Physics 116B
Introduction

Physics 116B, 2/3/07

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Physics 116B: Intro. to Digital Electronics

- Why digital?
  - logic levels, logical variables, binary numbers

- Circuit analysis with pulses: DE’s and Laplace transforms
  - Transistors as switches (binary circuit elements: on or off)

- Analog meets digital I: Comparator, Schmitt trigger
  - RC timer circuits: one-shots, relaxation oscillator

- Boolean algebra and logic gates: combinational circuits
  - Includes arithmetic operations

- Flip-flops and counters: sequential circuits
  - Finite state machines and implementation

- Logic circuit makes computer; use computer to do logic

- Analog meets digital II: DAC’s, ADC’s, digital signal processing
  - Sampled signals, sampling theorem
Why Digital?

• Low quiescent power → small size, large parts count

• Ease of replication – not sensitive to component values
  • Stability

• Define logic levels with “noise margin” → noise immunity
  • TTL “High” level $V_{out} > 2.4 \text{ V}$, $V_{in} > 2.0 \text{ V}$
    TTL “Low” level $V_{out} < 0.4 \text{ V}$, $V_{in} < 0.8 \text{ V}$
  • Gives ± 0.4 V noise margin

• Some things are naturally digital – examples:
  • alarm circuits; trigger pulses in physics experiments;
    numerical calculation with binary numbers; data tabulation;
    numerical control system; telegraph communication;
    telephone switching networks; data communication – etc.

• Extend to sampled waveforms for bandwidth-limited signals
Resistor-Transistor Logic (RTL) Inverter

- Example of digital transistor circuit
- Illustrates low power dissipation of BJT in cutoff or saturation
RTL Inverter Pulse Response

• Illustrates some of the things we will be concerned with this quarter

• Simple RTL inverter (logical “NOT” function)

• Use 2N2222A BJT with emitter grounded, collector connected to +5 V through $R_C = 1 \text{ k}\Omega$

• Input at base through 1 kΩ resistor, output at collector

• This is a preview of Lab 13, “Inside Digital IC’s”

• Measure output for 5 V input pulse 50 ns wide
  • Input pulse has 5 ns rise time, care taken to avoid pulse distortion (ringing, reflections, reduced BW etc.)

• Compare with SPICE simulation
Test Pulse Setup

- Input pulse with 5 ns rise time connected to breadboard with terminated 50 Ω coaxial cable
- Oscilloscope has 200 MHz bandwidth
The RTL Inverter on the Breadboard

- Some care taken to reduce stray capacitance due to breadboard
Response for 5V 50 ns Pulse

- 50 ns per division horizontal scale
- 5 V, 50 ns input pulse starts at leftmost vertical division
- Note rapid “fall” time (turn on), extended interval before rise (turn off), slower rise time than fall time
• This is for 5 V input pulse
• Note long storage time due to excess charge in base
• The simulation shows reasonable agreement with the measurement
Add Diodes to Make DTL Logic Circuit

- DTL stands for “Diode-Transistor Logic”
Jacquard Loom Uses Punched Cards to “Program” Woven Patterns

- “Digital” control – precursor of numerically controlled machines
- Pattern of weave could be changed by changing the cards
- Punched card concept later used for tabulation, computation