Hardware Black Magic:
Designing Printed Circuit Boards

Dr. Fouad (Dr. K) Kiamilev
Corey (c0re) Lange
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?

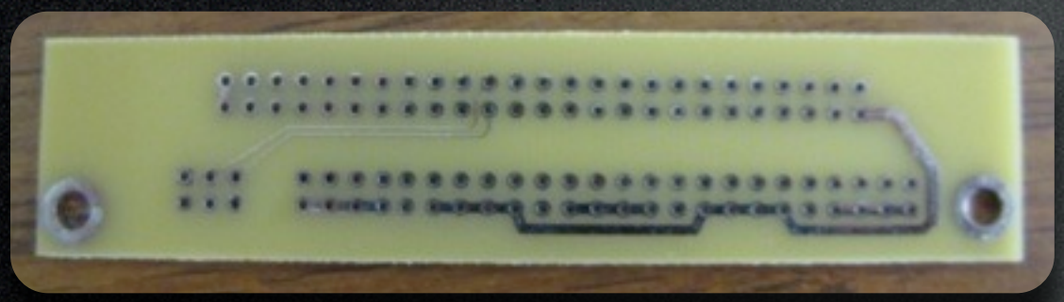
- Stephen Janansky
  - Researcher
  - Hardware Hacker
  - Embedded Systems Designer
  - Network Engineer

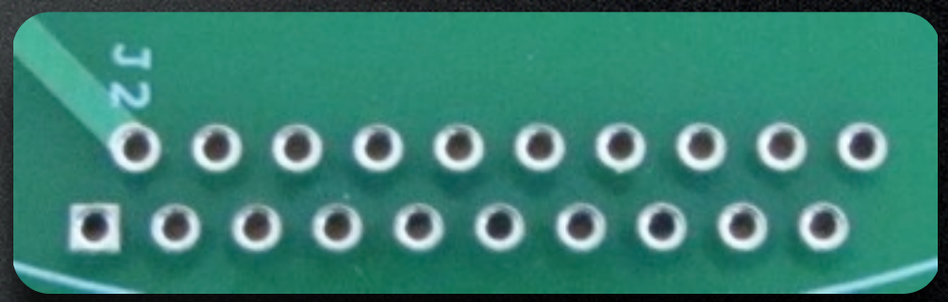
What we are doing here?

- 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?

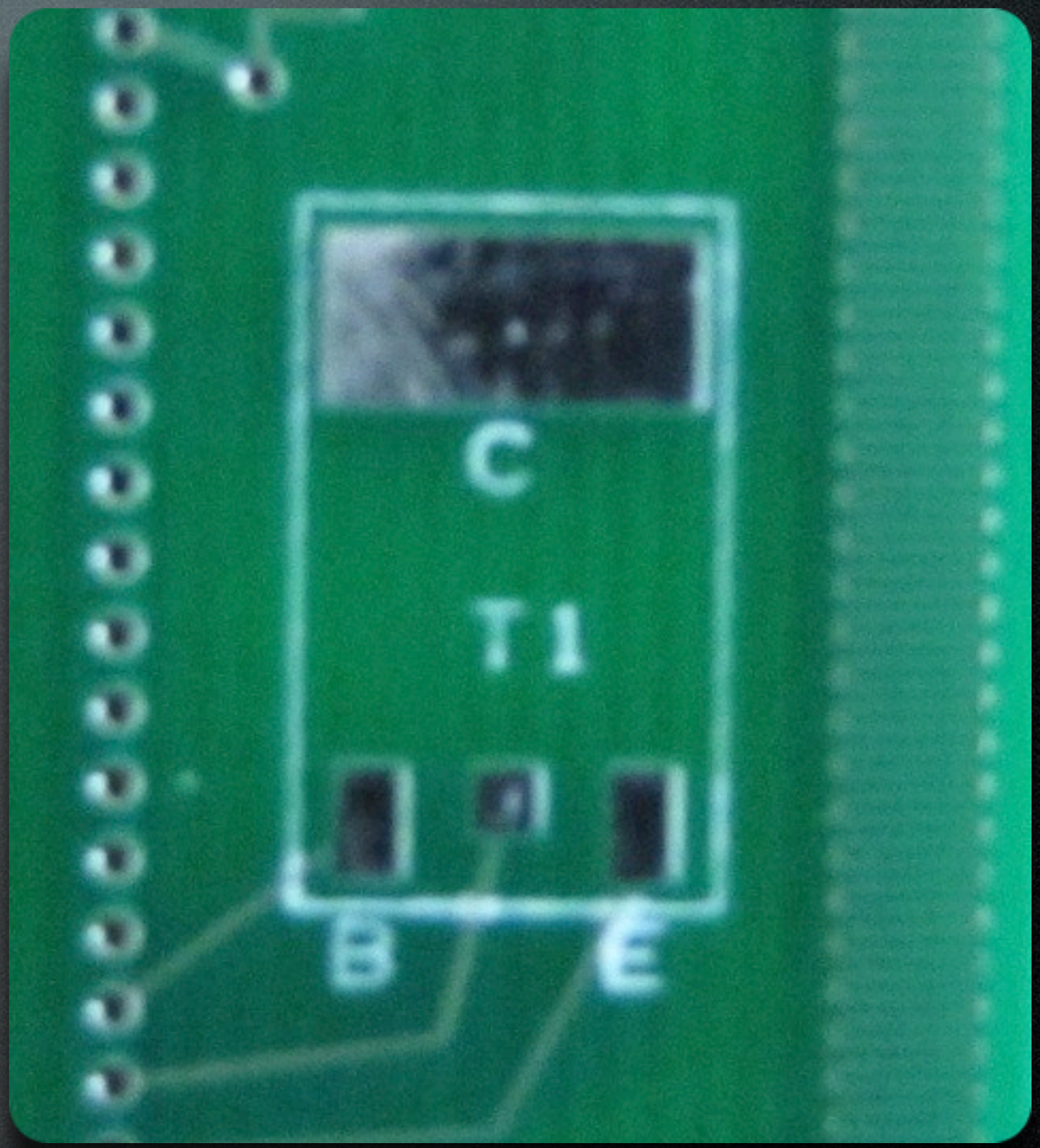
- Layers of dielectric and metal
  - Usually copper and FR4
  - Anywhere from 2 to 20
- A means to layout circuits
- Prototype vs. Production





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?

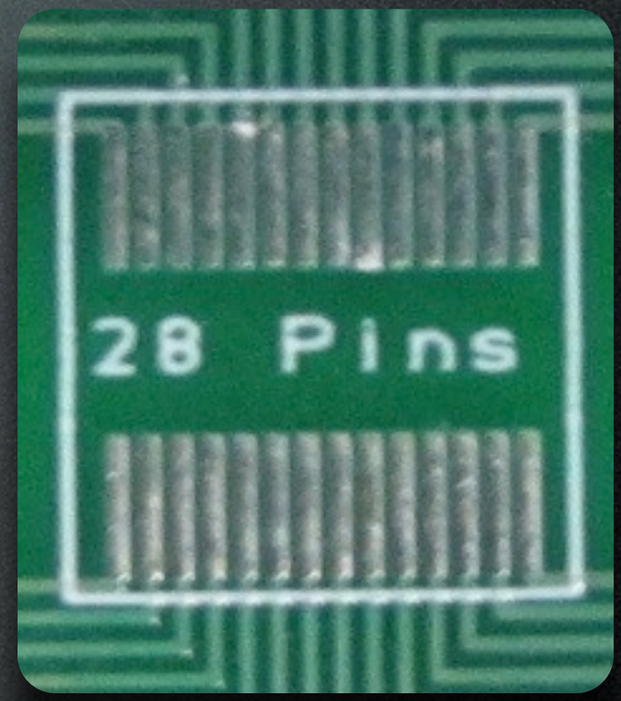
- Plated hole going through the board that connects the layers together
  - Yes, all of the layers (be careful!)
  - Well, not always...
- Blind Vias
- Buried Vias

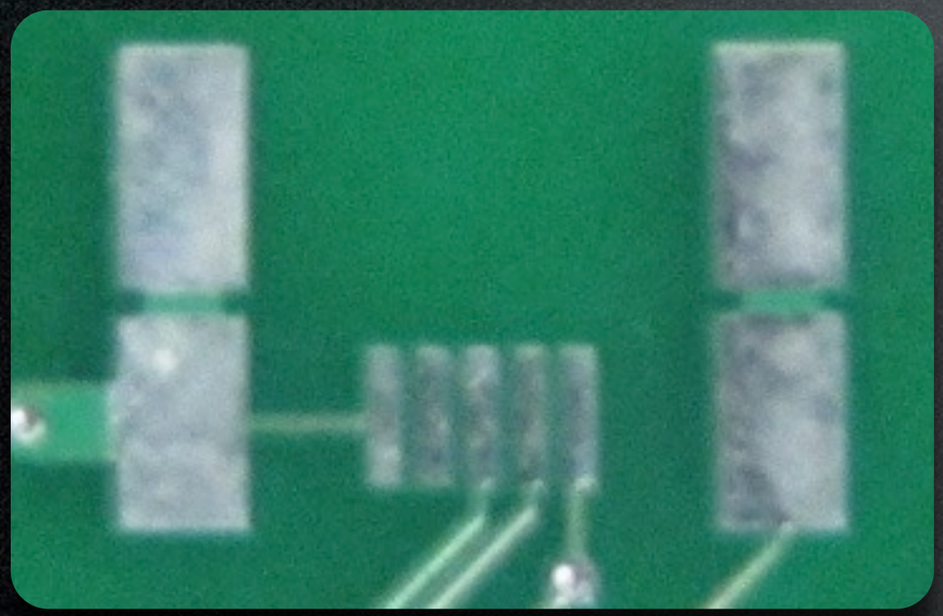
Components

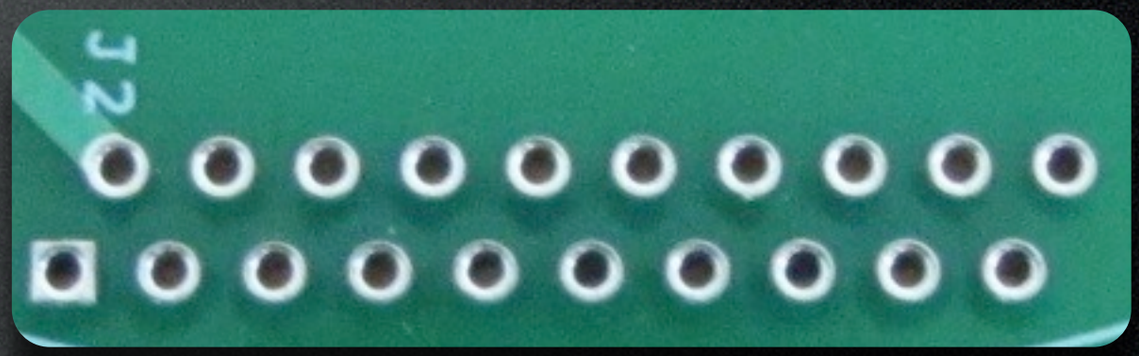
- A circuit without components is like...
- A bird without wings
- A car without wheels
- A grad student without funding

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

National Semiconductor

July 2006

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

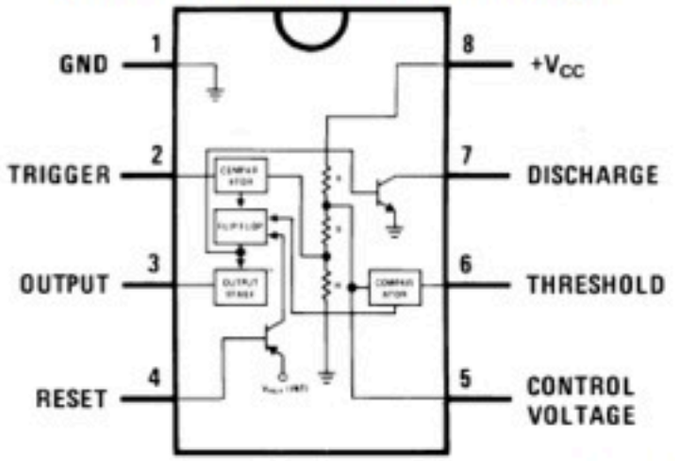
- Direct replacement for SE555/NE555
- Timing from microseconds through hours
- Operates in both astable and monostable modes
- Adjustable duty cycle
- Output can source or sink 200 mA
- Output and supply TTL compatible
- Temperature stability better than 0.005% per °C
- Normally on and normally off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

Dual-In-Line, Small Outline and Molded Mini Small Outline Packages



00785103

Top View

Ordering Information

Package	Part Number	Package Marking	Media Transport	NSC Drawing
8-Pin SOIC	LM555CM	LM555CM	Rails	M08A
	LM555CMX	LM555CM	2.5k Units Tape and Reel	
8-Pin MSOP	LM555CMM	Z55	1k Units Tape and Reel	MUA08A
	LM555CMMX	Z55	3.5k Units Tape and Reel	
8-Pin MDIP	LM555CN	LM555CN	Rails	N08E

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.

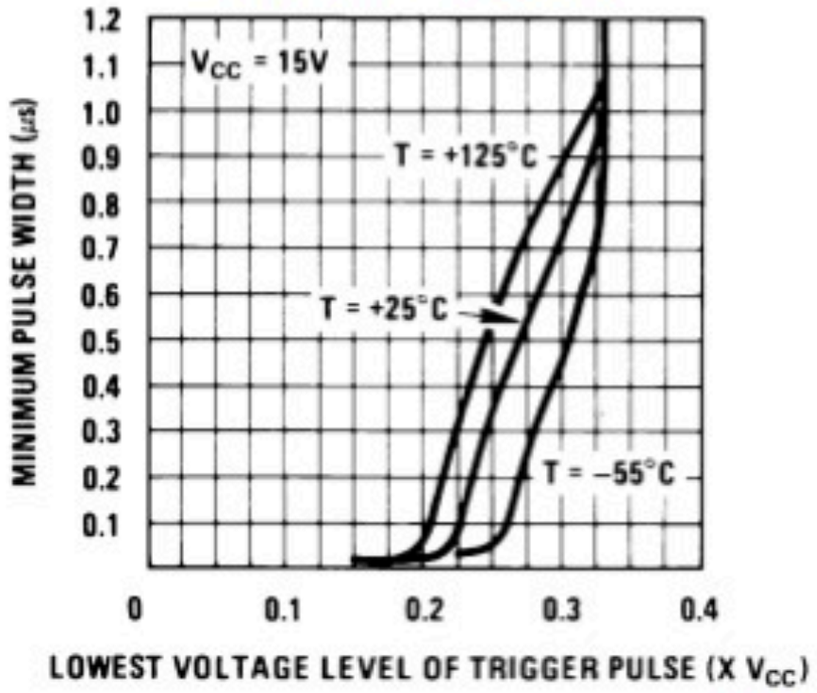
Electrical Characteristics (Notes 1, 2)

(T_A = 25˚C, V_{CC} = +5V to +15V, unless othewise specified)

Parameter	Conditions	Limits			Units
		LM555C			
		Min	Typ	Max	
Supply Voltage		4.5		16	V
Supply Current	V_{CC} = 5V, R_L = ∞		3	6	
	V_{CC} = 15V, R_L = ∞		10	15	mA
	(Low State) (Note 4)				
Timing Error, Monostable					
Initial Accuracy			1		%
Drift with Temperature	R_A = 1k to 100kΩ,		50		ppm/˚C
	C = 0.1µF, (Note 5)				
Accuracy over Temperature			1.5		%

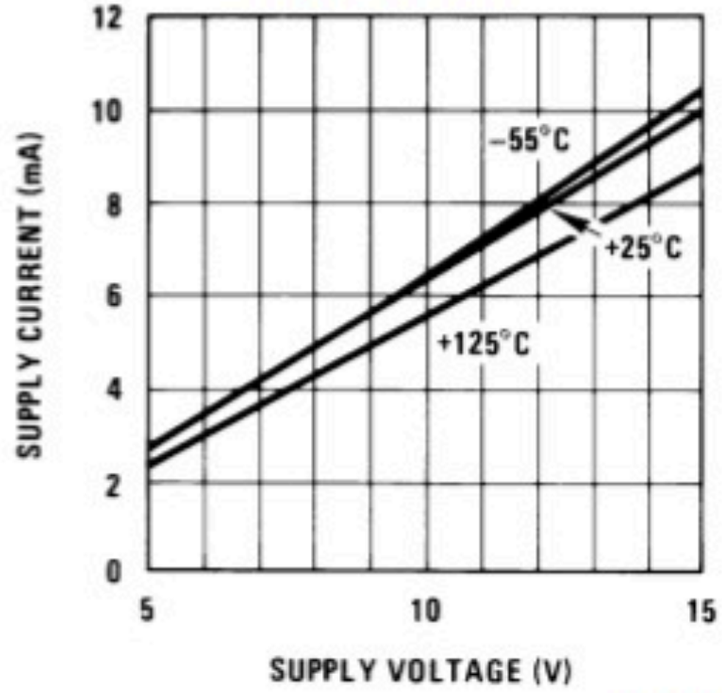
Typical Performance Characteristics

Minimuim Pulse Width Required for Triggering



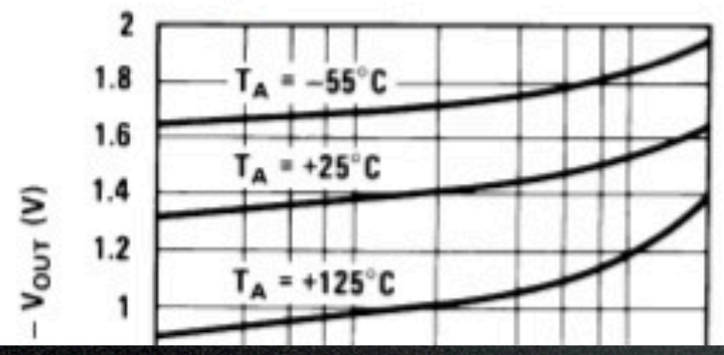
00785104

Supply Current vs. Supply Voltage

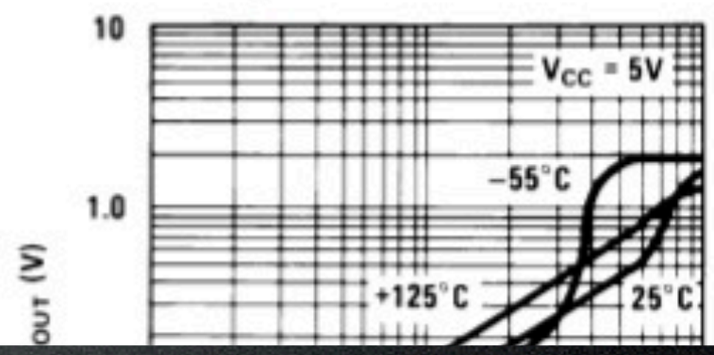


00785119

High Output Voltage vs. Output Source Current

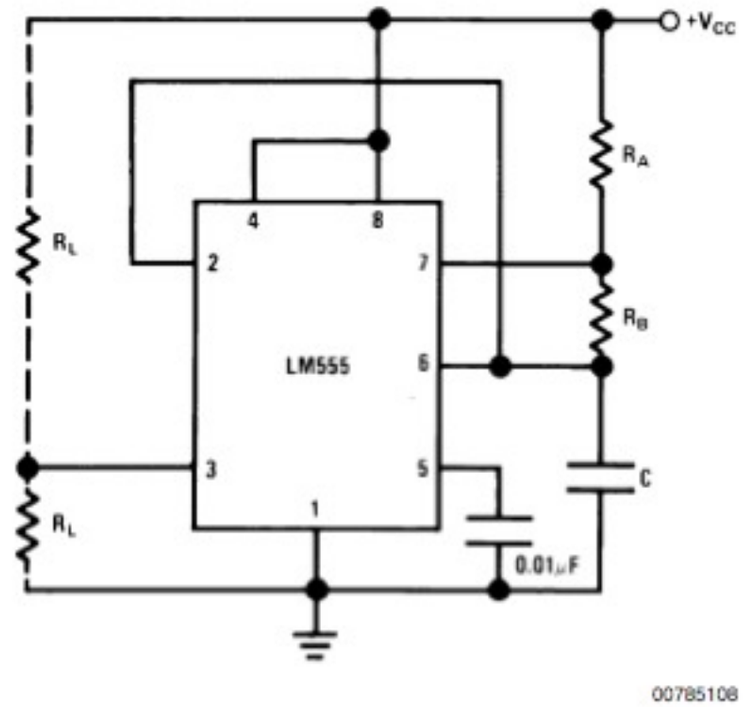


Low Output Voltage vs. Output Sink Current



ASTABLE OPERATION

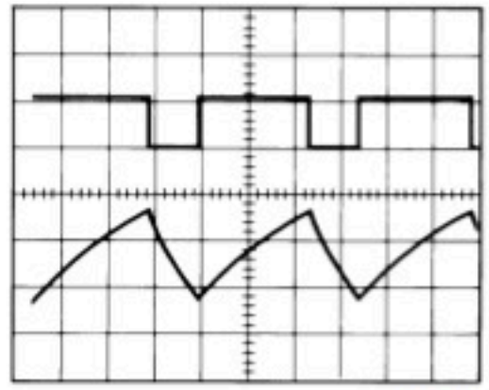
If the circuit is connected as shown in *Figure 4* (pins 2 and 6 connected) it will trigger itself and free run as a multivibrator. The external capacitor charges through $R_A + R_B$ and discharges through R_B. Thus the duty cycle may be precisely set by the ratio of these two resistors.



00785108

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.



00785109

V_{CC} = 5V — Top Trace: Output 5V/Div.
TIME = 20µs/DIV. — Bottom Trace: Capacitor Voltage 1V/Div.
R_A = 3.9kΩ
R_B = 3kΩ
C = 0.01µF

FIGURE 5. Astable Waveforms

The charge time (output high) is given by:

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

And the discharge time (output low) by:

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

Thus the total period is:

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

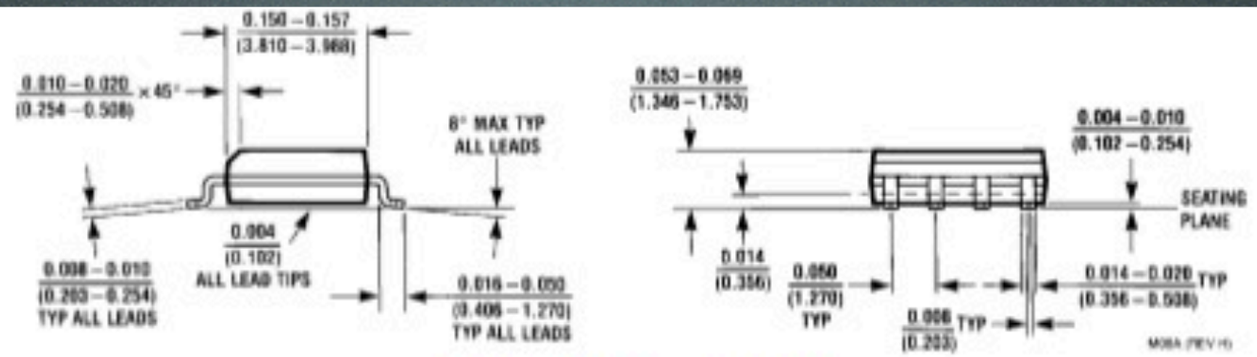
The frequency of oscillation is:

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

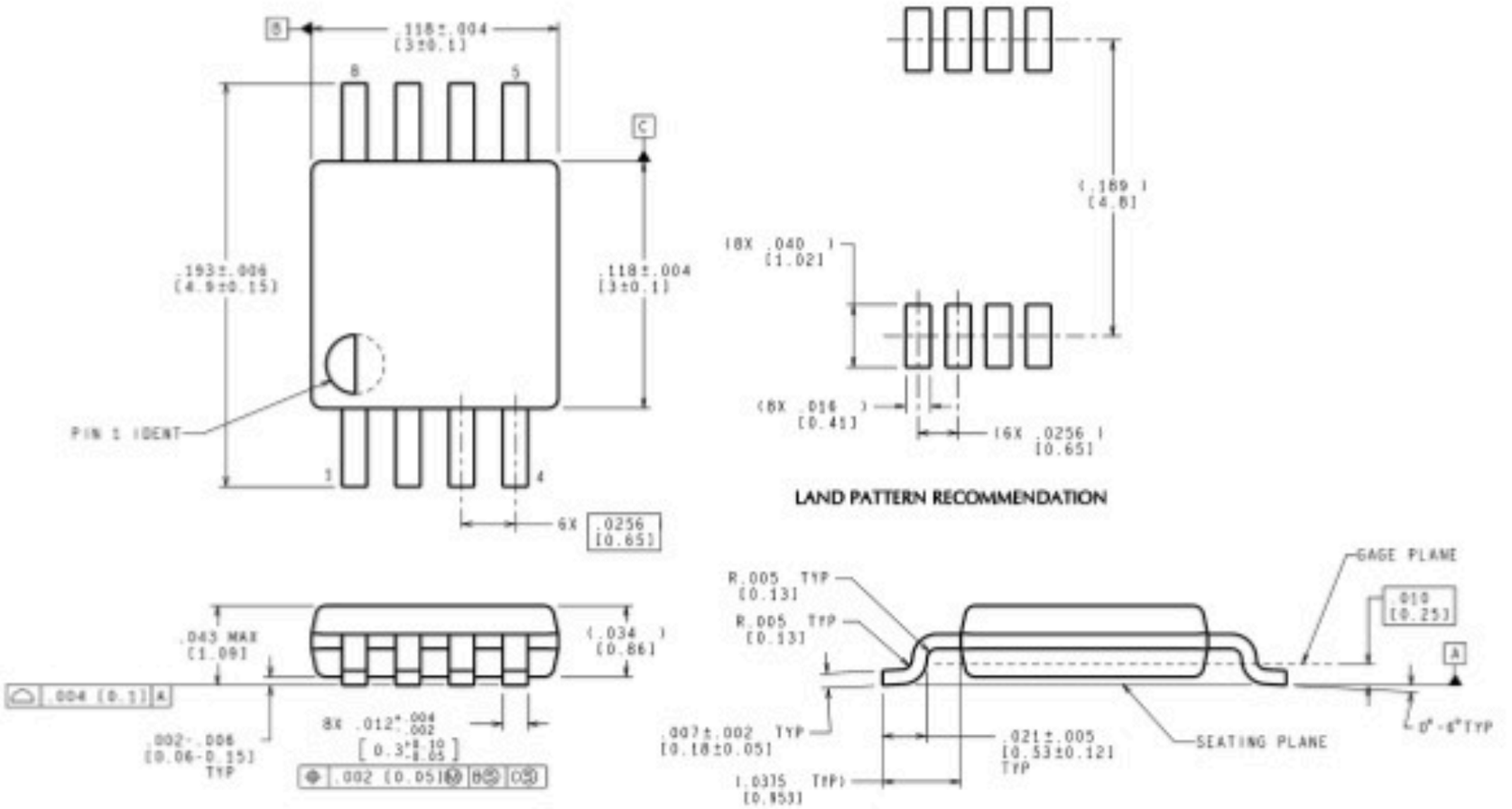
Figure 6 may be used for quick determination of these RC values.

The duty cycle is:

$$D = \frac{R_B}{R_A + 2R_B}$$

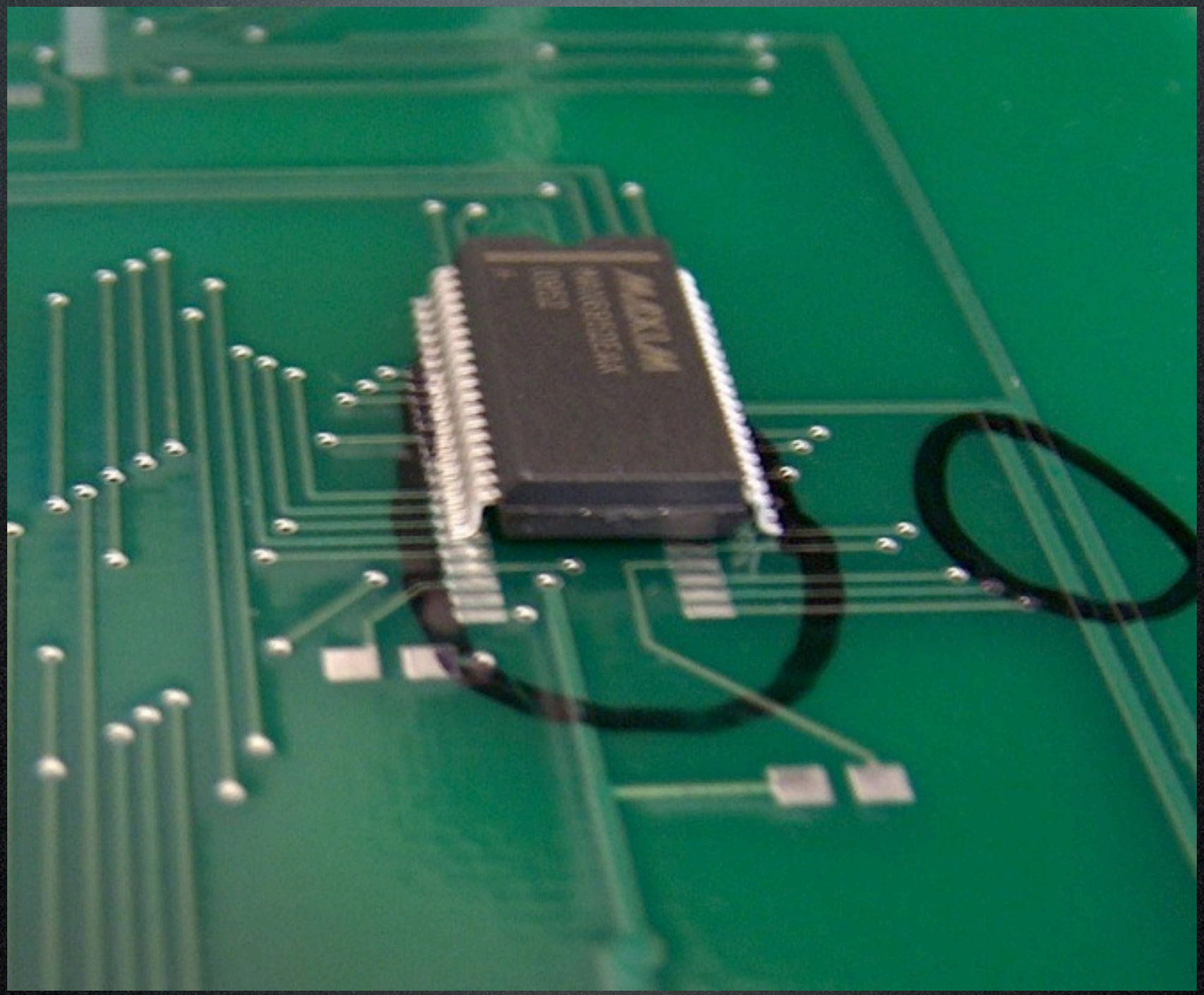


Small Outline Package (M)
NS Package Number M08A



8-Lead (0.118" Wide) Molded Mini Small Outline Package
NS Package Number MUA08A

What happens when you don't listen to the datasheet:

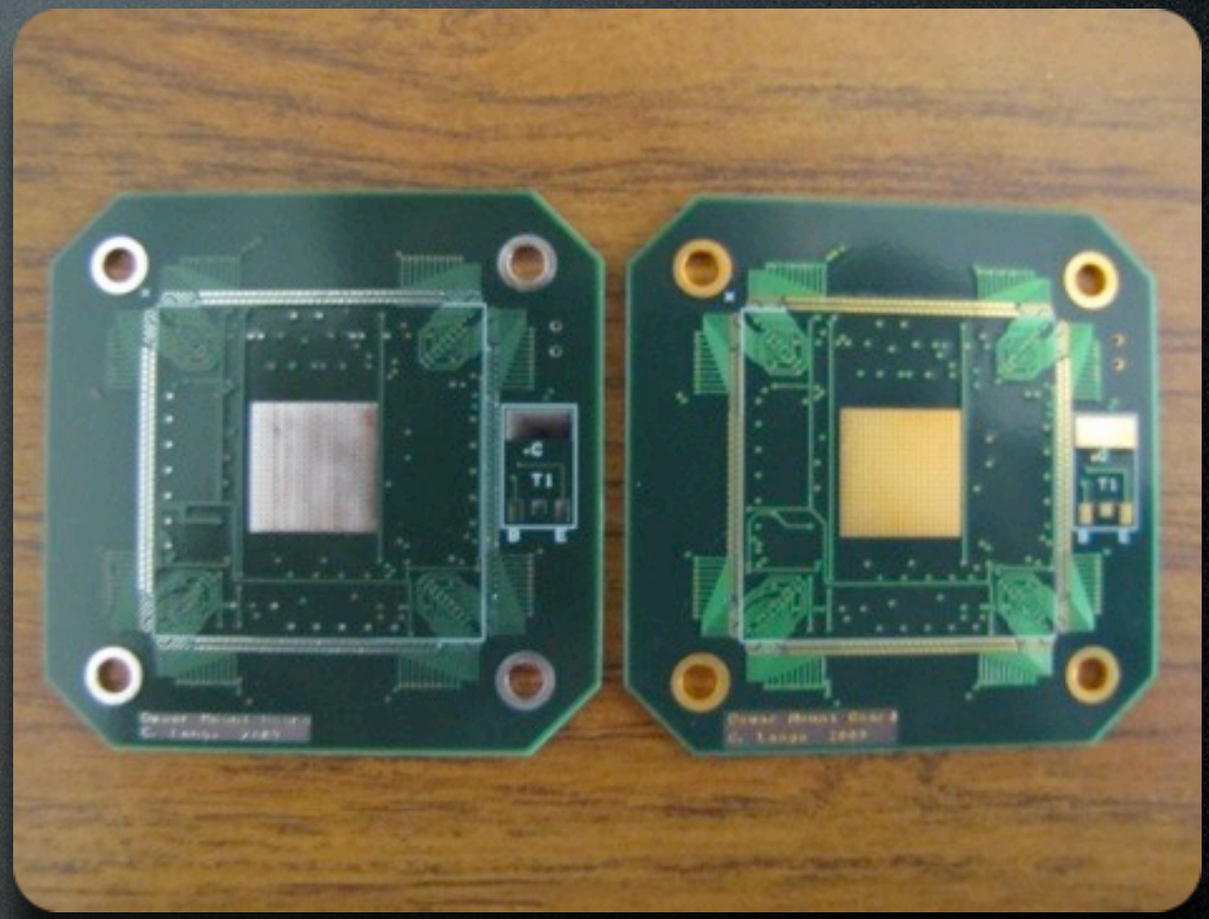


Design Rules

- 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

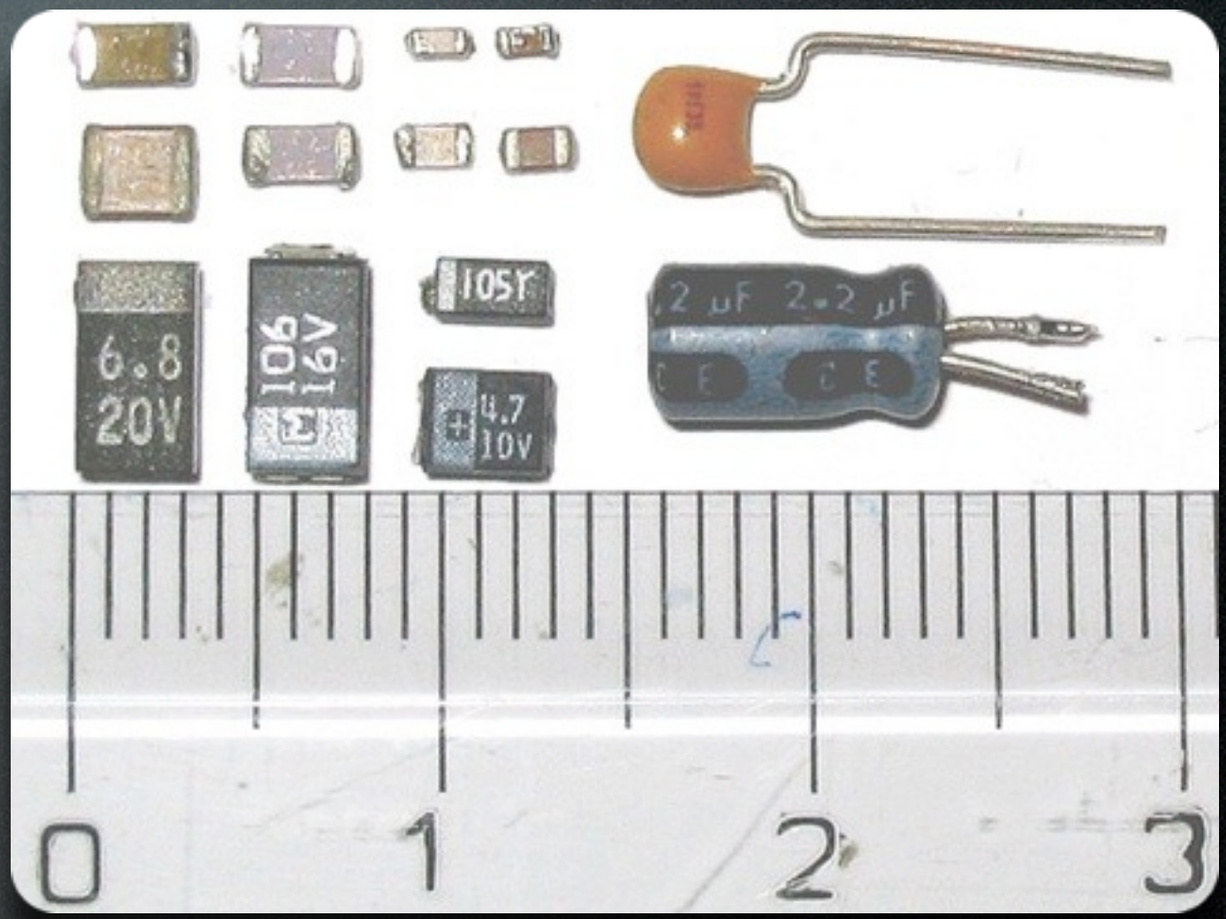


Secrets of the Pros

- 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
    - Try Googling it

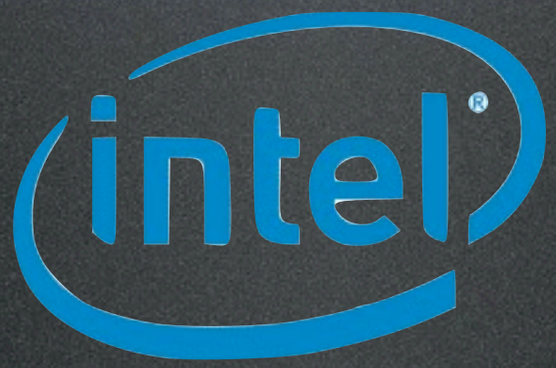
Enough Talk!

- 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?