

Building Your Project - Part 2 - *Ideas*

Don't start from scratch!....."appropriate"! (Rule #1)

- don't be so proud... avoid NIH syndrome!
- build on others experience, stand on their heads and add your value

Where do I find other designs?

- web sites: national.com, maxim-ic.com, linear-tech.com, ti.com, analog.com,
- look for "application notes", technical briefs, white papers
- Google
- search for: electronic designs, circuit ideas etc.
- trade magazines: EDN, Electronic Design (Ideas for Design column)
- hobbyist magazines: QST, Ham Radio (old), Circuit Cellar, Nuts and Volts
- books: The Art of Electronics, ARRL Handbook
- sourcebook of Electronic Circuits (library)

Building Your Project - Part 2 - *Ideas*

Keep a design notebook

- keep all scribbles, notes, doodles, good and bad ideas
- don't throw anything away

Pencil and paper rule!

- fast, cheap, easily altered, portable, stays out of the way of your thinking
- keep all your notes, scribbles in a notebook

Designs Change; use hand drawn diagrams/schematics until all is settled.

- why do it over and over making it look "nice"?
- make it work, then make it pretty. (Rule #2) (don't polish poop!)

Label things clearly and use sensible labels for your co-workers

Show your ideas to others and get their feedback

Building Your Project - Part 2 – *Other thoughts*

Figure out all you can from calculations, paper analysis

- use worst case numbers
- check power dissipation, current consumption, input and output currents
- upfront design time saves ~4x backend time

If you "borrowed" something, be able to explain its operation completely

Never succumb to this argument:

- "Let's just try it and see if it works,
if it doesn't we'll just fiddle around with it till it does."

Building Your Project - Part 2 - *Simulation*

What about simulation?

- simulation is not design
- simulation is a confirmation of what you believe works
 - its the "warm fuzzies" for your design
- simulation is a way to check out what you can't build

Digital simulation is very valuable

- very good models available
- no excuse for not thoroughly simulating your digital design

Analog simulation is very valuable if good models are available otherwise, use 1st principles. They are usually accurate enough.

- BJT beta varies %50
- Vth on MOSFET varies 25%
- Resistors usually 5% tolerance
- Capacitor tolerance varies from 5% to 80%
- Inductors are at best good to 5%

So.....who cares about results to 3 decimal places!?

Building Your Project - Part 2 - *Simulation*

Simulating uP behavior using a IDE tool is invaluable – do it when appropriate

Last thought on simulation:

- If you are confident it works...
- and can prototype it in 20 minutes or less.....
- then don't bother to simulate it

Building Your Project - Part 2 - *Prototyping*

Prototyping shakes out bugs very effectively

- introduces the real-world effects you could not simulate
- cases where prototyping is the only way to see if something works
 - RF circuits.
 - accurate simulation of parasitics can be difficult.

Take time to prototype well

- focus on a clean, working prototype, not the finished product
- avoid thinking..... " Its just a prototype.....who cares.....?"
- don't waste good analysis time on a rotten prototype?
- be neat, be careful, take good measurements

A surprising number of prototypes get shipped!.....

- somebody did their homework!

Building Your Project - Part 2 - *Prototyping*

Analog prototyping (DC to 200Mhz)

- use copper clad board, three dimensional dead bug methods
- use commercial "protoboards" for only the roughest prototyping
5pf between adjacent pins, poor decoupling, unreliable contacts

Why "*dead bug*" prototyping?

- continuous, nearly ideal ground plane
- 3 dimensional wiring, short leads
- low parasitic capacitance (to ground plane and other components)
- easy to mount almost anything using your imagination
- cut with paper cutter, shear, tin snips, hacksaw
- fast, easy to change, cheap, easy to organize your circuit your way

- build each part separately and test completely.
- resolve any questions about operation.
- make it neat, construct it carefully, make it work,
- prove your analysis was correct.
- if your analysis was wrong, figure out why.
- dig deep, understand all the behavior if possible

Building Your Project - Part 2 - *Prototyping*

Digital Prototyping (0 to 100Mhz)

- commercial protoboard for 3-4 "slow" (i.e. 4000, 74LS) ICs
- remember decoupling, but it won't be good

- solderboard, dead bug or wirewrapping for 5-8 ICs
- soldering preferred, easier to debug, less change for wire crumbs
- wirewrapping: hard to see, easy to nick wires, hard to find shorts
- dead bug: good power distribution, decoupling, easy wiring, easy tracing,
- easy to rip up and try again

- >5-8 ICs, use a Flash PLD, CPLD or FPGA and save yourself the grief
- I would use a CPLD or FPGA for almost anything digital

- use 1, 0.1uF ceramic capacitor for each digital chip (use short leads)
- use 1, 10uF electrolytic capacitor per board (bulk capacitor)
- use a local voltage regulator (LM29xx) series on each board
- prevents power supply disasters
- implements the "idiot diode" for you
- use low ESR output capacitor for LM29xx series

Building Your Project - Part 2 - *Prototyping*

Digital Prototyping

Check function of all digital designs with a simulator

Use VHDL or Verilog to rapidly prototype digital circuits

- rapid changes in circuits (seconds vs hours)
- reuse old code
- simulation speed for HDL tools 10x gate level tools

Try corner cases, wrong inputs, pathological situations

Try doing things to your circuit, that "shouldn't ever happen"

- wrong input sets
- asynchronous resets

Its easy to digitally simulate so, beat the snot out of it, no excuses!

- better to debug with a simulator than an o-scope or logic analyzer
- full observability
- no real-world effects, bad connections, etc

Building Your Project - Part 2 - *Prototyping*

Mixed Signal Prototyping

*(Analog * Digital) OR (Digital * Power) OR (RF * Anything)*

Keep circuit domains physically separated as much as is practical

Keep electrically separated

- decoupling, passive and active filtering
- single-point grounding

Electric field shielding is easy with copper clad board

- cut with shears, solder the seams
- bring signals in and out with feed through capacitors if necessary

Building Your Project - Part 2 – *Parts to Use*

Capacitors

Ceramic

- NP0: Accurate, temp. stable, good at RF, (<10000pf)
- X7R: Fairly stable, 10% tol., decoupling or non-critical timing
- Z5U: Not stable, decoupling only, 20% tol.

Electrolytic: big values (1uF-1F) , wide tol., leaky, bulk decoupling, not RF

Tantalum: like above, more reliable, more stable, lower ESR, lower leakage

Low ESR Electrolytic or Tantalum: low ESR, high frequency apps. (100KHz)

Polystyrene: stable, low leakage, accurate, good at RF, (<10000pf)

Stacked Metalized Film: stable, accurate, low leakage, audio freqs. not RF

Building Your Project - Part 2 – *Parts to Use*

Transistors

2N4401, 2N4403,

Small sig NPN,PNP, low noise, good beta at 150mA, good linearity

2N7000

N-Ch, enhancement mode MOSFET, 5 ohm R_{dson}

J310

N-Ch depletion mode JFET, low noise, $g_m=10,000\mu\text{mhos}$

IRF510

N-Ch, enhancement mode Power MOSFET

2N3055

NPN Power

CA3046

General purpose transistor array

LM394, MAT-01

Superbeta pair, highly matched pair, very low noise at audio frequencies

CA3127,

One differential pair plus two other uncommitted xistors, $f_t=1\text{Ghz}$

CA3102, CA3049

Two differential pairs with constant current source, $f_t=1\text{Ghz}$

Building Your Project - Part 2 – *Parts to Use*

Diodes

1N4001-1N4004

General purpose 1A rectifier diodes

1N5819

Schottky Diode, 1A, 0.3V forward voltage drop, good "stupid" diode

1N914, 1N4148

Small signal diodes, good to VHF frequencies

1N34

Small signal germanium diode, good to VHF

1n5xxx

0.5W Zener diodes, 10% tolerance at 20mA

TL431

Variable output precision zener diode, or fixed 2.5V reference, cheap

Building Your Project - Part 2 – *Parts to Use*

ICs (OPAMP, Buffers, Voltage Regulators, MMICs, etc)

- NE5534, NE5532; Single/dual OPAMP single/dual supply, low noise
- LM386, LM380; Audio power amps (.5-1W)
- LM1496 Gilbert cell
- NE602 Gilbert cell mixer with oscillator
- LM339 Cheap, quad comparator
- LT1016 Very fast, easy to use comparator (\$4.00)
- MAX961 Very, very fast comparator
- LM317, LM2941 Adjustable voltage regulators, 29xx is low drop out
- MAR-1, MAR-3, MAV-11 (Minicircuits) DC-to-light amplifiers

CPLD

- 22V10 variants Atmel and others, The cockroach of PLDs
- XC95xx Xilinx, cheap, 175Mhz, JTAG prog., Good tools
- Coolrunner II series Xilinx, cheap, 300Mhz, JTAG prog., Good tools

FPGA

- Xilinx: XC4xxx, Spartan III, Good free tools available
- Altera: MAX II, Cyclone II, Good free tools available

Building Your Project - Part 2 – *Parts to Use*

Microcontrollers (flash programmable)

- Microchip PIC

 - 16F84, 16F628, 16F877, etc.

- Atmel AVR

 - ATmega128, Atmega8, Atmega48, Tiny26, etc.

- Motorola

 - 68HC11, 68HC908

Compilers/Assemblers/IDEs

- AVR Studio, PICstart,

- Eval versions available

- Codevision (AVR)

- GNU(AVR, PIC, 68HC11, 68HC12)