Semiconductor Electronics Q & A

Session 6e for Electronics and Telecommunications
A Fairfield University E-Course
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Module: Semiconductor Electronics
(in two parts)

- Text: “Electronics,” Harry Kybett, Wiley, 1986, ISBN 0-471-00916-4
- References:
  - Electronics Tutorial (Thanks to Alex Pounds)
  - Electronics Tutorial (Thanks to Mark Sokos)
- 5 - Semiconductors, Diodes and Bipolar Transistors
  - 5 on-line sessions plus one lab
- 6 - FETs, SCRs, Other Devices and Amplifiers
  - 5 on-line sessions plus one lab
- Mastery Test part 3 follows this Module

Section 6: FETs, SCRs, Other Devices and Operational Amplifiers

- 0BJECTIVES: This section reviews additional important semiconductor devices and their applications. The Operational Amplifier is also studied.

Section 6 Schedule:

Session 6a	01/15	Field Effect Transistors	Kybett pp 70 – 77, pp 201-209
Session 6b	01/20	Transistors as a switch	Kybett pp 78 –107
Session 6c	01/22	SCR's, Triacs and UJTs	Notes
Session 6d	01/27	Class A, B, and C Amplifiers	Notes
Session 6e (no class Monday)	01/29	Q & A	
Session 6f (Lab - 02/08, Sat.)	02/05	Operational Amplifiers	Kybett pp 209-215
Session 6g (Quiz 6 due 02/23)	02/10	Review for Quiz 6 (no class 2/17 or 2/19)	
Session 6h	02/24	Discuss Quiz 6	
Session 6i	**02/26**	**Review for MT3**	
MT3	03/01	MT3 Exam	
Session 6j	03/10	Discuss MT3	

Topics

- Semiconductors and Doping
- Diodes and Applications
- Bipolar Transistors
- Transistor Amplifiers

Part 5

- Field Effect Transistors
- Transistors as a switch
- Other Devices
- Class A, B, and C amplifiers
- Operational Amplifiers

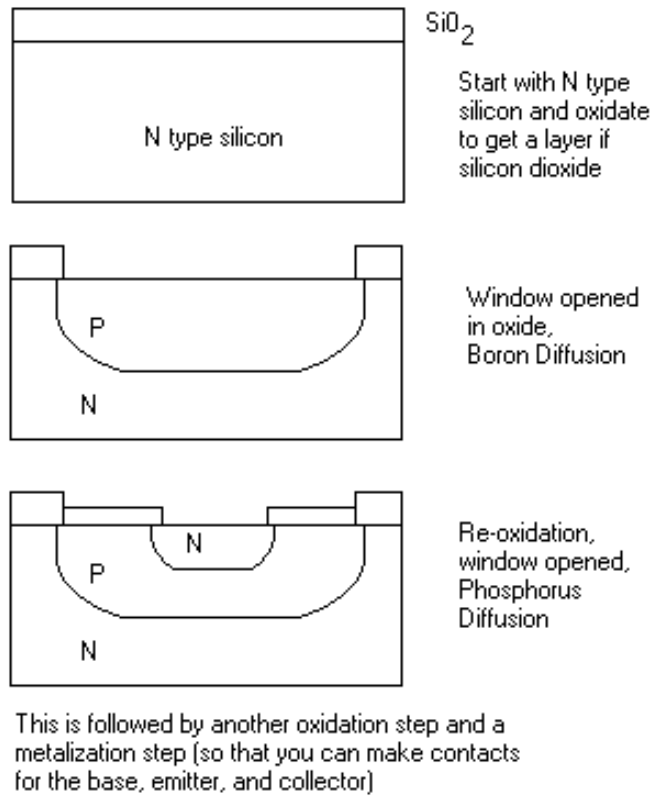
Part 6

Semiconductor Review

- Pure semiconductors (Si, Ge, GaAs) are crystals
  - Elemental semiconductors are in group 4 of the periodic chart
  - Outer 4 electrons are trapped in covalent bonds
  - High resistivity when pure
- Doping
  - N-Type formed by diffusing group 5 impurities
  - P-Type formed by diffusing group 3 impurities
  - More impurities; Less resistivity
  - “Majority” carriers (electrons or holes) determines “Type” (equal carriers combine to cancel each other)
- PN junctions used to create electronic devices (diodes, transistors, etc.)

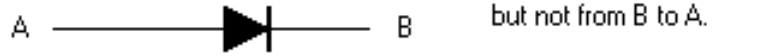
PN Junction Review

- Diffusion creates junctions just below the surface
- A diode is formed as one PN junction
  - Depletion region forms when reverse biased
- A bi-polar transistor is two pn junctions separated by a very narrow “base” region



Diodes

- Diodes are electronic one-way valves
  - Current can flow from anode to cathode
  - Current is blocked in the reverse direction (depletion region)



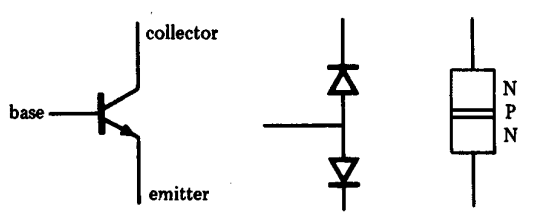
- Forward voltage drop
  - Silicon $V_f = 0.7$ volts
  - Germanium $V_f = 0.3$ volts
  - Schottky $V_f = 0.1$ volts
  - GaAs (LED) $V_f = 2$ volts
- Peak Inverse Voltage (PIV, PRV, Zener)
- These are non-linear devices (no superposition)

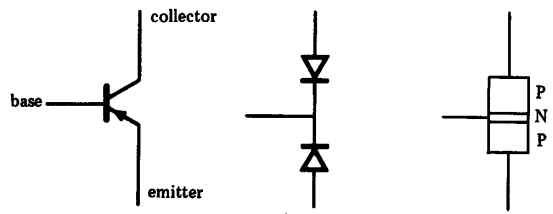
Diode Analysis Review

- First determine if the diode is:
  - Forward biased: conducting with a small voltage drop
  - Reverse biased: an open switch
  - In reverse breakdown (PIV): conducting with a large voltage drop (The Zener voltage)
- Replace the diode with a simple equivalent and then analyze the circuit (Ohm and Kirchoff)
- Check power dissipation in each component to avoid overheating

Bipolar Transistor Review

- Transistors have three leads: base, emitter and collector
- Testing via ohm meter
  - Two diodes back to back: test each separately for impedance ratio
  - Check collector to emitter for high impedance (leakage)
- Beta (β): Current gain $\beta = I_C/I_B$, as long as no "saturation" ($V_{CE} > 0.2v$)
  - Transistor "action"
  - Carriers injected into "depletion region" (very thin base region)
- NPN and PNP: currents and voltages reversed
- Analyze Base current (I_B) flow as a diode
- Collector current: $I_C = I_B * \beta$
- Collector voltage: $V_C = V_{batt} - I_C * R_C$



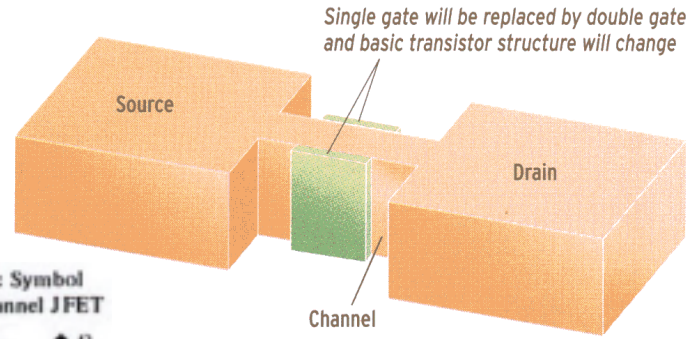


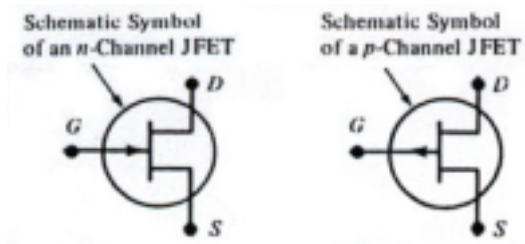
Transistor Review (2)

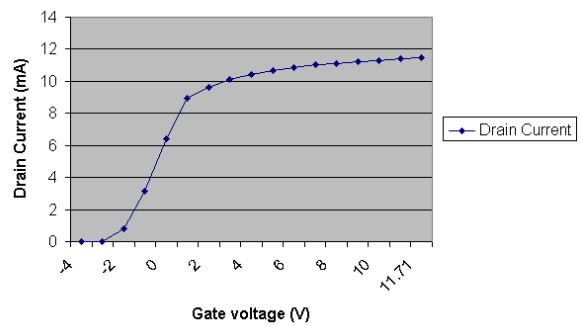
- Amplifier Configurations
  - Common Emitter (voltage gain)
  - Common Collector (buffer, low output impedance)
  - Common Base
    (only used in some high frequency applications)
- Non-Linear Operation
  - Saturation: Transistor is fully on (V_{ce}= 0.2, low β)
  - Cutoff: Transistor is off (V_{be}< 0.5, I_c = 0)

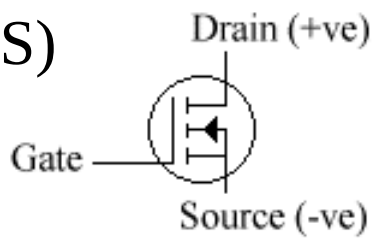
FET Summary

- A voltage-controlled resistor
- Channel material
  - N-channel FET
  - P-channel FET
- FET types
  - Junction FET (JFET)
  - Metal Oxide Gate FET (MOSFET)
  - Complementary Symmetry MOSFET (CMOS)
- Simple high input impedance amplifiers
- Very effective as switches



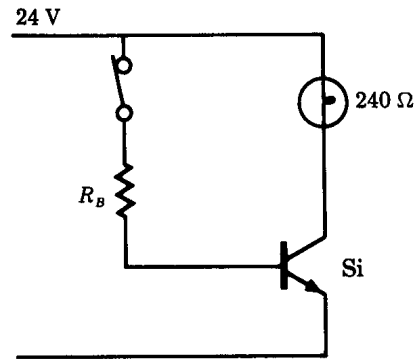


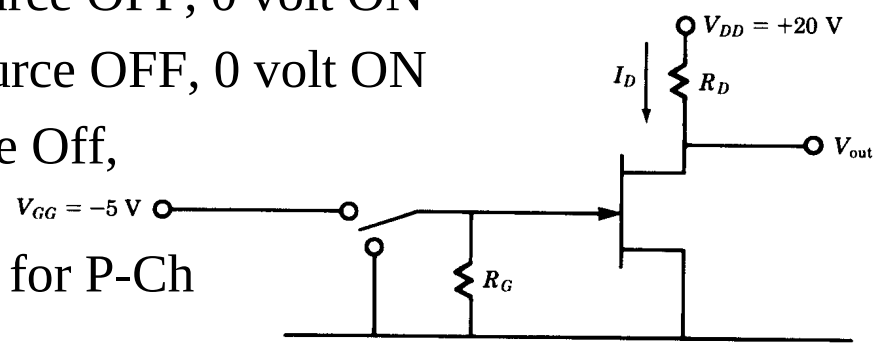




Transistor Switch Summary

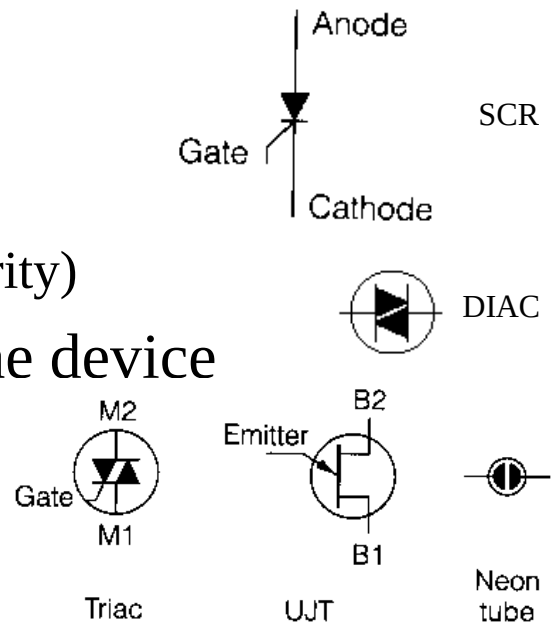
- Can be either Bipolar or FET
- They operate fully in saturation or cutoff
  - Cutoff: no current
  - Saturation: Vce < 0.2 v
- Bipolar: Current controlled switch
  - NPN: +0.7 volt base-emitter ON
  - PNP: -0.7 volt base-emitter ON
- FET: Voltage controlled switch
  - N-Ch JFET: -5 volt gate-source OFF, 0 volt ON
  - P-Ch JFET: +5 volt gate-source OFF, 0 volt ON
  - MOSFET: 0 volt gate-source Off,
    5 volt gate-source ON
    Positive for N-Ch, Negative for P-Ch





Other Devices

- SCR: Half wave current controlled triggered switch
  - 4 layers, normally off, triggered on
  - Reverse bias turns it off
- Triac: Full wave triggered switch
  - Effectively two SCR's in parallel (reverse polarity)
- Diac (and neon bulb): 2-terminal Avalanche device
  - Normally high impedance,
  - Low impedance triggered by threshold voltage
  - Reverse bias turns it off
- UJT: 3-terminal voltage controlled avalanche/recovery (action is between the emitter and base1)

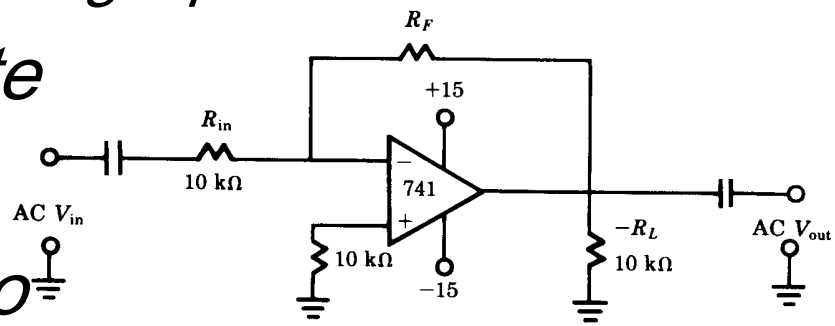


Amplifier Summary

Class	Duty Cycle	Efficiency	Application	Notes
A	100%	Low	Linear small signal	Transistor always on
B (AB)	50%	~ 50%	Linear power	Each transistor conducts half the time
C	< 50%	~ 80%	RF Power	Transistor conducts for short pulse; Resonant circuit produces sine wave
D	High speed switching	~ 85%	DC power supplies and Low frequency linear power	Not in Mastery Test

Op-Amp Summary

- *Gain - infinite (for all practical purposes)*
  - $\mathbf{A_f = -R_f/R_{in}}$ *using the inverting input and feedback*
- *Input impedance - infinite*
- *Differential input*
- *Output impedance - zero (short circuit protected)*
- *Bandwidth - high*
  - *Slew Rate: sets bandwidth*
- *Voltage out - zero (when voltages into each input are equal)*



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MT3	**03/01**	**MT3 Exam – 9 AM**	Cheshire, 99 Realty Drive Tim Bunce – PSC Supervisor
Session 6j	03/10	Discuss MT3	