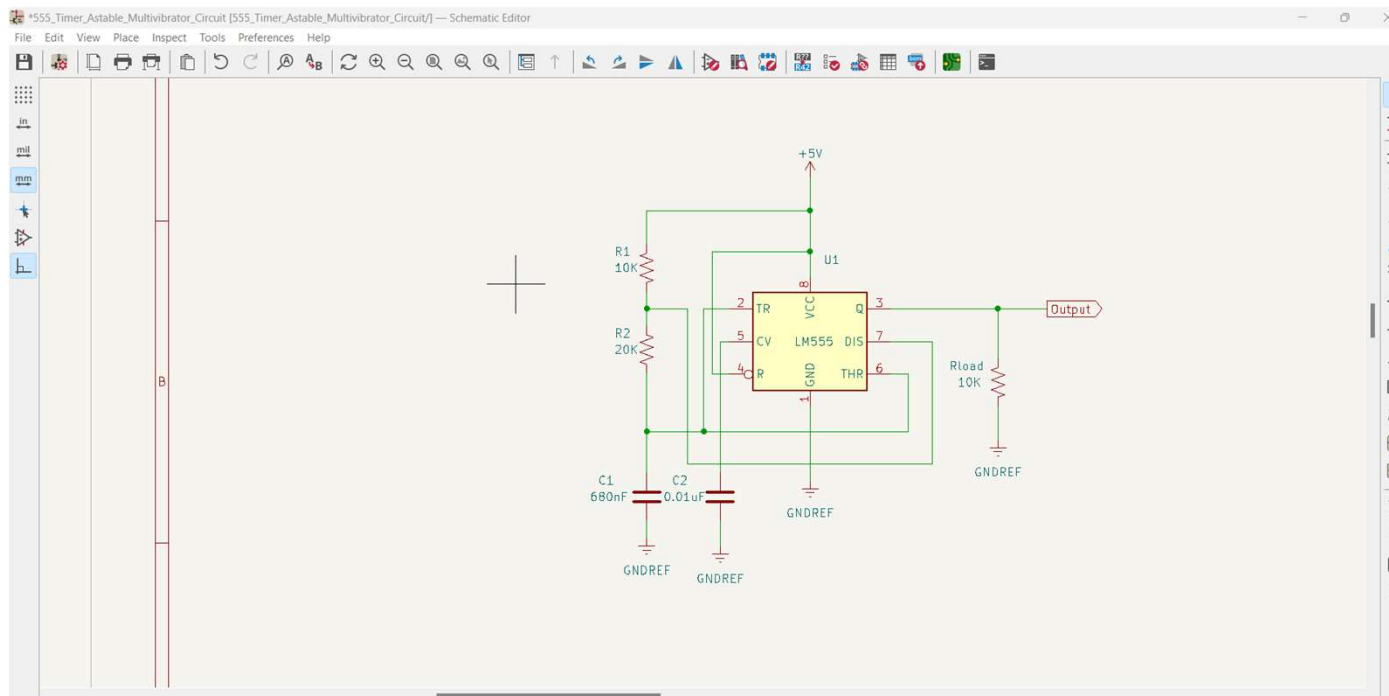
Orientation and location of the 555 Timer Astable Multivibrator Electronic components on to Schematic Editor.



Drawing A 555 Timer Astable Multivibrator Electronic Circuit Schematic Diagram Activity ...



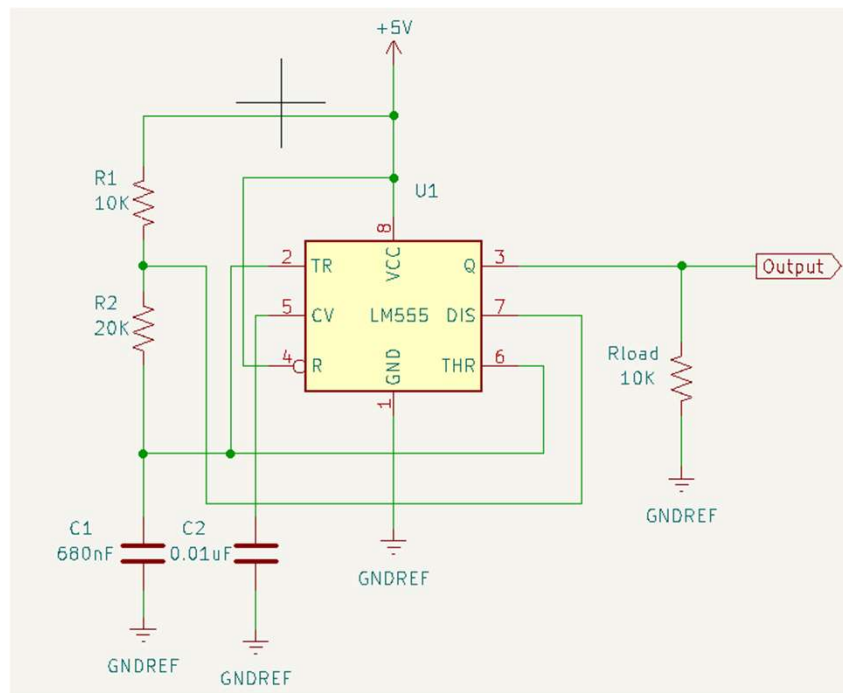
The completed 555 Timer Astable Multivibrator Electronic Circuit Schematic Diagram



Wiring the
circuit
components
using the wire
tool

Drawing A 555 Timer Astable Multivibrator Electronic Circuit Schematic Diagram Activity ...

The completed 555 Timer Astable Multivibrator Electronic Circuit Schematic Diagram



Question 5

What symbol is used to obtain parts to place on the KiCad Schematic editor?

- a) resistor**
- b) line**
- c) gnd**
- d) operational amplifier**



Thank you for attending

Please consider the resources below:

Kicad. (n.d.). *Getting started with kicad 6.0.*

https://docs.kicad.org/6.0/en/getting_started_in_kicad/getting_started_in_kicad.html



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