Hardware Black Magic: Designing Printed Circuit Boards

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Stephen (afterburn) Janansky
Who are we?

- University of Delaware
- Department of Electrical and Computer Engineering
- CVORG
Who are we?

- Dr. Fouad Kiamilev
- Professor
- Fearless Leader
- Procurer of Funding
Who are we?

- Corey Lange
- Grad Student
- Geek
- Eternally Grateful for Aforementioned Funding
Who are we?

- Stephen Janansky
  - Researcher
  - Hardware Hacker
  - Embedded Systems Designer
  - Network Engineer
What we are doing here?

• Printed Circuit Board (PCB) Design
  • It’s easy!
  • It’s fun!
  • It will let everyone you know how much of a nerd you really are!
But what is a PCB?

- Layers of dielectric and metal
  - Usually copper and FR4
  - Anywhere from 2 to 20
- A means to layout circuits
- Prototype vs. Production
What to do with Cu?

- Create electrical connections between components
  - Traces/Tracks
  - Pours/Planes
- Need to use vias to connect layers
What’s a via?

• Plated hole going through the board that connects the layers together

  • Yes, all of the layers (be careful!)

  • Well, not always...

• Blind Vias

• Buried Vias
Components

- A circuit without components is like...
  - A bird without wings
  - A car without wheels
  - A grad student without funding
Components

- A collection of pads or vias that a chip or discrete part will connect to the board
- a.k.a. Footprint
Datasheets: Who cares?

- We do!
- Shows lots of valuable information:
  - Electrical specifications
  - Usual applications/schematics
  - Footprint sizes
LM555 Timer

General Description
The LM555 is a highly stable device for generating accurate time delays or oscillation. Additional terminals are provided for triggering or resetting if desired. In the time delay mode of operation, the time is precisely controlled by one external resistor and capacitor. For astable operation as an oscillator, the free running frequency and duty cycle are accurately controlled with two external resistors and one capacitor. The circuit may be triggered and reset on falling waveforms, and the output circuit can source or sink up to 200mA or drive TTL circuits.

Features
- Direct replacement for SE555/NE555
- Timing from microseconds through hours
- Operates in both astable and monostable modes
- Adjustable duty cycle
- Output can source or sink 200 mA
- Output and supply TTL compatible
- Temperature stability better than 0.005% per °C
- Normally on and normally off output
- Available in 8-pin MSOP package

Applications
- Precision timing
- Pulse generation
- Sequential timing
- Time delay generation
- Pulse width modulation
- Pulse position modulation
- Linear ramp generator

Connection Diagram

Ordering Information

<table>
<thead>
<tr>
<th>Package</th>
<th>Part Number</th>
<th>Package Marking</th>
<th>Media Transport</th>
<th>NSC Drawing</th>
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<td>Rails</td>
<td>M08A</td>
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<td>8-Pin MDIP</td>
<td>LM555CN</td>
<td>LM555CN</td>
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**Absolute Maximum Ratings (Note 2)**

If Military/Aerospace specified devices are required, please contact the National Semiconductor Sales Office/Distributors for availability and specifications.

- **Supply Voltage**: +18V
- **Power Dissipation (Note 3)**
  - LM555CM, LM555CN: 1180 mW
  - LM555CMM: 613 mW
- **Operating Temperature Ranges**
  - LM555C: 0°C to +70°C
- **Storage Temperature Range**
  - -65°C to +150°C

**Soldering Information**

- **Dual-In-Line Package**
  - Soldering (10 Seconds): 260°C
- **Small Outline Packages**
  - (SOIC and MSOP)
    - Vapor Phase (60 Seconds): 215°C
    - Infrared (15 Seconds): 220°C

See AN-450 “Surface Mounting Methods and Their Effect on Product Reliability” for other methods of soldering surface mount devices.

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**Electrical Characteristics (Notes 1, 2)**

(T<sub>a</sub> = 25°C, V<sub>CC</sub> = +5V to +15V, unless otherwise specified)

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<td><strong>Min</strong></td>
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<tr>
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<td>V&lt;sub&gt;CC&lt;/sub&gt; = 15V, R&lt;sub&gt;L&lt;/sub&gt; = ∞</td>
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<td>Drift with Temperature</td>
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<td>Accuracy over Temperature</td>
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Typical Performance Characteristics

Minimum Pulse Width Required for Triggering

Supply Current vs. Supply Voltage

High Output Voltage vs. Output Source Current

Low Output Voltage vs. Output Sink Current
ASTABLE OPERATION

If the circuit is connected as shown in Figure 4 (pins 2 and 6 connected) it will trigger itself and free run as a multivibrator. The external capacitor charges through $R_A + R_B$ and discharges through $R_B$. Thus the duty cycle may be precisely set by the ratio of these two resistors.

FIGURE 4. Astable

In this mode of operation, the capacitor charges and discharges between $1/3 V_{CC}$ and $2/3 V_{CC}$. As in the triggered mode, the charge and discharge times, and therefore the frequency are independent of the supply voltage.

FIGURE 5. Astable Waveforms

The charge time (output high) is given by:

$$t_1 = 0.693 \left( R_A + R_B \right) C$$

And the discharge time (output low) by:

$$t_2 = 0.693 \left( R_B \right) C$$

Thus the total period is:

$$T = t_1 + t_2 = 0.693 \left( R_A + 2R_B \right) C$$

The frequency of oscillation is:

$$f = \frac{1}{T} = \frac{1.44}{\left( R_A + 2R_B \right) C}$$

Figure 6 may be used for quick determination of these RC values.

The duty cycle is:

$$D = \frac{R_B}{R_A + 2R_B}$$
What happens when you don’t listen to the datasheet:
Design Rules

• If you design it, they still might not be able to fab it.

• Machines are only so precise
  • Smaller == $$$

• Allow for tolerances

• Design Rule Check (DRC) is a must!!!!
The Finishing Touches

- Soldermask
- Plating metal
- Silkscreen
Secrets of the Pros

• When in doubt, make the pad/via/through-hole bigger than you think it should be
  • Through Hole ROT: +0.010” to diameter
  • Will allow more room to solder or allow for an better fit

• Use 1:1 printouts to make sure components fit properly
More Secrets

• The Capacitor - An EE’s Duct Tape
  • Reduces noise!
  • Stores extra charge!
  • Slices a transfer function!
  • And even more!!!!

Source: Wikimedia Commons
How can we design PCB’s?

- **Software Packages:**
  - Express PCB
    - Free
  - PCB Artist
    - Free
  - EAGLE
    - Free
  - Oregano
    - Free, Linux

- **PCB**
  - Free, Linux
  - gEDA
    - Free, Linux
  - Cadence Allegro
    - Really not free
    - High-Speed
  - Hundreds more
    - Really not free
    - High-Speed

- **Hundreds more**
  - Try Googling it
Enough Talk!

- Let’s design a PCB!
- We are going to use Advanced Circuits’ PCB Artist
- How about we redesign the DEFCON17 Badge?
- All materials and information is available at Kingpin’s site: www.grandideastudio.com
Demo Time
Quick Thanks

- UD Computer Engineering
- UD Alumni Association
- Intel
- Advanced Circuits
- DEFCON
Questions/Comments/Concerns/Debates?