

# Oscillation Coupling For a Firefly

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## **Abstract**

In this lab you will study the 555-timer and familiarize yourself with the astable operation mode. Further you will design and build a firefly that operates at a chosen duty cycle and frequency. Lastly build eight more fireflies to study the oscillation coupling between the fireflies.

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# 1 Introduction

In this lab you will learn about the 555 timer and design a relaxation oscillator using the 555 timer that will operate in the astable operation mode. The circuit that will be designed and further built mimics a firefly that lives in South-East Asia and the goal is to build a group (4 or more) of these circuits. Also you will be required to use Pspice and Matlab to simulate the synchronization behaviors of electronic fireflies. In doing so you will be able to study relaxation oscillator circuits, how the groups synchronize, and learn about the control mechanism of these fireflies.

## 2 About The Fireflies

Fireflies are beetles in the family Lampyridae and occur as more than 2000 species worldwide. According to Darwin each sect of firefly evolved differently therefore they exhibit their own characteristics. The firefly that we wish to mimic is the *Pteroptyx Cribellata*, which can be found in India to the Philippines and New Guinea. This specific firefly is unique because mass groups of these fireflies gather together and flash in unison.

A good description of this act is described by[1] as follows: “Imagine a tree thirty-five to forty feet high thickly covered with small ovate leaves, apparently with a firefly on every leaf and all the fireflies flashing in perfect unison at the rate of about three times in two seconds, the tree being complete darkness between the flashes. Imagine a dozen such trees standing close together along the river’s edge with synchronously flashing fireflies on every leaf. Imagine a tenth of a mile of river front with an unbroken line [mangrove] trees with fireflies on every leaf flashing in synchronism, the insects on the trees at the ends of the line acting in perfect unison with those in between. Then, if one’s imagination is sufficiently vivid, he may form some conception of this amazing spectacle.”

The author[1] found that each flash is triggered by nerve impulses in the brain that travel down the ventral nerve cord to the firefly’s lantern. To synchronize these fireflies must have a sensing mechanism to know when neighbors are flashing. Imagine a group of fireflies; in one firefly it is close to the normal time of blinking but a neighbor flashes and this stimuli causes the insect to flash sooner than otherwise would have occurred. This is precisely what our firefly circuits are achieving.

## 3 555-Timer Overview

To complete this lab successfully it will be helpful to get a general understanding of the 555 timer. In Figure 1, a block diagram of the 555 timer is shown. This does not represent the internal parts of the 555 timer but it does describe the 555 practically. That is, this is a simplification so the user can understand the internal operations of the timer circuit.

This diagram shows the 555-timer as a free running oscillator (astable mode). The astable mode can be viewed as: charge the capacitor, discharge the capacitor and repeated indefinitely. This repeated charging/discharging of C1 is accomplished by switching the capacitor to either Vcc or ground (see Figure 2).

The switching mechanism is the transistor (Q1) in Figure 1. By choosing R1-R3 to be  $5\text{ k}\Omega$  we can divide the voltage of  $V_{cc}$  by  $\frac{1}{3}$ . The idea is to charge the capacitor until it reaches  $\frac{2}{3}V_{cc}$ , then close the switch causing  $C_1$  to discharge until it reaches  $\frac{1}{3}V_{cc}$ . This process is repeated indefinitely and is illustrated in Table 1.

When the SR Flip-Flop is set (S=1) the capacitor ( $C_1$ ) will charge from  $\frac{1}{3}$  to  $\frac{2}{3}V_{cc}$ . At the time when  $C_1$  reaches  $\frac{2}{3}V_{cc}$ , the Flip-Flop will reset (R=1) causing the capacitor to discharge until it reaches  $\frac{1}{3}V_{cc}$  and so on.

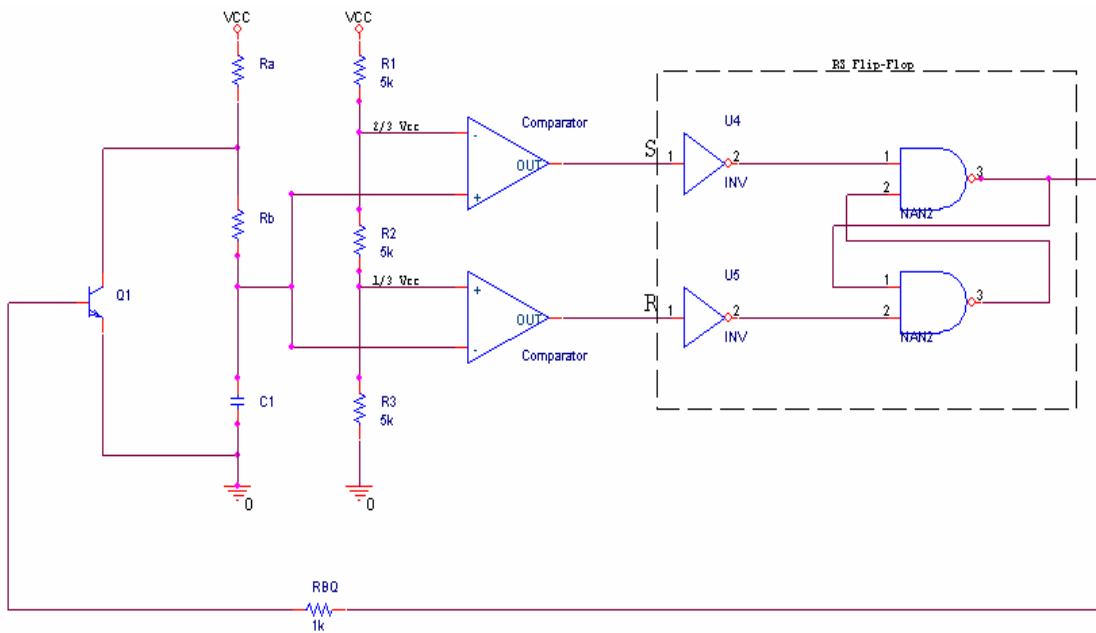


Figure 1: Diagram of 555 timer.

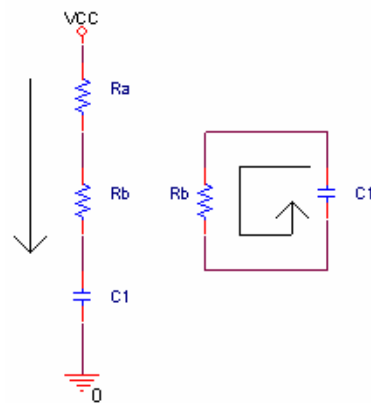


Figure 2: Charge and discharge of  $C_1$ .

Table 1: Switching the capacitor.

Mode	Switch	Effect	How...	Time Required
1	OFF	Charge $C_1$ from $\frac{1}{3}$ to $\frac{2}{3}V_{cc}$	Ra + Rb to Vcc	$\ln(2)*(Ra+Rb)*C_1$
2	ON	Discharge $C_1$ from $\frac{2}{3}$ to $\frac{1}{3}V_{cc}$	Rb to ground	$\ln(2)*Rb*C_1$

## 4 List of Components

In this section, the listed components are recommended for building the firefly. Each components are described according to their specifications.

### 4.1 Necessary Equipment (1 firefly)

- 9 Volt battery holder
- 9 Volt battery
- 50 K $\Omega$  potentiometer
- 10  $\mu$ F capacitor
- 22 nF capacitor
- 100  $\mu$ F capacitor
- 8-pin chip socket
- 555-timer
- Circuit board
- Green LED
- 4 IR LED's
- IC phototransistor
- 8-pin or 6-pin DIP switch
- Solder Gun
- Solder
- Wire

## 4.2 Part Description

### (1)LM555

The 555 timer is a digital logic circuit that is used to produce a periodic square wave signal. The resistors and capacitors in the 555 timer have a direct effect on the duty cycle and the frequency which will be discussed a little later. Figure 3 shows the internal circuit and pin numbers of a 555 timer.

**Pin 1 (Ground)** This is the pin that connects to the ground of the device. When it is operated from the positive power supply, pin one is normally connected to circuit common.

**Pin 2 (Trigger)** Pin 2 is the input of the 555 timer which causes the output to go high and begin the timing cycle. Triggering occurs when the voltage going into the trigger is  $\frac{2}{3}$  above the voltage supply to  $\frac{1}{3}$  below the voltage supply. Trigger input current is about 0.5 microamps. The action is level sensitive and the trigger voltage may move very slowly. To avoid retriggering, the trigger voltage must return to a voltage above  $\frac{1}{3}$  of the power supply before the end of the timing cycle.

**Pin 3 (Output)** This is the output pin of the 555 timer. When the timing cycle begins at high level this output is 1.7 volts less than the supply voltage; and then it returns to a low level near 0 at the end of the cycle. The maximum current from the output at both low and high levels is approximately 200 mA.

**Pin 4 (Reset)** Pin 4 is the pin which resets the timer and returns the output to a low state. When this pin is not in use, it is normally connected to the positive supply.

**Pin 5 (Control)** When the external voltage is used in this pin, it will allow changing the triggering and threshold voltage of the timer. When the timer is operating in the astable or oscillating mode, this input could be used to alter or to modulate the frequency output. If this pin is not in use it would be better to connect a capacitor to avoid possible false or erratic triggering from noise effects.

**Pin 6 (Threshold)** The threshold has the similar function as the trigger pin to the timer. Pin 6 is used to reset the latch and cause the output to go low. The reset would occur when the voltage going into this pin is from a voltage below  $\frac{1}{3}$  of the input power supply to a voltage above  $\frac{2}{3}$  of the input power supply.

**Pin 7 (Discharge)** This pin is an open collector output which is in phase with the main output on pin 3 and has similar current sinking capability. Pin 7 is usually connected to a resistor in series with a capacitor in the astable connection.

**Pin 8 (V +)** This is the positive supply voltage of the 555 timer. The operating range is from +4.5 volts (minimum) to +16 volts (maximum).

### (2)LED IR EMITTING ALGAAS 940NM

This LED has an operating temperature of -40 to 100 degree Celsius. The current ratings for this LED are 100mA for the forward current and 10uA for the reverse current.

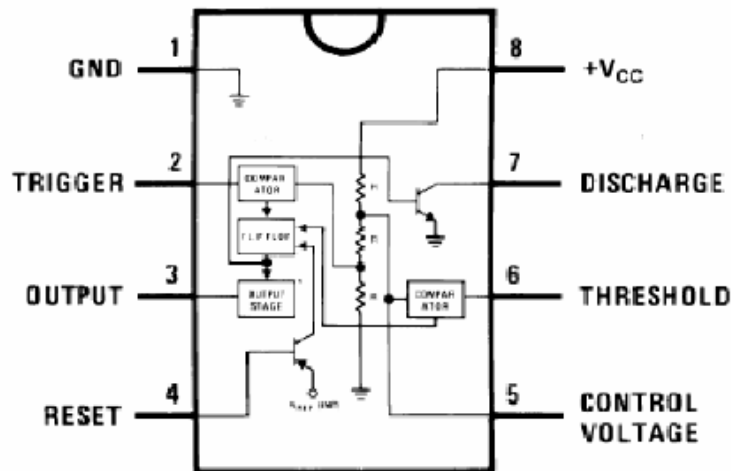


Figure 3: 555 timer.

The forward voltage rating is 1.6V. The emission angle of light is 40 degree in the infra-red wavelength of 940nm.

### (3) Green LED

This is a green LED and the model type is T 1-3/4. Its lens is round, style of 5 mm. Its lead style is radial, Millicandela rating of 120, voltage rating of 4V.

### (4) IC Phototransistor

This phototransistor senses wavelengths of light around 880nm and has a half angular response curve of 20 degree. The operating temperature is from -40 to 100 degree Celsius and emitter collector voltage of 5V.

### (5) Pot 50KΩ Resistors

This resistor is a ceramic resistor. It has the resistance of 50kΩ, 0.3 W of power, single turns, top adjustment, and with the tolerance of ±25%.

### (6) Capacitors

**10μf Capacitor:** This capacitor is a tantalum capacitor. It has the capacitance of 10μF, voltage-rated of 10V, maximum temperature of 125 degree Celsius, and with the tolerance of ±10%.

**20nF Capacitor:** This capacitor is a ceramic capacitor. It has the capacitance of 20nF, voltage-rated of 50V, general purpose of featuring and with the tolerance of ±5%.

**100μF Capacitor:** This capacitor is an electrolytic capacitor. It has the capacitance of 100μF, voltage-rated 10V, maximum temperature of 85 degree Celsius, featuring of aluminum, and with the tolerance of ±20%.

### (7) DIP Switch

This is an 8 pin switch package that has a voltage rating of 24 volts and a current rating of 25mA (see APPENDIX H). DIP switches are always toggle switches, which means they have two possible positions (on or off).

### (8) Power Source

For power we are using a common 9V alkaline battery. The operating temperature of the battery is -20 to +54 degree Celsius. It also features 570 mAh rated capacity, 4.8V rated cut-off voltage and 620Ω rated load.

### (9) Chip socket

This socket is a DIP socket. It has gold contact finishing, solder contact termination, 8 pins with length of 0.095” each, and the width of this socket is 0.3”.

## 5 Circuit Design

The firefly circuit is to be constructed following the circuit diagram in Figure 4 which is originally from[1] except some components.  $R_a$ ,  $R_b$ , and  $C_1$  are to be chosen so the frequency of the flashing green LED is about 1 Hz and the duty cycle be around 95%. These values can be designed using Equations 1 and 2. Lets chose  $R_a = 150k\Omega$  and  $R_b = 1k\Omega$ . This would require a capacitor ( $C_1$ ) equal to approximately  $10\mu F$ . You are encouraged to test this for yourself.

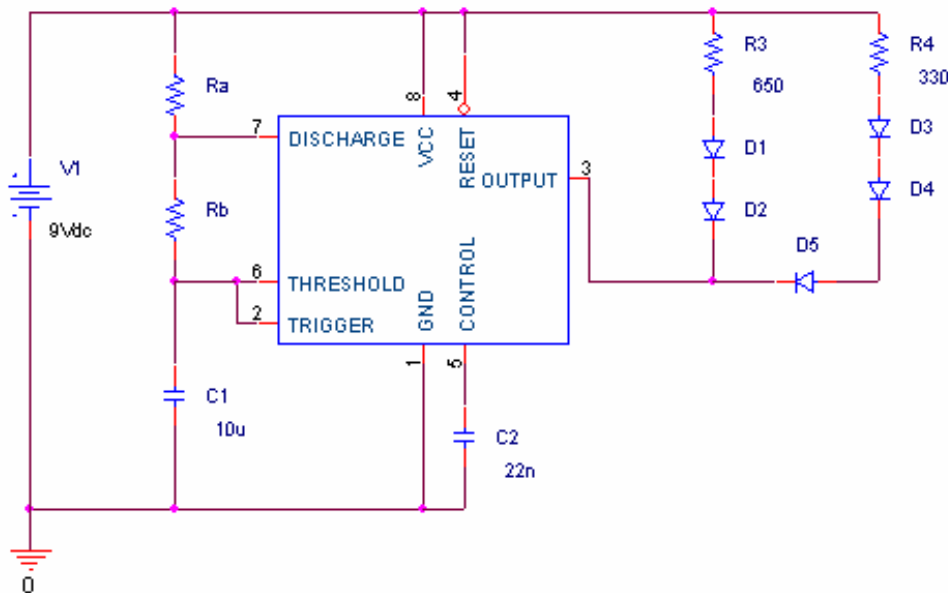


Figure 4: Firefly circuit connection.

It is encouraged that you build this circuit on a breadboard first to test the circuit



and become more familiar with how it works. An oscilloscope should be used to view the capacitor ( $C_1$ ) voltage waveform. Look to see what the difference between the actual duty cycle and frequency and the designed values.

Now we are going to add a control mechanism to the firefly so they will synchronize when put in close proximity (1" - 6"). The actuator that we are using is a phototransistor that will sense infra-red (IR) light given off by the IR LED's of the other fireflies. The control of the firefly is the 555-timer circuit itself. The previous circuit that was constructed can be used but the phototransistors (4 of them) need to be added in parallel. The collectors will be connected to power (or is you chose to, connect to the DIP switch). The emitters will be connected to pin 6 of the 555-timer (see Figure 5).

$$D(duty\ cycle) = \frac{R_a + R_b}{R_a + 2R_b} \quad (1)$$

$$T(Period) = (R_a + 2R_b)C \ln(2) \quad (2)$$

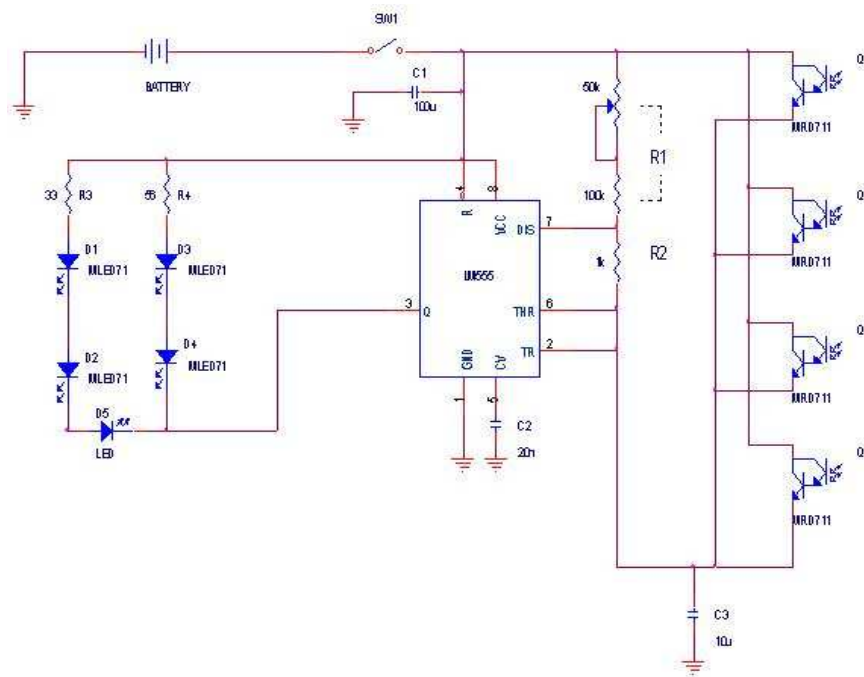


Figure 5: Completed firefly circuit.

## 6 Experiments

The easiest experiment to conduct is determining the time they take to synchronize as a function of the coupling between them. The stronger the signal that the phototransistors receive, the faster the devices should reach synchronization. The amount of energy the phototransistors receive is inversely proportional to the square of the distance between them. This means that the farther you move the fireflies away from each other, the less light they will receive causing more time delay for synchronization. Does the average time for synchronization have the same curve as the transmitted energy curve?

If you build nine fireflies it is interesting to look at different topologies and determine how they synchronize. One arrangement is three rows by three columns where the center firefly will receive flashes from four fireflies, the corner will receive flashes from two fireflies and the others in-between will receive flashes from three neighboring fireflies (see Figure 6).

Another good arrangement would be in a circular pattern using eight fireflies. This topology would allow fireflies to only sense the ones directly next to them. The coupling could occur randomly or it might propagate in a clockwise or counterclockwise pattern. Or arrange them in a straight line with a barrier somewhere dividing the group into two sub-groups. You should see synchronization in the two sub-groups be different than each other.

You should also look at how the group will respond to disturbances. A disturbance that should be observed is the phenomena of an “oddball”. By oddball, it is meant that one firefly will blink at either a faster or slower frequency than the group. This can easily be accomplished if you use the potentiometer as described above. Adjustments to Ra which includes the 50kΩ potentiometer and the 100kΩ resistor will adjust the frequency and this will create a disturbance when brought into the system. This could result in delays of synchronization or just eliminate synchronization all together depending on where it is placed.

In Figure 7 and 8, the numbers labeled on each receivers correspond to the numbers on the DIP switch. The first channel of the DIP switch is the switch for power.

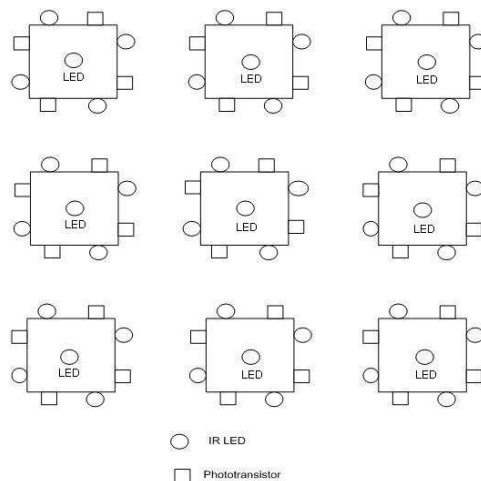


Figure 6: Three by three Topology.

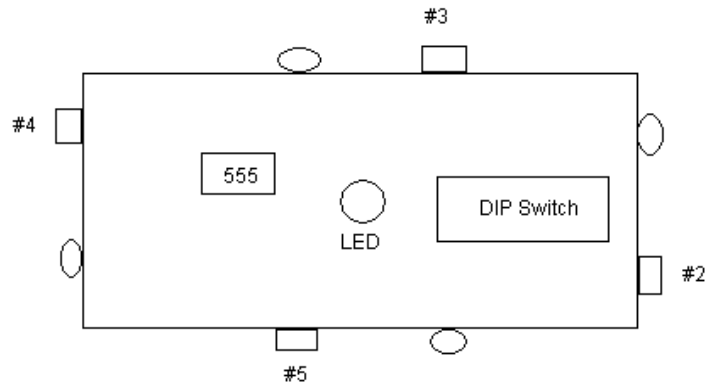


Figure 7: Receiver switch numbers and locations.

Switch	Device
1	Power
2	#2 receiver
3	#3 receiver
4	#3 receiver
5	#4 receiver

Figure 8: DIP switch.

## 7 Simulation

Both Pspice and Matlab are powerful simulation tools in the circuit design and controls applications. In this section, you will have an idea of how to simulate a firefly circuit in Pspice and use Matlab to translate those output datas from Pspice.

### 7.1 Pspice

Basically PSpice is a PC version of SPICE (MicroSim Corp.) which is a powerful analog circuit simulator that is used to verify circuit designs and simulations in integrated circuits. Pspice programs are available in DL517 and CL260 computer labs.

#### (1) Create a New Project

Open the **Capture CIS** under the Cadence directory (see Figures 9 and 10), and then open a new project. Click on **OK** as seen on Figure 11.

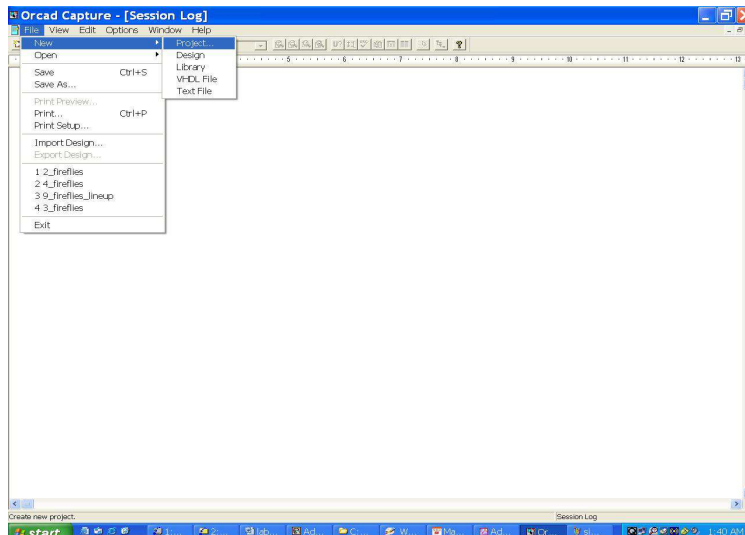


Figure 9: Open a new project.

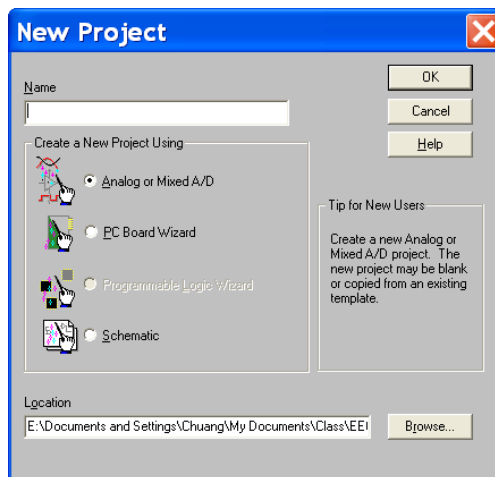


Figure 10: Name a new project.

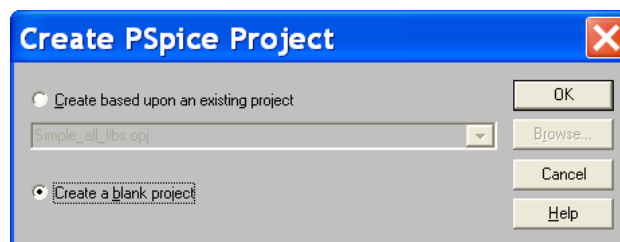


Figure 11: Create a blank project.

## (2) Pspice A/D Simulation

Once the circuit is completed, click on **New Simulation** (see Figure 12) and type in

a name of this simulation profile. After clicking on **OK**, we need to edit the **Simulation Setting** (see Figure 13). Choose the **Time Domain (Transient)** under the **Analysis** option. Then choose a start time and stop time for your simulation.

**Note:**

In order to avoid an error such as

```
ERROR -- Time step = 6.241E-12 is too small in Transient
Analysis at Time = 106.2E-12. Minimum allowable step size =
100.0E-12. The device which is changing too fast is
X$X_X2.qb_DtoA1.c1.
```

in a longer period of simulation, you may need to include a text file contains the following line:

```
.OPTIONSRELTOL = SCHEDULE(0s, .1, 100s, .05)
```

(see Figure 14)

, this line indicates that RELTOL should have a value of 0.1 from time 0 up to time 100s, and a value of 0.05 from time 100s and beyond (that is: RELTOL=0.1 for  $t$ , where  $0 \leq t < 100s$ , and RELTOL=.05 for  $t$ , where  $t \geq 100s$ ).

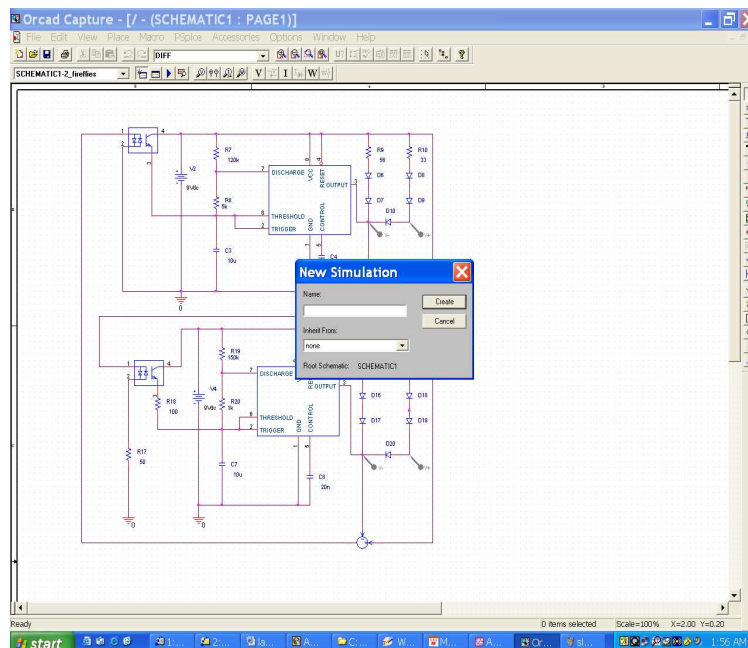


Figure 12: New simulation.

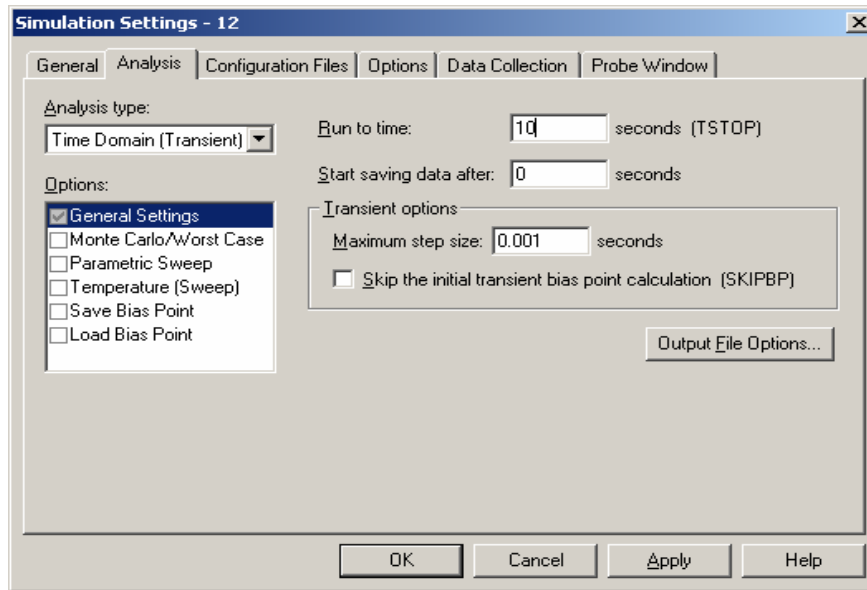


Figure 13: Simulation setting.

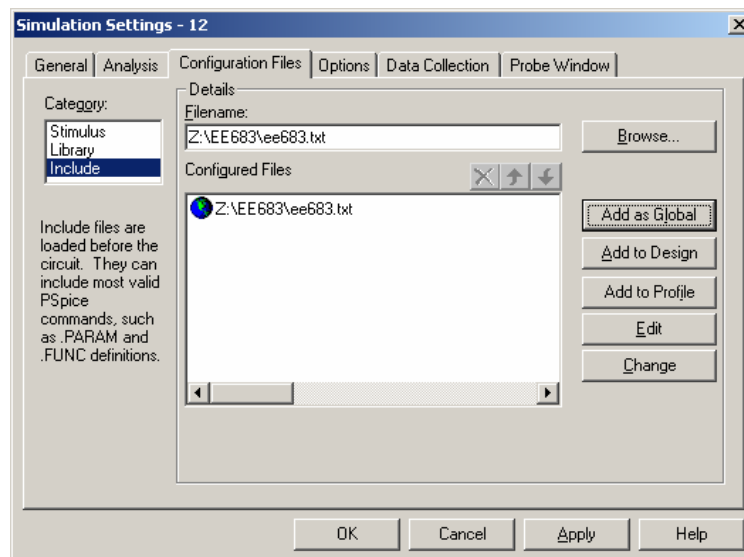


Figure 14: Include file

### (3) Export The Simulation Result

Click on **File**—>**Export**—>**Text** in Pspice A/D window (see Figure 15). Then choose the node bias that you want to export (see Figure 16).

The text file should be similar with Figure 17. However, Matlab could not recognize the format such as “9.011025428772e-00”. Therefore, we need to use Microsoft Excel to rearrange the data in the output text file (see Figure 18)

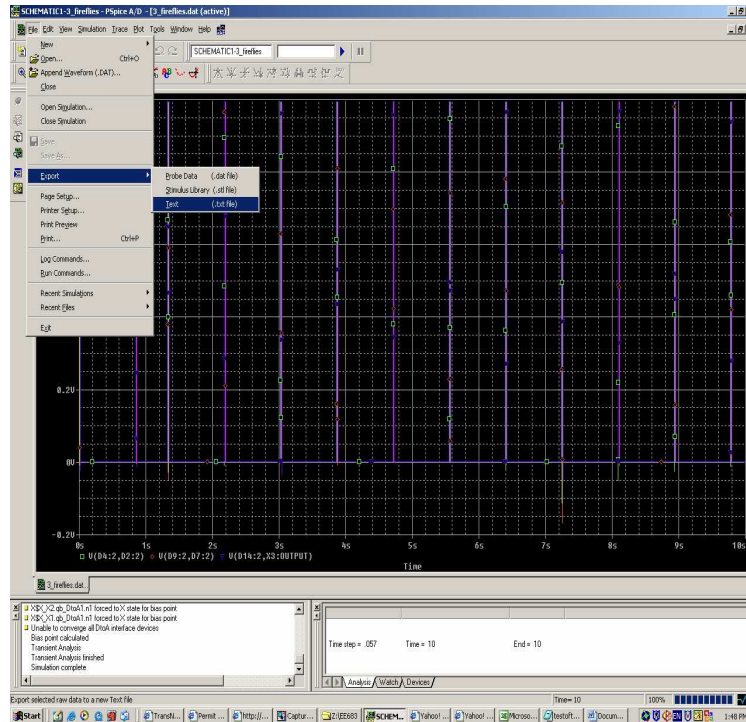


Figure 15: Export simulation result.

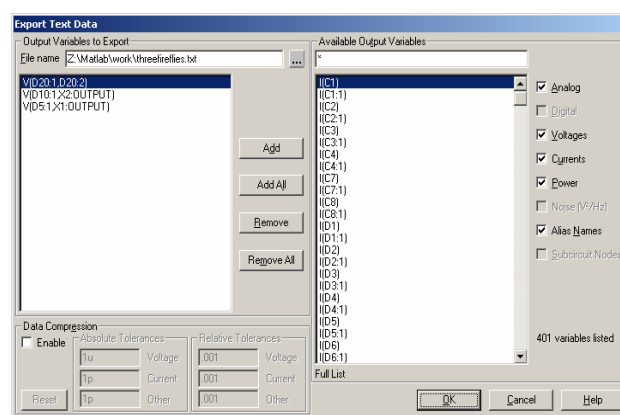


Figure 16: Choose the nodes for exporting.

```

test.txt - Notepad
File Edit Format Help
Time          V(D20:1,D20:2)          V(D10:1,X2:OUTPUT)      V(D5
0.000000000000e+000  9.011025428772e-001    9.011354446411e-001    9.01102
1.000000000000e-005  9.942536354065e-001    9.942531585693e-001    3.02886
1.000010000000e-005  9.969592094421e-001    9.969520568848e-001    2.89726
1.000030000152e-005  9.969620704651e-001    9.969539642334e-001    2.60543
1.000070000457e-005  9.969303992126e-001    9.969229698181e-001    2.08663
1.000150001066e-005  9.968795776367e-001    9.968724250793e-001    1.43241
1.000310002284e-005  9.967846870422e-001    9.96775344849e-001    9.07897
1.000630004721e-005  9.966163635254e-001    9.966096878052e-001    7.48634
1.001270009594e-005  9.964442253113e-001    9.964375495911e-001    9.72747
1.002550019341e-005  9.961071014404e-001    9.961018562317e-001    8.47816
1.004640950280e-005  9.956870079041e-001    9.956822395325e-001    8.88824
1.006764663773e-005  9.957122802734e-001    9.957084655762e-001    9.00268
1.011012090760e-005  9.954562187195e-001    9.954533576965e-001    9.00268
1.019506944733e-005  9.942235946655e-001    9.942231178284e-001    8.99314
1.036496652680e-005  9.936528205872e-001    9.936532974243e-001    8.99314
1.070476068573e-005  9.949469566345e-001    9.949445724487e-001    8.99314
1.138434900360e-005  9.943294325146e-001    9.943280220032e-001    8.99314
1.274532563939e-005  9.942407608032e-001    9.942407608032e-001    8.99314
1.546187891083e-005  9.941711423781e-001    9.941711423781e-001    8.99314
2.089858545380e-005  9.941816329956e-001    9.941811561584e-001    8.99314
3.177199853974e-005  9.941868782043e-001    9.941868782043e-001    8.99314
5.351882471161e-005  9.942131042480e-001    9.942126274109e-001    8.99314
9.701247705536e-005  9.943609237671e-001    9.943580627441e-001    8.99314
1.859997817429e-004  9.941897392273e-001    9.941897392273e-001    8.99314
3.579743911179e-004  9.942030906677e-001    9.942026138506e-001    8.99314
7.059236098679e-004  9.942364692688e-001    9.942340850830e-001    8.99314
1.401822047368e-003  9.943456649780e-001    9.943389892578e-001    8.98361
2.401822047368e-003  9.941868782043e-001    9.941859245300e-001    8.99314

```

Figure 17: Text file

```

threefireflies.txt - Notepad
File Edit Format Help
Time          "V(D5:1,DIFF1:INL)"    "V(D9:2,X2:OUTPUT)"    "V(D20:1,D19:2)"
0.000000000000  0.901016235352        0.901016235352        0.901016235352
0.000010000000  0.003023147583        0.994144439697        0.994144439697
0.000010000100  0.002892494202        0.994144439697        0.994144439697
0.000010000300  0.002600689861        0.994145393372        0.994145393372
0.000010000700  0.002084732056        0.994146823883        0.994146823883
0.000010001500  0.001431465149        0.994149208069        0.994149208069
0.000010002475  0.001060485840        0.994152545929        0.994152545929
0.000010003952  0.000932693481        0.994156837463        0.994156837463
0.000010005725  0.000888824463        0.994161605835        0.994161605835
0.000010007783  0.000899314880        0.994168381555        0.994168381555
0.000010011900  0.000902175903        0.994176864624        0.994176864624
0.000010015760  0.000900268555        0.994179248810        0.994179248810
0.000010019600  0.000900268555        0.994184017181        0.994184017181
0.000010024030  0.000899314880        0.994188785553        0.994188785553
0.000010028550  0.000899314880        0.994194507599        0.994194507599
0.000010034342  0.000899314880        0.994188785553        0.994188785553
0.000010042672  0.000899314880        0.994188308716        0.994188308716
0.000010053121  0.000899314880        0.994185924530        0.994185924530
0.000010074018  0.000899314880        0.994182109833        0.994182109833
0.000010114949  0.000899314880        0.994179248810        0.994179248810
0.000010196810  0.000899314880        0.994175434113        0.994175434113
0.000010360532  0.000899314880        0.994180679321        0.994180679321
0.000010687976  0.000899314880        0.994181632996        0.994181632996
0.000011342864  0.000899314880        0.994180679321        0.994180679321
0.000012054496  0.000899314880        0.994180202484        0.994180202484
0.000013077597  0.000899314880        0.994179725647        0.994179725647
0.000014150290  0.000899314880        0.994181156158        0.994181156158
0.000014305226  0.000899314880        0.994181156158        0.994181156158

```

Figure 18: Rearranged text file.

## 7.2 Matlab

### (1) Matlab Command

Use the **fopen** to load text file. When **fopen** couldn't not open the file, it returns -1 to fid(file identifier). Use **fgetl** command to read the text file line to line and use **str2num** command to convert strings to numbers. For example:

```

fid = fopen('threefireflies.txt'); %load the data file
i=1; %initialize variable i
while 1
    curlin=fgetl(fid);

    if curlin(1) ~= 'T' %if the first character is not t
        if ~ischar(curlin) %if it is not a character
            break %stop reading
        end
    end

```



```

T(i,:)=str2num(curlin(1:4));
A(i,:)=str2num(curlin(16:23));
B(i,:)=str2num(curlin(31:38));
C(i,:)=str2num(curlin(46:53));

end

end

fclose(fid)

```

Write a loop and use the `getframe` command in order to generate the movie. You can store the frames to MPEG format by using `mpgwrite.m` command which can be download either from <http://www.mathworks.com/support/solutions/data/8154.shtml>.

## (2)Change The Time Scale

The time scale is needed to be readjusted because the sampling time is not equally distributed in the output file from Pspice. There are two ways to change the time scale; first is to change the **Printing Step** in the **Simulation Setting** in Pspice (see Figure 19). Second way is to adjust the time scale by Matlab (see APPENDIX A).

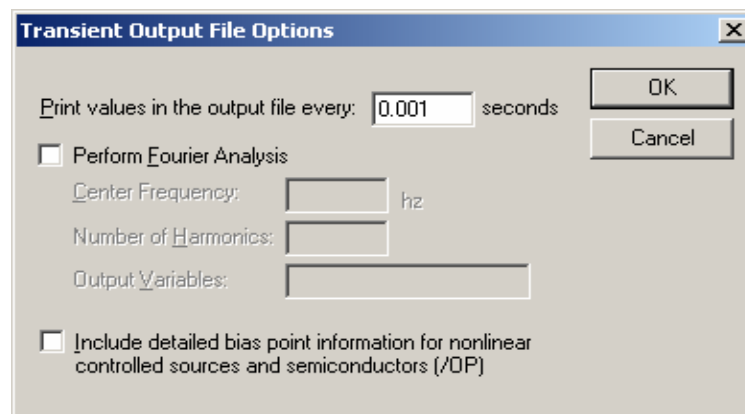


Figure 19: Setup printing steps.

## (3)Flowchart

The code for simulating three fireflies can be found in APPENDIX A. Figure 20 is the flowchart for coding the three fireflies.

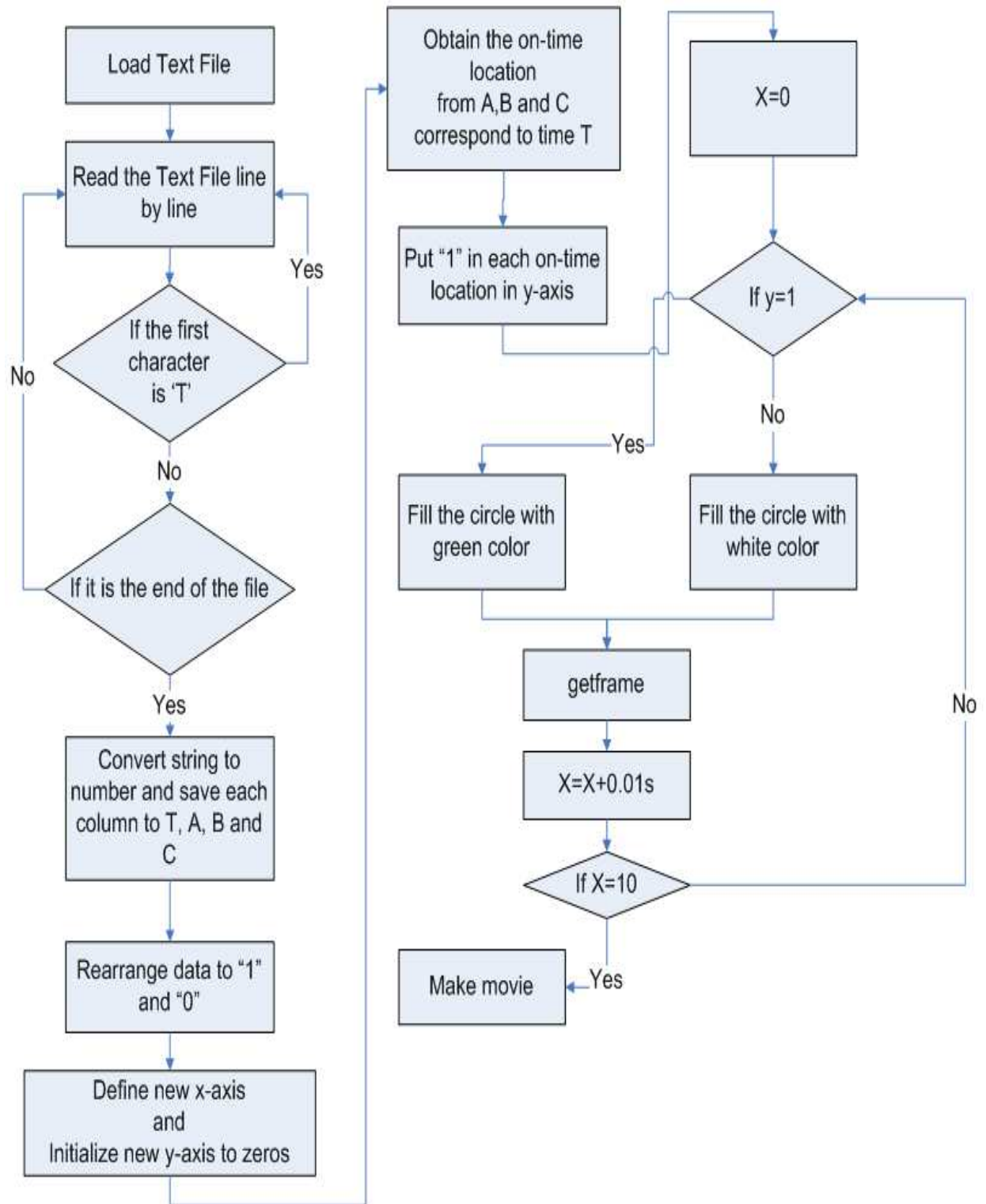


Figure 20: Program flowchart.

## A APPENDIX: Matlab Codes

```
%EE683 Group Project
%Ting-Hsiang Chuang

clc clear all close all

fid = fopen('fourfireflies.txt'); %load the data file

i=1; %initialize variable i

while 1

    curlin=fgetl(fid);

    if curlin(1) ~= 'T' %if the first character is not T

        if ~ischar(curlin) %if it is not a character

            break %stop reading

        end

        T(i,:)=str2num(curlin(1:4)); %store the time in 3 decimal second
        A(i,:)=str2num(curlin(20:27)); %store the first firefly data
        B(i,:)=str2num(curlin(39:46)); %store the second firefly data
        C(i,:)=str2num(curlin(58:65)); %store the third firefly data
        D(i,:)=str2num(curlin(77:84)); %store the third firefly data

        if A(i,*)>=0.65
            A(i,*)=1;
        else
            A(i,*)=0;
        end

        if B(i,*)>=0.65
            B(i,*)=1;
        else
            B(i,*)=0;
        end

        if C(i,*)>=0.65
            C(i,*)=1;
        else
```

```

        C(i,:)=0;
    end

    if D(i,*)>=0.65
        D(i,:)=1;
    else
        D(i,:)=0;
    end

    i=i+1;

end

end

fclose(fid)

ida=find(A(:)==1);           %Find the location of 1
idb=find(B(:)==1);
idc=find(C(:)==1);
idd=find(D(:)==1);

ta=T(ida);                  %At the time where A=1 (on)
tb=T(idb);
tc=T(idc);
td=T(idd);

x=[0:0.01:10]';           %New time axis

ya=zeros(length(0:0.01:10),1); %Initialize each y-axis
yb=zeros(length(0:0.01:10),1);
yc=zeros(length(0:0.01:10),1);
yd=zeros(length(0:0.01:10),1)

for i=1:length(ya)

    for j=1:length(ta)
        if x(i)==ta(j)           %Put 1 in y-axis when the
            ya(i)=1;             %on_time = new time axis
        end
    end

    for j=1:length(tb)

```

```

        if x(i)==tb(j)
            yb(i)=1;
        end
    end

    for j=1:length(tc)
        if x(i)==tc(j)
            yc(i)=1;
        end
    end

    for j=1:length(td)
        if x(i)==td(j)
            yd(i)=1;
        end
    end

end

                                                                    %Make light bulb
n = -180:180;
t = sin(n*pi/180);
v = cos(n*pi/180);

                                                                    %Define the area to be recorded
rect = get(gcf,'Position');
rect(1:2) = [0 0];

m=1;

for xx=1:length(ya)

    tt(m,:)=x(xx,:);
    yya(m,:)=ya(xx,:);
    yyb(m,:)=yb(xx,:);
    yyc(m,:)=yc(xx,:);
    yyd(m,:)=yd(xx,:);

    subplot(221)
    if yya(m)==1
        fill(t,v,'g');
    else
        fill(t,v,'w');
    end
end

```

```

axis off

subplot(222)
if yyb(m)==1
    fill(t,v,'g');
else
    fill(t,v,'w');
end
axis off

subplot(223)
if yyc(m)==1
    fill(t,v,'g');
else
    fill(t,v,'w');
end
axis off

subplot(224)
if yyd(m)==1
    fill(t,v,'g');
else
    fill(t,v,'w');
end
axis off

M(m)=getframe(gcf,rect);

m=m+1;

end

%convert to MPEG format

map=colormap;

mpgwrite(M, map,'movie3')
```

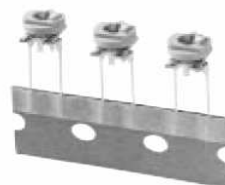
# B APPENDIX: Digikey Part No. AAS54CT-ND

**Panasonic**

Ceramic Substrate Trimmer Potentiometers/EVMA□

6 mm Square Dustproof Ceramic Trimmer Potentiometers (Cermet, Radial Taping)

Type: **EVMAAS/EVMAES**



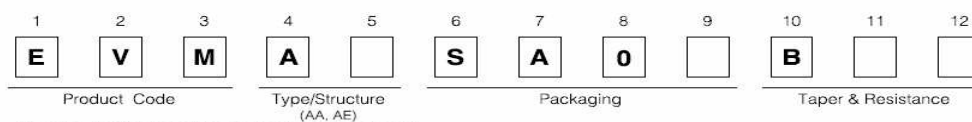
■ **Features**

- High reliability realized by cermet element
- Excellent automatic insertion by the strong lead terminal
- Available for automatic adjustment due to slot & taper shape suitable for screwdriver
- Dustproof type which electrically activated wiper is enclose insulated rotor cap
- Conforming to JIS C 5260-1:1999

■ **Recommended Applications**

- Audio visual equipment, Office Automation equipment, Communication equipment
- Other general electronic equipments

■ **Explanation of Part Numbers**



\* For the details of Part Number, refer to page EV19.

■ **Major Specifications**

	EVMAAS	EVMAES (Low Resistor Value)
Total Resistance Value	100 Ω to 1 MΩ	10 Ω to 500 Ω
Resistance Tolerance	±25 %	
Power Rating	0.3 W	0.5 W
Maximum Operating Voltage	100 V	$\sqrt{P \cdot R}$
Rotation Torque	2 to 30 mN · m	
Stopper Strength	50 mN · m min.	
Temperature Coefficient of Resistance	±200 × 10 <sup>-6</sup> /°C	·10 Ω ≤ R ≤ 20 Ω ..... ±200 × 10 <sup>-6</sup> /°C ·20 Ω < R ≤ 200 Ω ..... ±150 × 10 <sup>-6</sup> /°C ·200 Ω < R ≤ 500 Ω .. ±100 × 10 <sup>-6</sup> /°C

■ **Minimum Quantity/Packing Unit**

Part Number	Radial taping	
	Quantity per Box	Packaging quantity
EVMAAS	1000	10000
EVMAES		

Design and specifications are each subject to change without notice. Ask factory for the current technical specifications before purchase and/or use. Should a safety concern arise regarding this product, please be sure to contact us immediately.

# C APPENDIX: Digikey Part No. 399-1469-ND



## TANTALUM MOLDED / AXIAL — MIL-C-49137/1&5 T322 & T323 (CX01 & CX05) SERIES

The KEMET T322 AND T323 (CX01 & CX05) Series offers a complete line of extended range molded solid tantalum capacitors designed specifically for high speed automatic insertion applications. These capacitors offer an extremely high capacitance-to-volume ratio while still maintaining excellent performance characteristics.

Supplied in six axial lead tubular case sizes, these capacitors are ideally suited for use in printed wiring boards and all applications requiring a high degree of packaging density and can be supplied in bulk packaging or lead-taped on reels.

The T322/T323 Series dimensions and tight lead wire-to-body concentricity permit installation by the same automatic insertion equipment used for diodes and resistors. Available in working voltages of

2, 4, 6, 10, 15, 20, 25, 35, and 50 volts. Operating temperature range -55°C to +85°C at full rated voltage and with 2/3 85°C rated voltage at 125°C.

The gold color epoxy utilized permits laser marking with outstanding permanency and legibility.

T323 Series capacitors are qualified under MIL-C-49137/1 & 5 as Military Style CX01 & CX05.

Typical applications include decoupling, blocking, bypassing and filtering in commercial computers, data processing, communications, and other electronic equipment. The low ESR/impedance at high frequencies offered by this capacitor is especially suitable for decoupling required by high speed computers.

### PERFORMANCE CHARACTERISTICS

- **CAPACITANCE/VOLTAGE RANGE:**  
0.1-330µF, 2-50 Volts.
- **CAPACITANCE TOLERANCE:** Available in standard EIA nominal values with ±20%, ±10% and ±5% tolerance.
- **DISSIPATION FACTOR:** Maximum DF limits are shown in corresponding series part number listings on pages 44-48. See Application Notes Section, page 76 for additional description.
- **DC LEAKAGE CURRENT:** Each corresponding part number table lists maximum leakage current for each capacitor on pages 44 through 48. See Application Notes Section, page 76 for additional description.
- **RATED VOLTAGE; WORKING VOLTAGE; SURGE VOLTAGE; REVERSE VOLTAGE:** See Application Notes Section, page 76 & 77 for description.
- **AC RIPPLE VOLTAGE:** Permissible AC ripple voltage is related to equivalent series resistance (ESR) and power dissipation capability. Maximum power dissipation for each case size is listed in Table below. For additional description see page 79.

Case Size	Power Dissipation (max.) @ 25°C (watts)
A	.060
B	.070
C	.080
D	.090
E	.100
F	.110

Maximum Power Dissipation Capability @ 25°C

- **IMPEDANCE and ESR:** See Application Notes Section, pages 77 & 78 for description. Reference ESR values are shown in adjoining column, this page.
- **ENVIRONMENTAL CONSIDERATIONS:**  
A. Shock Test: MIL-STD-202, Method 213.  
B. Thermal Shock, MIL-STD-202, Method 107.  
C. Moisture Resistance: MIL-STD-202, Method 106.  
D. Solderability: MIL-STD-202, Method 208.

**T322 ESR (OHMS) at 100 kHz @ +25°C**  
(The ESR values provided below are for reference only. No warranty, as stated on page 3 and reincorporated here, is made as to the accuracy of these values for any particular T322 Series product.)

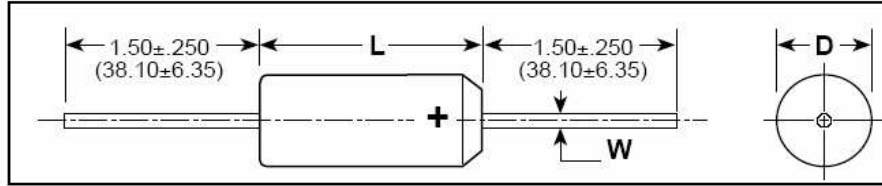
Cap. µF	6 Volt	10 Volt	15 Volt	20 Volt	25 Volt	35 Volt	50 Volt
0.10						26.0	26.0
0.12						26.0	26.0
0.15						21.0	21.0
0.18						21.0	21.0
0.22						17.0	17.0
0.27						17.0	17.0
0.33						15.0	15.0
0.39						15.0	15.0
0.47						13.0	13.0
0.56						14.0	13.0
0.68						12.0	10.0
0.82						12.0	10.0
1.00				10.0		10.0	8.0
1.20				10.0		10.0	8.0
1.50			10.0	9.0		8.0	6.0
1.80			10.0	9.0		8.0	6.0
2.20			8.0	7.0		6.0	5.0
2.70		13.0	8.0	7.0		6.0	5.0
3.30	13.0	10.0	6.0	5.5		5.0	4.0
3.90	13.0	10.0	6.0	5.5		5.0	4.0
4.70	10.0	8.0	5.0	4.5		4.0	3.0
5.60	10.0	8.0	5.0	4.5		4.0	3.0
6.80	8.0	6.0	4.0	3.6		3.1	2.5
8.20	8.0	6.0	4.0	3.6		3.1	2.5
10.0	6.0	5.0	3.2	2.9		2.5	2.0
12.0	6.0	5.0	3.2	2.9		2.5	2.0
15.0	5.0	3.7	2.5	2.3		2.0	1.6
18.0	5.0	3.7	2.5	2.3		2.0	1.6
22.0	3.7	2.7	2.0	1.8		1.5	1.3
27.0	3.7	2.7	2.0	1.8		1.5	1.3
33.0	3.0	2.1	1.6	1.4		1.2	1.0
39.0	3.0	2.1	1.6	1.4		1.2	1.0
47.0	2.0	1.7	1.3	1.2		1.0	0.8
56.0	2.0	1.7	1.3	1.2		1.0	0.8
68.0	1.8	1.3	1.0	0.9		0.8	0.6
82.0	1.8	1.3	1.0	0.9		0.8	0.6
100.0	1.6	1.0	0.8	0.6			
120.0	1.6	1.0	0.8				
150.0	0.9	0.8	0.6				
180.0	0.9	0.8					
220.0	0.9	0.6					
270.0	0.9						
330.0	0.7						

For additional Environmental Test Information see pages 80, 81 and 82.

- **LEAD MATERIAL:** Solder coated steel core with copper ply per MIL-STD-1276.
- **LEAD TAPE and REEL:** Reeling per specification RS-296. See pages 71 and 73 for additional information.



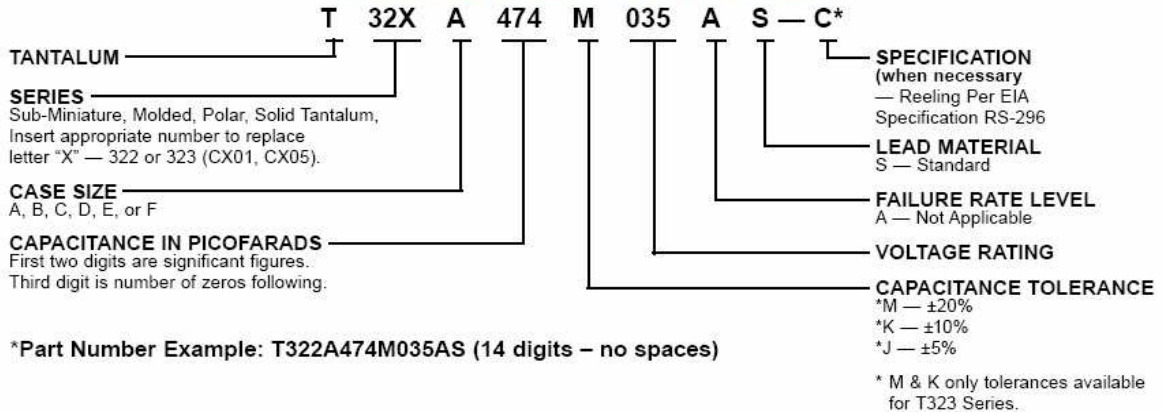
**CAPACITOR OUTLINE DRAWINGS**



**DIMENSIONS — INCHES & (MILLIMETERS)**

CASE SIZE	D (MAX)	L (MAX)	W
A	.095 (2.41)	.260 (6.6)	.020 (.51)
B	.110 (2.79)	.290 (7.37)	.020 (.51)
C	.180 (4.57)	.345 (8.76)	.020 (.51)
D	.180 (4.57)	.420 (10.67)	.020 (.51)
E	.280 (7.11)	.530 (13.46)	.025 (.64)
F	.300 (7.62)	.710 (18.03)	.025 (.64)

**T322 & T323 ORDERING INFORMATION**



## D APPENDIX: Digikey Part No. 399-1978-ND



### MULTILAYER CERAMIC CAPACITORS/AXIAL & RADIAL LEADED

Multilayer ceramic capacitors are available in a variety of physical sizes and configurations, including leaded devices and surface mounted chips. Leaded styles include molded and conformally coated parts with axial and radial leads. However, the basic capacitor element is similar for all styles. It is called a chip and consists of formulated dielectric materials which have been cast into thin layers, interspersed with metal electrodes alternately exposed on opposite

edges of the laminated structure. The entire structure is fired at high temperature to produce a monolithic block which provides high capacitance values in a small physical volume. After firing, conductive terminations are applied to opposite ends of the chip to make contact with the exposed electrodes. Termination materials and methods vary depending on the intended use.

#### TEMPERATURE CHARACTERISTICS

Ceramic dielectric materials can be formulated with a wide range of characteristics. The EIA standard for ceramic dielectric capacitors (RS-198) divides ceramic dielectrics into the following classes:

**Class I:** Temperature compensating capacitors, suitable for resonant circuit application or other applications where high Q and stability of capacitance characteristics are required. Class I capacitors have predictable temperature coefficients and are not affected by voltage, frequency or time. They are made from materials which are not ferro-electric, yielding superior stability but low volumetric efficiency. Class I capacitors are the most stable type available, but have the lowest volumetric efficiency.

**Class II:** Stable capacitors, suitable for bypass or coupling applications or frequency discriminating circuits where Q and stability of capacitance characteristics are not of a major importance. Class II capacitors have temperature characteristics of  $\pm 15\%$  or less. They are made from materials which are ferro-electric, yielding higher volumetric efficiency but less stability. Class II capacitors are affected by temperature, voltage, frequency and time.

**Class III:** General purpose capacitors, suitable for by-pass coupling or other applications in which dielectric losses, high insulation resistance and stability of capacitance characteristics are of little or no importance. Class III capacitors are similar to Class II capacitors except for temperature characteristics, which are greater than  $\pm 15\%$ . Class III capacitors have the highest volumetric efficiency and poorest stability of any type.

KEMET leaded ceramic capacitors are offered in the three most popular temperature characteristics:

**C0G:** Class I, with a temperature coefficient of  $0 \pm 30$  ppm per degree C over an operating temperature range of  $-55^{\circ}\text{C}$  to  $+125^{\circ}\text{C}$  (Also known as "NP0").

**X7R:** Class II, with a maximum capacitance change of  $\pm 15\%$  over an operating temperature range of  $-55^{\circ}\text{C}$  to  $+125^{\circ}\text{C}$ .

**Z5U:** Class III, with a maximum capacitance change of  $+22\%$  -  $56\%$  over an operating temperature range of  $+10^{\circ}\text{C}$  to  $+85^{\circ}\text{C}$ .

Specified electrical limits for these three temperature characteristics are shown in Table 1.

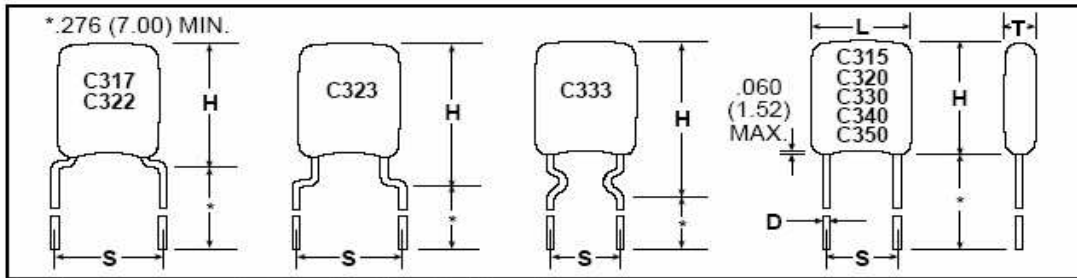
#### SPECIFIED ELECTRICAL LIMITS

PARAMETER	TEMPERATURE CHARACTERISTICS		
	C0G	X7R	Z5U
Dissipation Factor: Measured at following conditions: C0G — 1 kHz and 1 vrms if capacitance > 1000 pF 1 MHz and 1 vrms if capacitance $\leq$ 1000 pF X7R — 1 kHz and 1 vrms* Z5U — 1 kHz and 0.5 vrms	0.15%	2.5%	4.0%
Dielectric Strength: 2.5 times rated DC voltage.	Pass Subsequent IR Test		
Insulation Resistance (IR): At rated DC voltage, whichever of the two is smaller	1,000 M $\Omega$ - $\mu$ F or 100 G $\Omega$	1,000 M $\Omega$ - $\mu$ F or 100 G $\Omega$	1,000 M $\Omega$ - $\mu$ F or 10 G $\Omega$
Temperature Characteristics: Range, $^{\circ}\text{C}$ Capacitance Change without DC voltage	-55 to 125 $0 \pm 30$ ppm/ $^{\circ}\text{C}$	-55 to 125 $\pm 15\%$	+10 to 85 $+22\%$ , $-56\%$

\* 1 MHz and 1 vrms if capacitance  $\leq$  100 pF on military product.

Table 1

STANDARD LEAD CONFIGURATION — OUTLINE DRAWINGS



Drawings are not to scale. See table below for dimensions.  
See page 9 for optional lead configurations.

DIMENSIONS — INCHES & MILLIMETERS

CASE SIZE	L MAX.	H MAX.	T MAX.	S(1) ±.030	D +.004 - .001
C315	.150 (3.81)	.210 (5.33)	.100 (2.54)	.100 (2.54)	.020 (.51)
C317	.150 (3.81)	.230 (5.84)	.100 (2.54)	.200 (5.08)	.020 (.51)
C320	.200 (5.08)	.260 (6.60)	.125 (3.18)	.100 (2.54)	.020 (.51)
C322	.200 (5.08)	.260 (6.60)	.125 (3.18)	.200 (5.08)	.020 (.51)
C323	.200 (5.08)	.320 (8.13)	.125 (3.18)	.200 (5.08)	.020 (.51)
C330	.300 (7.62)	.360 (9.14)	.150 (3.81)	.200 (5.08)	.020 (.51)
C333	.300 (7.62)	.390 (9.91)	.150 (3.81)	.200 (5.08)	.020 (.51)
C340	.400 (10.16)	.460 (11.68)	.150 (3.81)	.200 (5.08)	.020 (.51)
C350	.500 (12.70)	.560 (14.22)	.200 (5.08)	.400 (10.16)	.025 (.64)

NOTE: 1 Inch = 25.4 mm.  
NOTE: (1) Measured at seating plane.

# E APPENDIX: Digikey Part No. P461-ND

## Panasonic LEDs — Level Meters High Brightness GA AIA's Red Light-Emitting Diodes

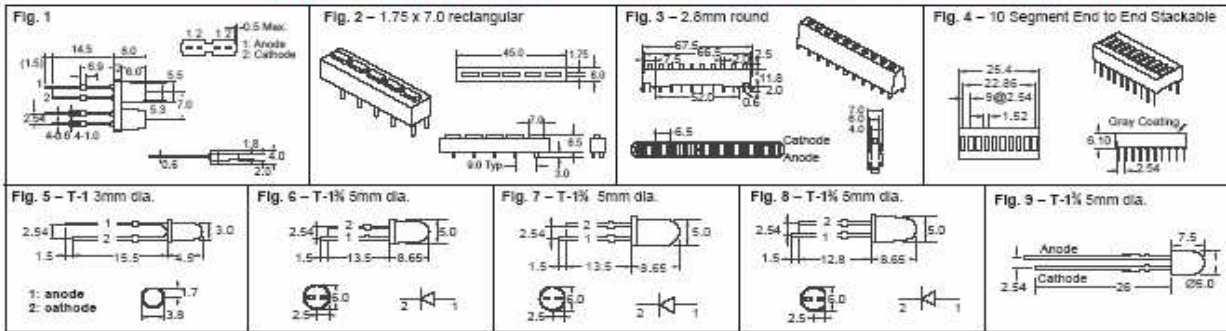


Fig.	Package	Color (Diffused)	IO (mod @5mA) Typ.	PD (mW)	VR (V)	IF (mA)	IO (mod) (mA)	$\lambda_p$ (nm)	Lens Size	Dimensions (mm)	Digi-Key Part No.	1	10	200	Panasonic Part No.	
1	2 Elements	Red	—	70	4	25	0.5	700	$\phi 1.8 \times 5.3$	6.0	P516-ND	50	45	39	LN22202P	
		Green	—	90	4	30	1.5	565	$\phi 1.8 \times 5.3$	6.0	P517-ND	66	60	52	LN23202P	
	3 Elements	Red	—	70	4	25	0.5	700	$\phi 1.8 \times 5.3$	6.0	P519-ND	74	68	59	LN23202P	
		Green	—	90	4	30	1.5	565	$\phi 1.8 \times 5.3$	6.0	P520-ND	98	90	77	LN23302P	
	4 Elements	Red	—	70	4	25	0.5	700	$\phi 1.8 \times 5.3$	6.0	P521-ND	98	90	77	LN23402P	
		Green	—	90	4	30	1.5	565	$\phi 1.8 \times 5.3$	6.0	P522-ND	91	83	71	LN24202P	
	5 Elements	Red	—	70	4	25	0.5	700	$\phi 1.8 \times 5.3$	6.0	P523-ND	1.31	1.20	1.03	LN24302P	
		Green	—	90	4	30	1.5	565	$\phi 1.8 \times 5.3$	6.0	P525-ND	1.25	1.14	98	LN25202P	
	6 Elements	Red	—	70	4	25	0.5	700	$\phi 1.8 \times 5.3$	6.0	P526-ND	1.64	1.49	1.28	LN25302P	
		Green	—	90	4	30	1.5	565	$\phi 1.8 \times 5.3$	6.0	P527-ND	1.64	1.49	1.28	LN25402P	
	7 Elements	Red	—	70	4	25	0.5	700	$\phi 1.8 \times 5.3$	6.0	P528-ND	1.50	1.37	1.15	LN25202P	
		Green	—	90	4	30	1.5	565	$\phi 1.8 \times 5.3$	6.0	P529-ND	1.55	1.75	1.53	LN26302P	
	8 Elements	Red	—	70	4	25	0.5	700	$\phi 1.8 \times 5.3$	6.0	P530-ND	1.95	1.78	1.53	LN26402P	
		Green	—	90	4	30	1.5	565	$\phi 1.8 \times 5.3$	6.0	P531-ND	1.75	1.50	1.37	LN27202P	
9 Elements	Red	—	70	4	25	0.5	700	$\phi 1.8 \times 5.3$	6.0	P532-ND	2.28	2.08	1.79	LN27302P		
	Green	—	90	4	30	1.5	565	$\phi 1.8 \times 5.3$	6.0	P533-ND	2.45	2.23	1.92	LN27402P		
2	—	Red	—	70	4	25	0.4	700	$\phi 1.7 \times 7.0$	7.55	P397-ND	1.45	1.32	1.14	LN25201P	
3	—	Green	—	90	4	30	1.0	565	$\phi 2.0$	2.5	P401-ND	3.85	3.50	3.01	LN19304P	
4	10 Elements	Green	—	60	5	20	1900	565	$\phi 1.52 \times 0.38$	—	4.6	P10723-ND	6.28	5.71	4.91	LN19310105A
		Red	—	60	3	20	1000	630	$\phi 1.52 \times 0.38$	—	4.6	P10723-ND	6.28	5.71	4.91	LN19310105A

### HIGH BRIGHTNESS LEDs

† Nondiffused lens. Water clear lens when off.

## Optoelectronics LEDs — Two Color

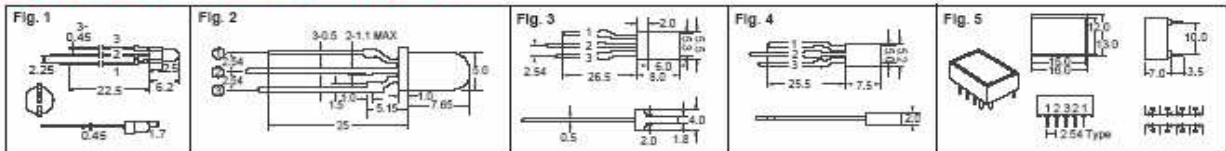
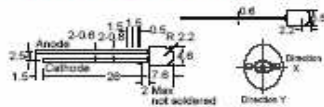


Fig.	Radiation Color/ Lens Color	PD (mW)	IF (mA)	VR (V)	IO (mod) (mA)	$\lambda_p$ (nm)	Dimensions (mm)	Digi-Key Part No.	1	10	200	1,000	Panasonic Part No.
1	#1, Green/3, Orange/White Diffused	90/90	30/30	4/3	8.0/8.0	565/630	$\phi 3.0$	P509-ND	66	6.00	103.20	240.84	LN2861WP38
	#1, Green/3, Red/White Diffused	70	25	4	3.0	700	$\phi 5.0$	P391-ND	59	5.40	92.88	240.84	LN111WP23
2	#1, Green/3, Red/Clear	70	25	4	3.0	700	$\phi 5.0$	P392-ND	59	5.40	92.88	240.84	LN111CP23
	#1, Amber/3, Red/White Diffused	70	25	4	3.0	700	$\phi 5.0$	P393-ND	66	6.00	103.20	240.84	LN111WP24
	#1, Amber/3, Green/White Diffused	50	30	4	15.0	565	$\phi 5.0$	P395-ND	66	6.00	103.20	240.84	LN111WP34
	#1, Orange/3, Green/White Diffused	50	30	4	15.0	565	$\phi 5.0$	P399-ND	66	6.00	103.20	240.84	LN111WP38
3	#1, Green/3, Red/White Diffused	70/90	25/30	4/4	8/4.5	700/565	$\phi 1.8 \times 5.3$	P435-ND	59	5.40	92.88	240.84	LN117WP23
4	#1, Orange/3, Green/White Diffused	90/90	30/30	4/3	3/2.5	565/630	$\phi 2.0 \times 0.5$	P435-ND	66	6.00	103.20	240.84	LN142WP38
5	#1, Orange/3, Green/White Diffused	60	20	3	8.0	565	$\phi 1.2 \text{ Dr } 15.0$	P395-ND	3.22	29.24	502.95	2164.57	LN2861WP38

\* Common Cathode

## Wide Angle LEDs



Color	$I_b$		$I_f$ (mA)	$V_f$ (V)		$\lambda_p$ (nm)	$\Delta\lambda$ (nm)	$I_{\text{max}}$ (mA)	$I_{\text{avg}}$ (mA)	$V_r$ (V)	Viewing Angle (deg)	IFDC Max	IFP Max	Digi-Key Part No.	Pricing			Panasonic Part No.	
	mod	Typ		Max	Typ										1	10	200		
Red	300	120	20	2.6	1.8	660	20	20	100	3	15	35	30	190	P462-ND	.50	5.40	62.88	LN295LFCP2U
Green	120	75	20	2.8	2.2	565	30	20	10	4	17	35	30	190	P463-ND	.30	2.75	47.30	LN295MFTP5U
Blue	370	145	20	4.0	3.5	470	30	20	10	5	15	35	30	100	P468-ND	2.67	24.95	463.32	LN295FPBW

\* The condition of IFP is duty 10%, pulse width 1ms.

1368 (T042)

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# F APPENDIX: Digikey Part No. QED234-ND

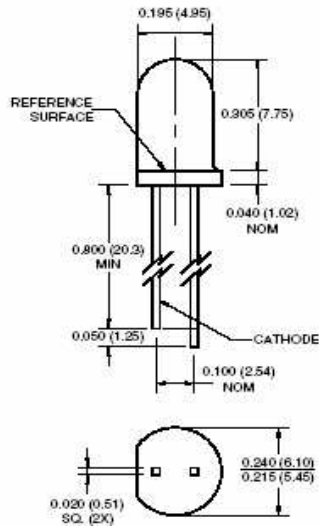


## PLASTIC INFRARED LIGHT EMITTING DIODE

**QED233**

**QED234**

### PACKAGE DIMENSIONS

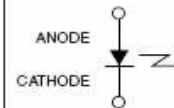


**NOTES:**

1. Dimensions for all drawings are in inches (mm).
2. Tolerance of  $\pm .010$  (.25) on all non-nominal dimensions unless otherwise specified.



### SCHEMATIC



### DESCRIPTION

The QED233 / QED234 is a 940 nm GaAs / AlGaAs LED encapsulated in a clear untinted, plastic T-1 3/4 package.

### FEATURES

- $\lambda = 940$  nm
- Chip material = GaAs with AlGaAs window
- Package type: T-1 3/4 (5mm lens diameter)
- Matched Photosensor: QSD122/123/124
- Medium Emission Angle,  $40^\circ$
- High Output Power
- Package material and color: Clear, untinted, plastic
- Ideal for remote control applications

**QED233**

**QED234**

<b>ABSOLUTE MAXIMUM RATINGS</b> ( $T_A = 25^\circ\text{C}$ unless otherwise specified)			
Parameter	Symbol	Rating	Unit
Operating Temperature	$T_{OPR}$	-40 to +100	$^\circ\text{C}$
Storage Temperature	$T_{STG}$	-40 to +100	$^\circ\text{C}$
Soldering Temperature (Iron) <sup>(2,3,4)</sup>	$T_{SOL-I}$	240 for 5 sec	$^\circ\text{C}$
Soldering Temperature (Flow) <sup>(2,3)</sup>	$T_{SOL-F}$	260 for 10 sec	$^\circ\text{C}$
Continuous Forward Current	$I_F$	100	mA
Reverse Voltage	$V_R$	5	V
Power Dissipation <sup>(1)</sup>	$P_D$	200	mW
Peak Forward Current	$I_{FP}$	1.5	A

1. Derate power dissipation linearly 2.67 mW/ $^\circ\text{C}$  above 25 $^\circ\text{C}$ .
2. RMA flux is recommended.
3. Methanol or isopropyl alcohols are recommended as cleaning agents.
4. Soldering iron 1/16" (1.6mm) minimum from housing.
5. Pulse conditions;  $t_p = 100 \mu\text{s}$ ,  $T = 10 \text{ ms}$ .

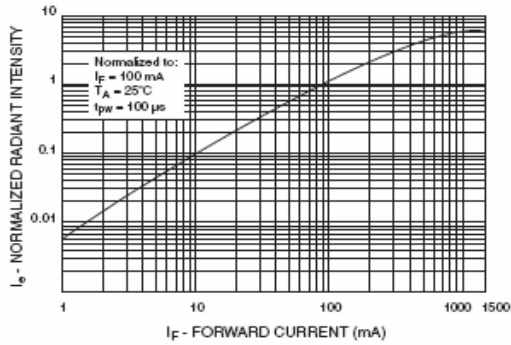
<b>ELECTRICAL / OPTICAL CHARACTERISTICS</b> ( $T_A = 25^\circ\text{C}$ )							
PARAMETER	TEST CONDITIONS	DEVICE	SYMBOL	MIN	TYP	MAX	UNITS
Peak Emission Wavelength	$I_F = 20 \text{ mA}$	ALL	$\lambda_{PE}$	—	940	—	nm
Spectral Bandwidth	$I_F = 20 \text{ mA}$	ALL	—	50	—	—	nm
Temp. Coefficient of $\lambda_{PE}$	$I_F = 100 \text{ mA}$	ALL	$TC_\lambda$	—	0.2	—	nm/K
Emission Angle	$I_F = 100 \text{ mA}$	ALL	$2\theta_{1/2}$	—	40	—	Deg.
Forward Voltage	$I_F = 100 \text{ mA}$ , $t_p = 20 \text{ ms}$	ALL	$V_F$	—	—	1.6	V
Temp. Coefficient of $V_F$	$I_F = 100 \text{ mA}$	ALL	$TC_V$	—	-1.5	—	mV/K
Reverse Current	$V_R = 5 \text{ V}$	ALL	$I_R$	—	—	10	$\mu\text{A}$
Radiant Intensity	$I_F = 100 \text{ mA}$ , $t_p = 20 \text{ ms}$	QED233	$I_E$	10	—	50	mW/sr
		QED234		27	—	—	
Temp. Coefficient of $I_E$	$I_F = 20 \text{ mA}$	ALL	$TC_I$	—	-0.6	—	%/K
Rise Time	$I_F = 100 \text{ mA}$	ALL	$t_r$	—	1000	—	ns
Fall Time		ALL	$t_f$	—	1000	—	

**QED233**

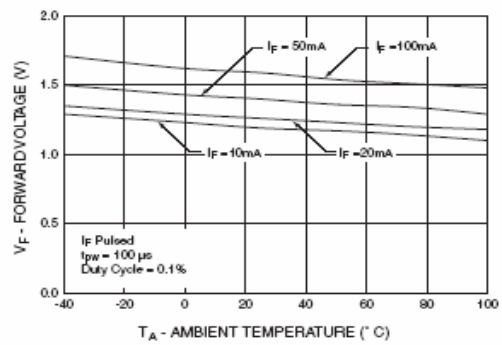
**QED234**

**TYPICAL PERFORMANCE CURVES TBD**

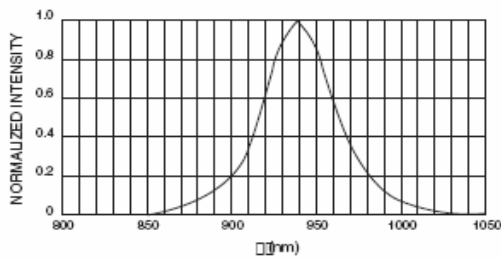
**Fig. 1 Normalized Radiant Intensity vs. Forward Current**



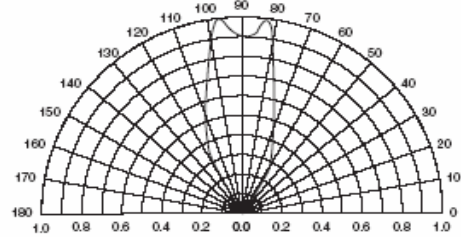
**Fig. 2 Forward Voltage Vs. Ambient Temperature**



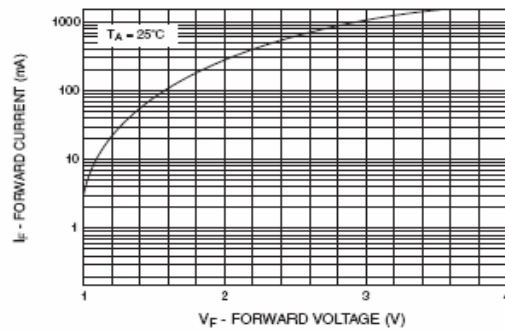
**Fig. 3 Normalized Radiant Intensity vs. Wavelength**



**Fig. 4 Radiation Diagram**



**Fig. 5 Forward Current vs. Forward Voltage**

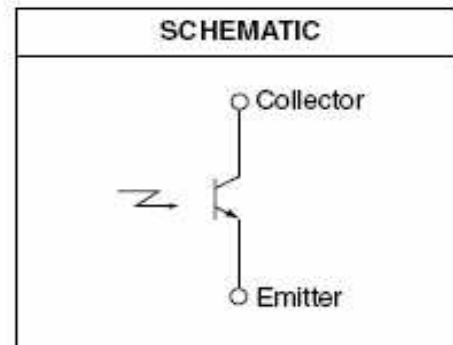
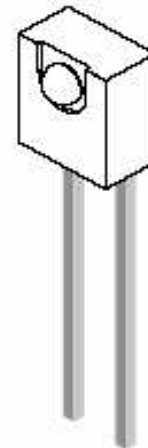
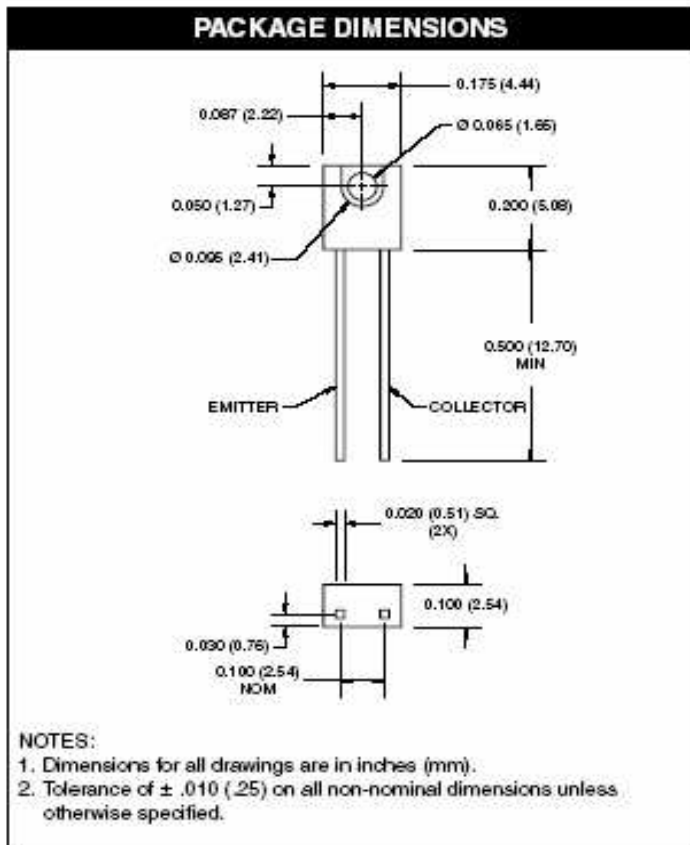


# G APPENDIX: Digikey Part No. QSE114-ND



## PLASTIC SILICON INFRARED PHOTOTRANSISTOR

QSE113 QSE114



### DESCRIPTION

The QSE113/114 is a silicon phototransistor encapsulated in a wide angle, infrared transparent, black plastic sidelooker package.

### FEATURES

- NPN silicon phototransistor
- Package type: Sidelooker
- Medium wide reception angle,  $50^\circ$
- Package material and color: black epoxy
- Matched emitter: QEE113
- Daylight filter
- High sensitivity



**QSE113 QSE114**

ABSOLUTE MAXIMUM RATINGS ( $T_A = 25^\circ\text{C}$ unless otherwise specified)			
Parameter	Symbol	Rating	Unit
Operating Temperature	$T_{OPR}$	-40 to +100	$^\circ\text{C}$
Storage Temperature	$T_{STG}$	-40 to +100	$^\circ\text{C}$
Soldering Temperature (Iron) <sup>(2,3,4)</sup>	$T_{SOL-I}$	240 for 5 sec	$^\circ\text{C}$
Soldering Temperature (Flow) <sup>(2,3)</sup>	$T_{SOL-F}$	260 for 10 sec	$^\circ\text{C}$
Collector Emitter Voltage	$V_{CE}$	30	V
Emitter Collector Voltage	$V_{EC}$	5	V
Power Dissipation <sup>(1)</sup>	$P_D$	100	mW

**NOTES:**

- Derate power dissipation linearly 1.33 mW/ $^\circ\text{C}$  above 25 $^\circ\text{C}$ .
- RMA flux is recommended.
- Methanol or isopropyl alcohols are recommended as cleaning agents.
- Soldering iron 1/16" (1.6 mm) minimum from housing.
- $\lambda = 880 \text{ nm}$  (AlGaAs).

ELECTRICAL / OPTICAL CHARACTERISTICS ( $T_A = 25^\circ\text{C}$ unless otherwise specified)						
Parameter	Test Conditions	Symbol	Min	Typ	Max	Units
Peak Sensitivity		$\lambda_{PS}$	—	880	—	nM
Reception Angle		$\theta$	—	$\pm 25$	—	Deg.
Collector Emitter Dark Current	$V_{CE} = 10 \text{ V}, E_o = 0$	$I_{CEO}$	—	—	100	nA
Collector-Emitter Breakdown	$I_C = 1 \text{ mA}$	$BV_{CEO}$	30	—	—	V
Emitter-Collector Breakdown	$I_E = 100 \mu\text{A}$	$BV_{ECO}$	5	—	—	V
On-State Collector Current <sup>(5)</sup> QSE113	$E_o = 0.5 \text{ mW/cm}^2, V_{CE} = 5 \text{ V}$	$I_{C(ON)}$	0.25	—	1.50	mA
On-State Collector Current <sup>(5)</sup> QSE114	$E_o = 0.5 \text{ mW/cm}^2, V_{CE} = 5 \text{ V}$	$I_{C(ON)}$	1.00	—	—	mA
Saturation Voltage <sup>(5)</sup>	$E_o = 0.5 \text{ mW/cm}^2, I_C = 0.1 \text{ mA}$	$V_{CE(SAT)}$	—	—	0.4	V
Rise Time	$I_C = 1 \text{ mA}, V_{CC} = 5 \text{ V}, R_L = 100\Omega$	$t_r$	—	8	—	$\mu\text{s}$
Fall Time		$t_f$	—	8	—	$\mu\text{s}$

Figure 1. Light Current vs. Radiant Intensity

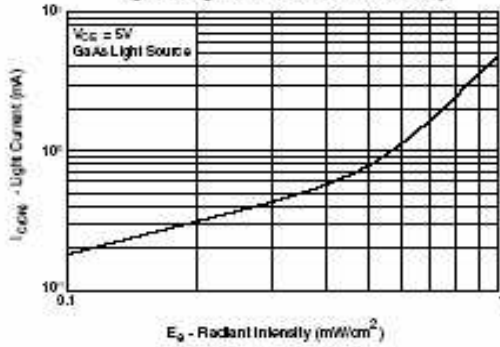


Figure 2. Angular Response Curve

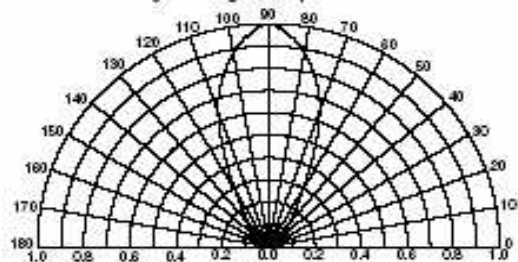


Figure 3. Dark Current vs. Collector - Emitter Voltage

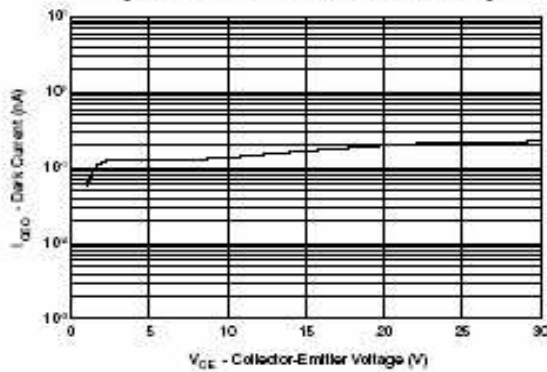


Figure 4. Light Current vs. Collector - Emitter Voltage

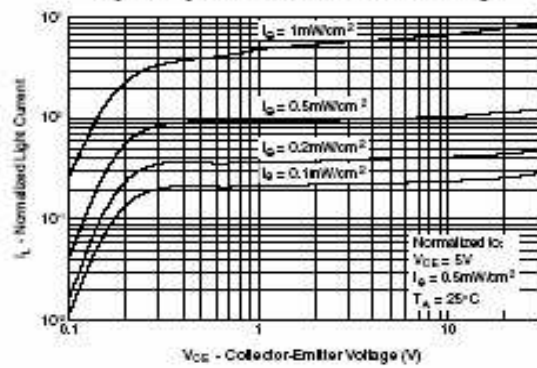
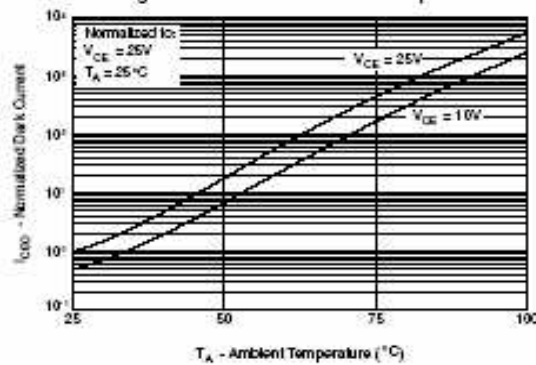


Figure 5. Dark Current vs. Ambient Temperature



## H APPENDIX: Digikey Part No. A6T-8101-ND

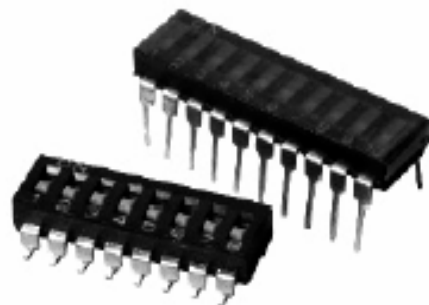
# OMRON

DIP Switch

A6T/A6S

### DIP Switch with Slide Pins

- Allows automatic mounting with DIP IC insertion machines
- Washable models with seal tape are available
- SMT (surface-mounted terminal) models are available with/without embossed tape



### Ordering Information

No. of poles	Flat actuator		Raised actuator	Flat actuator			Raised actuator
	Standard	With seal tape		Standard	Tape seal	Tape seal in embossed tape	
	DIP terminal	DIP terminal	DIP terminal	SMT terminal	SMT terminal	SMT terminal	SMT terminal
1	A6T-1101	A6T-1102	A6T-1104	---	---	---	---
2	A6T-2101	A6T-2102	A6T-2104	A6S-2101	A6S-2102	---	A6S-2104
3	---	---	---	A6S-3101	A6S-3102	---	A6S-3104
4	A6T-4101	A6T-4102	A6T-4104	A6S-4101	A6S-4102	A6S-4102-P	A6S-4104
5	---	---	---	A6S-5101	A6S-5102	---	A6S-5105
6	A6T-6101	A6T-6102	A6T-6104	A6S-6101	A6S-6102	A6S-6102-P	A6S-6104
7	---	---	---	A6S-7101	A6S-7102	---	A6S-7104
8	A6T-8101	A6T-8102	A6T-8104	A6S-8101	A6S-8102	A6S-8102-P	A6S-8104
9	---	---	---	A6S-9101	A6S-9102	---	A6S-9104
10	A6T-0101	A6T-0102	A6T-0104	A6S-0101	A6S-0102	---	A6S-0104

Important note: Switches cannot be water-washed.

## Specifications

### ■ CHARACTERISTICS

Switching capacity	25 mA at 24 VDC	
Insulation resistance	100 M $\Omega$ min. (at 250 VDC)	
Contact resistance	200 m $\Omega$ max. (initial value)	
Dielectric strength	500 VAC for 1 min between terminals of same polarity, and between terminals of different polarity	
Vibration resistance	Malfunction: 10 to 55 Hz, 1.5-mm double amplitude	
Shook resistance	Malfunction: 300 m/s <sup>2</sup> min. (approx. 30G min.)	
Life expectancy	Mechanical	1,000 operations min.
	Electrical	1,000 operations min.
Ambient temperature	Operating	-20°C to 70°C (with no icing)
Ambient humidity	Operating	35% to 90%
Operating force	30 gf	

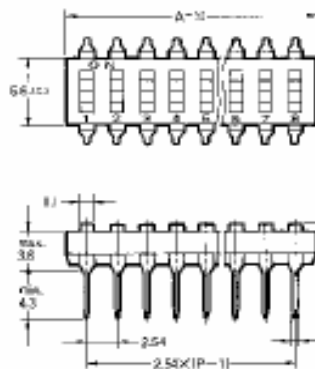
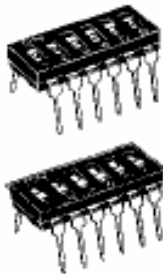
## Dimensions

Unit: mm (inch)

Note: Unless otherwise specified, a tolerance of  $\pm 0.4$  mm applies to all dimensions.

### ■ FLAT ACTUATED WITH DIP TERMINAL STANDARD/WITH SEAL TAPE

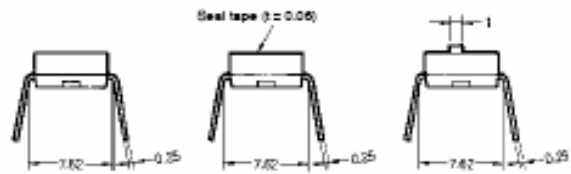
A6T-□101  
A6T-□102



Flat Actuated  
Standard

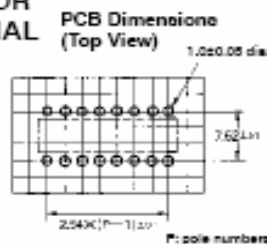
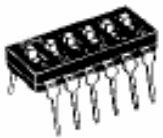
With Seal Tape

Raised Actuator



### ■ RAISED ACTUATOR WITH DIP TERMINAL

A6T-□104



No. of poles	Part number			A
1	A6T-1101	A6T-1102	A6T-1104	3.48
2	A6T-2101	A6T-2102	A6T-2104	6.02
4	A6T-4101	A6T-4102	A6T-4104	11.10
6	A6T-6101	A6T-6102	A6T-6104	16.18
8	A6T-8101	A6T-8102	A6T-8104	21.26
10	A6T-0101	A6T-0102	A6T-0104	26.34

## References

- [1] Moss F Garver W. Electronic fireflies. *Scientific American*, 269:128–130, 1993.