Experiment 3: The Unijunction Transistor Oscillator Circuit Part 1

Intended Learning Outcomes

1. Be familiarized with the different parameters of the unijunction transistor.
2. Be familiarized with the operation of a UJT-based relaxation oscillator.
3. Be able to experimentally measure the different parameters of the unijunction transistor.

Discussion

The unijunction transistor (UJT) is three-terminal breakover device; the three terminals being labeled as emitter, base 1, and base 2. It is considered as a breakover device since it needs to exceed a certain voltage level for it to conduct heavily. The schematic symbol and its basic construction are shown on Fig. 3.1.

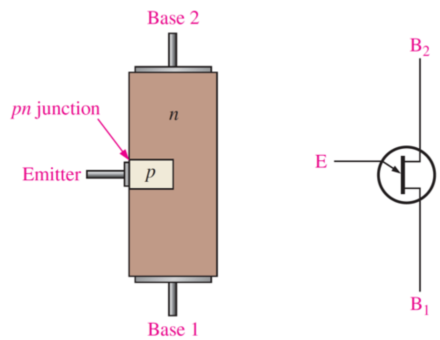


Fig. 3.1 UJT's basic construction and schematic symbol

When the voltage across the emitter and base 1 is less than the peak voltage, no current can flow from the emitter to the base. The UJT is considered OFF in this condition. Once the emitter to base 1 voltage exceeds the peak voltage even by a small amount, the emitter and base 1 circuit becomes almost short circuit and current can surge from one terminal to another. The UJT is then considered ON. Generally, in all UJT circuits, the burst of current from emitter and base 1 is short-lived, and the UJT quickly reverts back to the OFF condition.

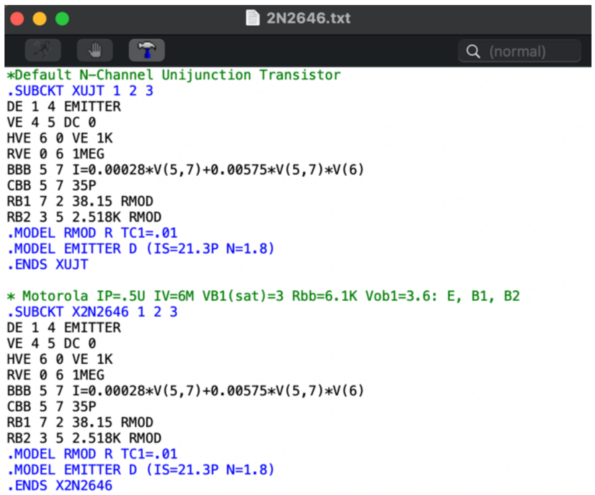
Materials

LTSpice Simulator

Pre-Experiment Set-up: Autogenerating a symbol in LTSpice

Presently, there is no existing symbol for a unijunction transistor in LTSpice. A representative symbol for the UJT should be generated first.

1. Download the UJT's device model attached and save it as 2N2646.txt in the LTSpice folder directory.
2. Open the text file in LTSpice. (Open LTSpice first then use the keyboard shortcut CTRL+O or ⌘+O). Once done, a window will open as shown on Fig. 3.2.




```
*Default N-Channel Unijunction Transistor
.SUBCKT XUJT 1 2 3
DE 1 4 EMITTER
VE 4 5 DC 0
HVE 6 0 VE 1K
RVE 0 6 1MEG
BBB 5 7 I=0.00028*V(5,7)+0.00575*V(5,7)*V(6)
CBB 5 7 35P
RB1 7 2 38.15 RMOD
RB2 3 5 2.518K RMOD
.MODEL RMOD R TC1=.01
.MODEL EMITTER D (IS=21.3P N=1.8)
.ENDS XUJT

* Motorola IP=.5U IV=6M VB1(sat)=3 Rbb=6.1K Vob1=3.6: E, B1, B2
.SUBCKT X2N2646 1 2 3
DE 1 4 EMITTER
VE 4 5 DC 0
HVE 6 0 VE 1K
RVE 0 6 1MEG
BBB 5 7 I=0.00028*V(5,7)+0.00575*V(5,7)*V(6)
CBB 5 7 35P
RB1 7 2 38.15 RMOD
RB2 3 5 2.518K RMOD
.MODEL RMOD R TC1=.01
.MODEL EMITTER D (IS=21.3P N=1.8)
.ENDS X2N2646
```

Fig. 3.2 The circuit model netlist of 2N2646

3. Highlight and right click the line ".SUBCKT X2N2646 1 2 3" then choose "Create Symbol."

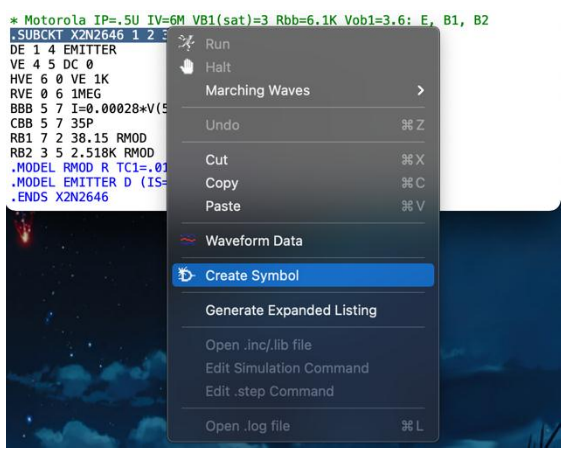


Fig. 3.3 Creating the symbol for 2N2646

4. Once done, a symbol will be created in the symbol editor of LTSpice with pins labeled as 1, 2, and 3. This symbol will represent the UJT in LTSpice.

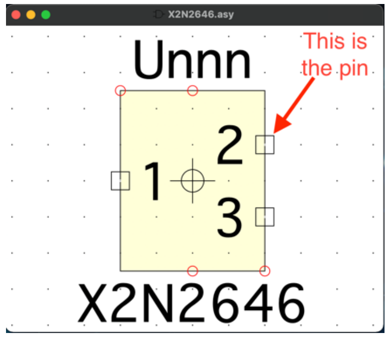


Fig. 3.4 The generated symbol in LTSpice's symbol editor

5. The pin's location can be changed by moving the pin to your desired location using the keyboard shortcut F7 (fn+F7 for MacOS). For easier wiring later, swap pins 2 and 3's location as shown on Fig. 3.5.

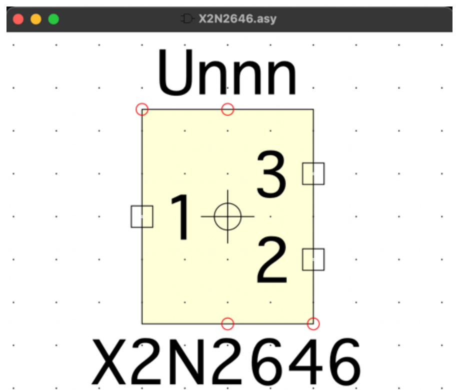


Fig. 3.5 Pins 2 and 3 were swapped

6. Right click the pin's label to edit each pin's label. Based on 2N2646's model netlist, pin 1 is the emitter terminal, pin 2 is the base 1 terminal, and pin 3 is the base 2 terminal.

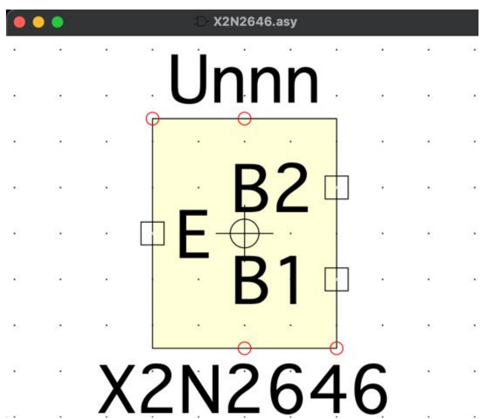


Fig. 3.6 All pins were re-labeled

7. After editing, save the symbol using CTRL+S (⌘+S) and close the symbol editor.
8. Make a new schematic and search for the new component `X2N2646`. The UJT 2N2646 is now ready for use!

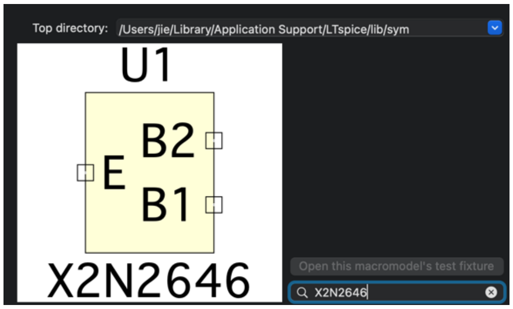


Fig. 3.7 The generated symbol in the component library

Experiment Proper

Part A.

1. Construct the circuit as shown on Fig. 3.8.

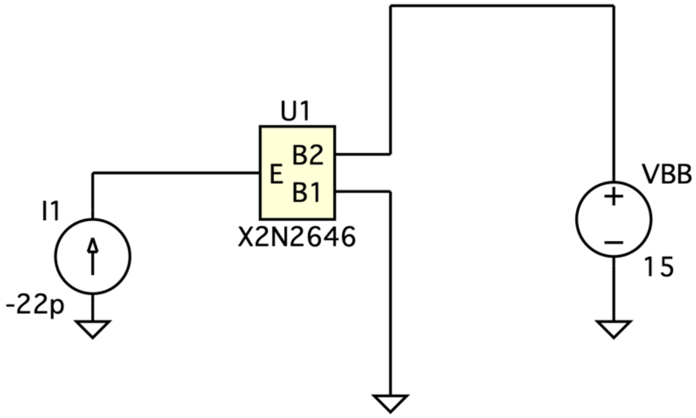


Fig. 3.8 Experimental circuit for Part A

2. Sweep I1, by running a DC sweep simulation (using .dc directive), from -22pA to 10µA with a step size of 1pA.
3. Plot the emitter voltage. This will show the IV characteristic curve of a UJT at $V_{BB} = 15V$.
4. Measure the peak voltage, V_P, using the cursor. (Maximum voltage in the plot)
5. Compute the intrinsic stand-off ratio using the formula:

$$\eta = \frac{V_P - 0.6}{V_{BB}}$$

6. Record the values of V_P and η in Table 3.1.
7. Reduce VBB to 10V and repeat steps 2 to 6.
8. Guide question: **Do V_P and η have dependency on other circuit parameters (such as voltage or current)? Explain your answer.**

Part B.

1. Construct the circuit shown in Fig. 3.9.

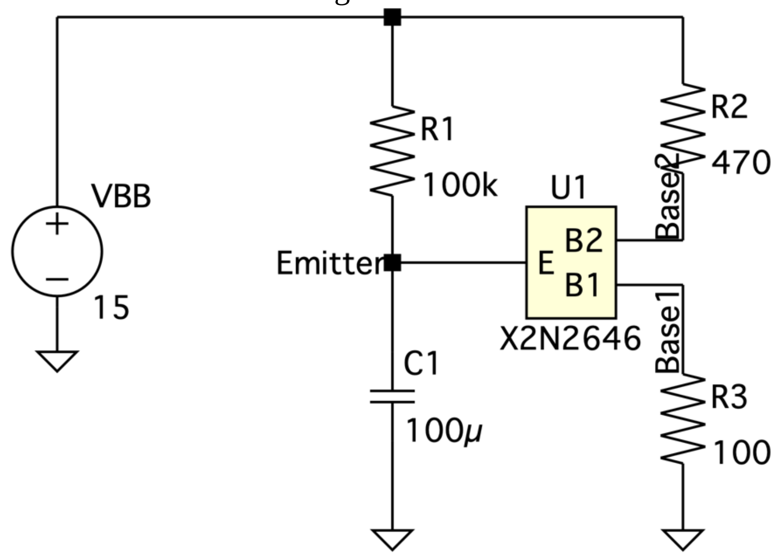


Fig. 3.9 UJT Relaxation Oscillator

2. Run a 20-second transient simulation (using .tran directive). To initialize the capacitor's voltage to zero, include the directive

.IC V(Emitter)=0

3. **Using different plot panes**, plot V(Emitter), V(Base2), and V(Base1).
4. On the trace of V(Emitter), measure the peak voltage, V_P, by placing the cursor to the maximum value of V(Emitter).
5. Compute the intrinsic stand-off ratio using the approximate formula:

$$\eta = \frac{V_p - 0.6}{V_{BB}}$$

6. Record the values of V_P, and η in Table 3.2.
7. Measure the delay time using the cursor. The delay time is the time required to charge the capacitor from 0 to V_P.
8. Calculate the delay time using:

$$t_{delay} = R_1 C_1 \, ln\left(\frac{1}{1 - \eta_{computed}}\right)$$

9. Record the measured and calculated delay time in Table 3-2.
10. Reduce VBB to 10V and repeat steps 2 to 9.
11. Guide Question: **Are there any big difference between the measured and calculated delay time? What could be the cause of this deviation (if there's any)?**

· End of Experiment 3 ·

Group Report Format:

Group No.: ____________________
Group Members: ________________
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Part A:
Plot of Part A Simulations (Step 3):

When $V_{BB} = 15V$:

<Insert Plot Here>

When $V_{BB} = 10V$:

<Insert Plot Here>

Table 3.1

	$V_{P(measured)}$	$\eta_{calculated}$
$V_{BB} = 15V$		
$V_{BB} = 10V$		

Answer to the Guide Question:

<Insert Answer Here>

Part B:
Plot of Part B Simulations (Step 3):

When $V_{BB} = 15V$:

<Insert Plot Here>

When $V_{BB} = 10V$:

<Insert Plot Here>

Table 3.2

	$V_{P(measured)}$	$\eta_{calculated}$	$t_{delay,meas}$	$t_{delay,calc}$
$V_{BB} = 15V$				
$V_{BB} = 10V$				

Answer to the Guide Question:

<Insert Answer Here>

Conclusion:

<Inset Conclusion Here>