Field Effect Transistors

Session 6a 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

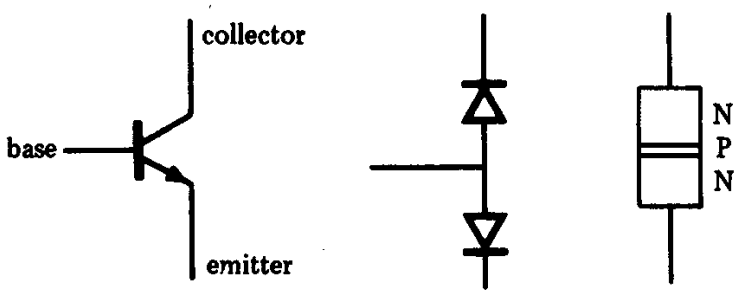
- 0BJECTIVES: This section reviews additional important semiconductor devices and their applications. The Operational Amplifier is also studied.

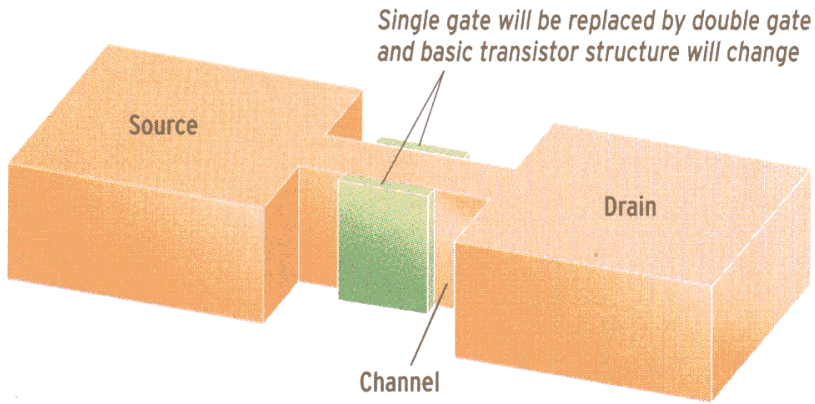
Section 6 Schedule:

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	
Session 6c (Lab - 02/01, Sat.)	01/27	Class "A", "B", and "C" Amplifiers	
Session 6e	02/05	Op-Amps	Kybett pp 209-215
Session 6f (Quiz 6 due 02/23)	02/10	Review for Quiz 6	
Session 6g	02/24	Discuss Quiz 6	
Session 6h	02/26	Review for MT3	
MT3	03/02	MT3 Exam	
Session 6i	03/10	Discuss MT3	

The Field Effect Transistor (FET)

- Bipolar Transistor: two diodes, thin base, a current controlled device
- FET: A thin current carrying “channel” pinched off by an electric field



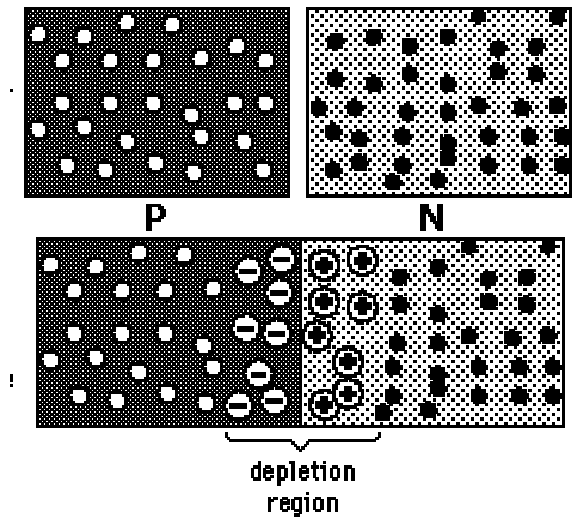


Junction FET (JFET)

- Formed by two diodes back to back
- The diodes MUST be reverse biased (forward biasing = high current = poof)
- Channel
  - The current “channel” (drain to source) is lateral through the central material
  - N-channel - N-type central material
  - P-channel - P-type central material
- Depletion regions (two) pinch off the channel as the diode reverse bias (gate voltage) is increased

Junction Diode Operation

- PN junction forms at the PN boundary
- Holes (P) and free electrons (N) combine
- “Depletion” Region forms (no free carriers)
- Forward “bias”; allows current
  - positive voltage on P
  - negative voltage on N
- Reverse “bias”; no current
  - positive voltage on N
  - negative voltage on P

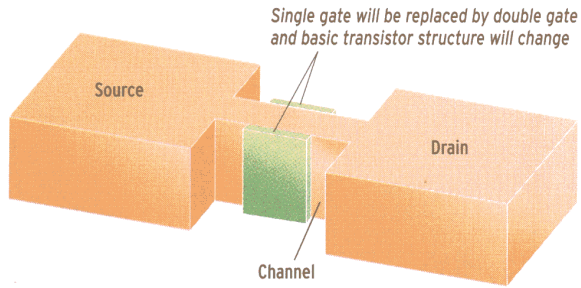


Insulated Gate FET
(MOSFET)

- Thin channel isolated from substrate by reverse biased junction
- Silicon dioxide insulating layer on top
- Metal “Gate” above SiO_2
- Capacitor formed between gate and channel
- Negative charge on gate (N-channel) repels carriers and pinches off the channel

FET Operation

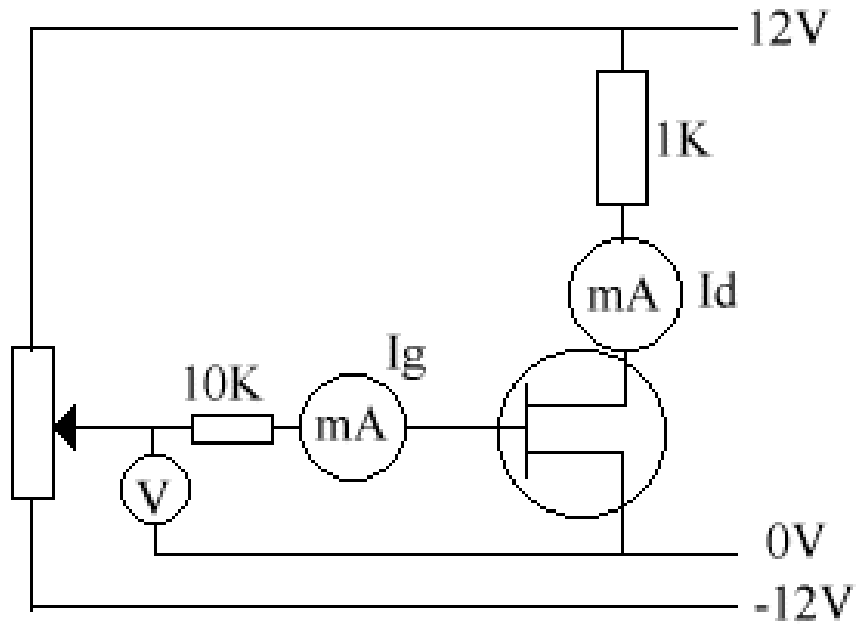
- The “Channel” is a conducting path from the source to the drain.
- A negative voltage on the “Gate” (for an N-Channel FET) produces an electric field that narrows the channel.



- As the gate voltage is made more negative, the gat narrows further thereby increasing the resistance to current flow.
- At a still more negative gate voltage the channel is pinched off and no current can flow.
- The FET is effectively a voltage controlled resistance

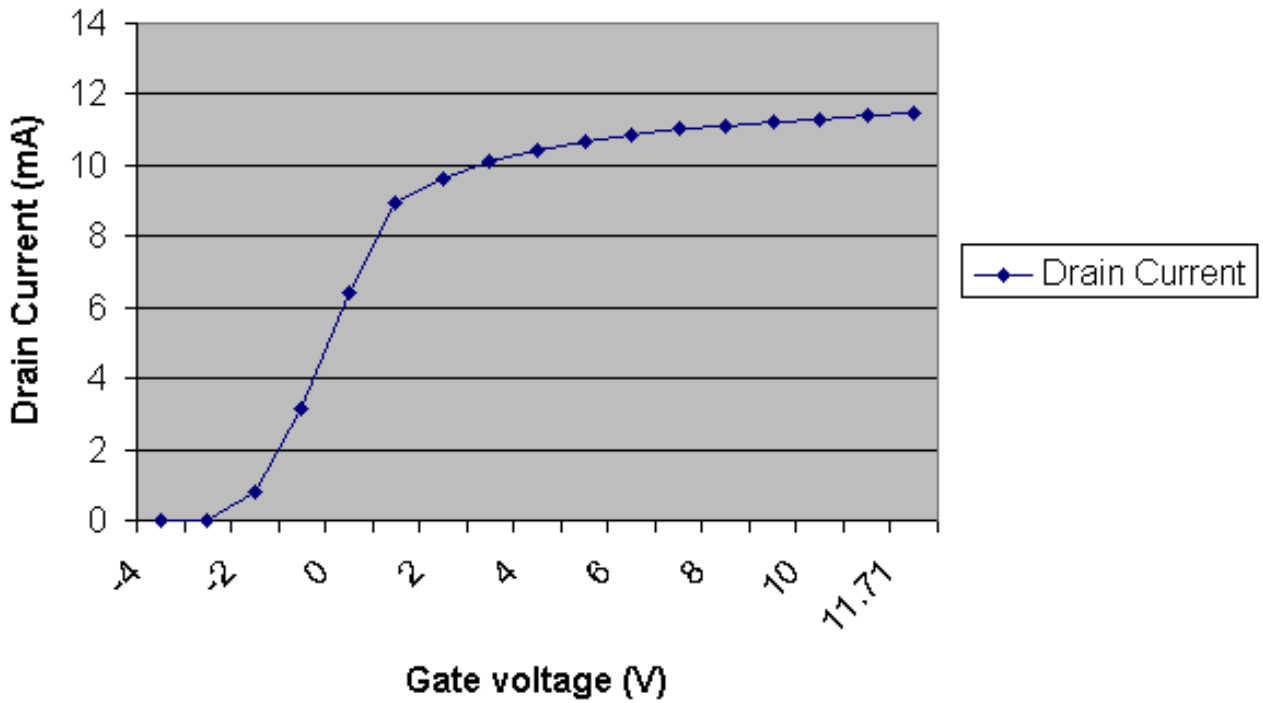
Measuring FET Characteristics

- Use a potentiometer to vary the gate voltage
- Apply a supply voltage from Drain to Source
- Measure the drain current



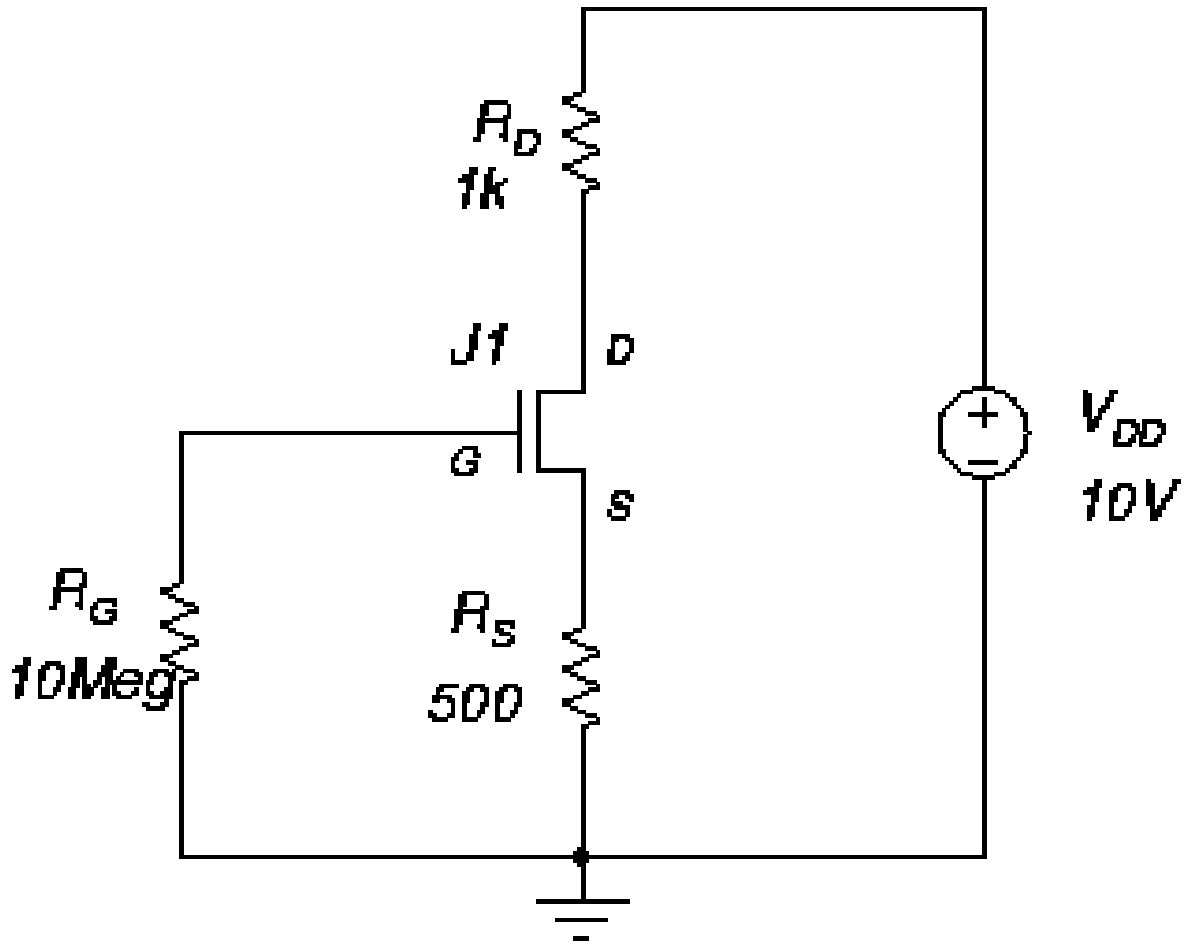
FET Characteristic curve

- A large negative gate voltage pinches off the channel
- As the gate voltage is made less negative, the channel opens and current flows from source to drain until the channel is fully open at about Vg = 0.

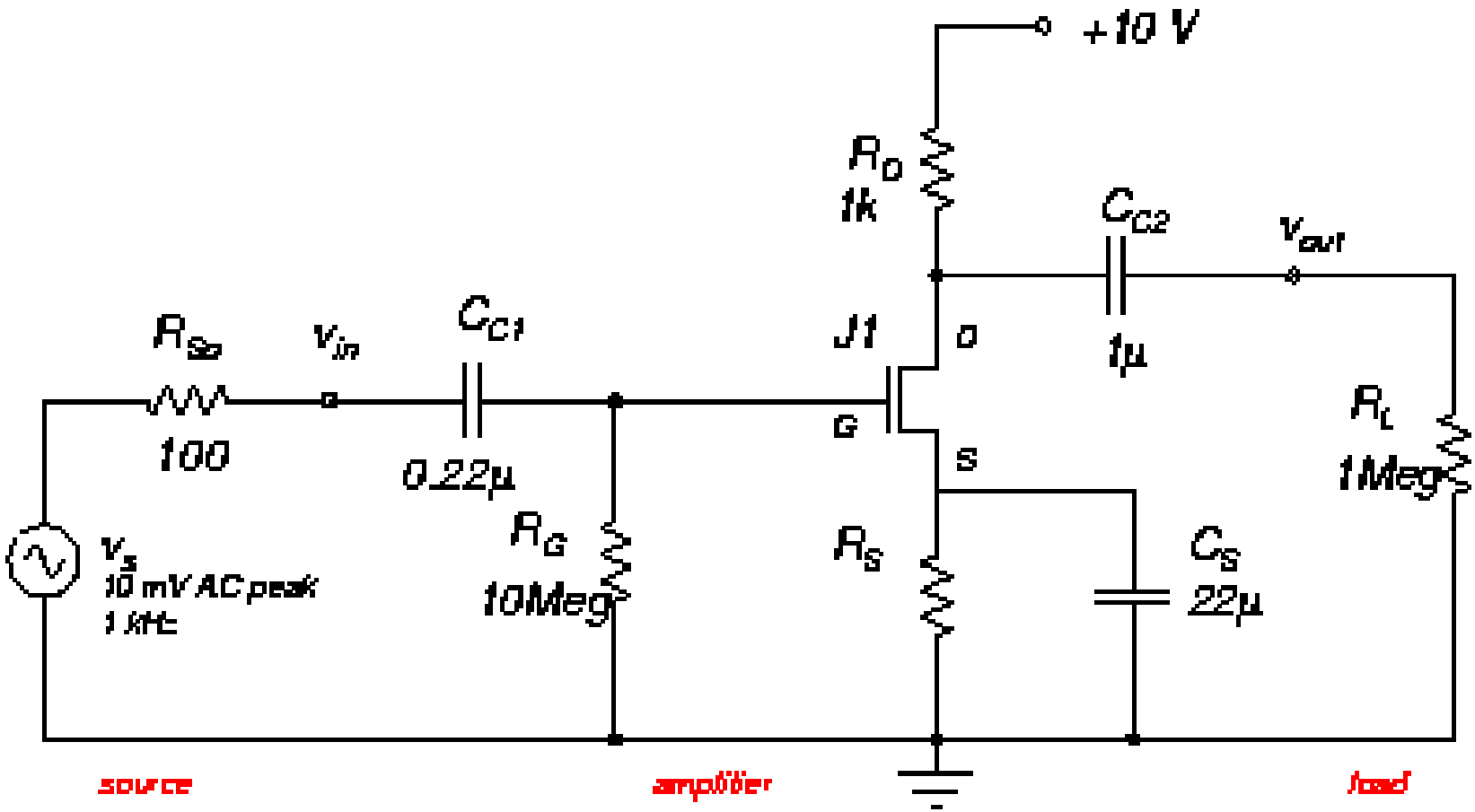


FET Biasing

- The drain/source current raises the average channel voltage
- The effective gate voltage is then negative.
- A stable or “quiescent” state is achieved.

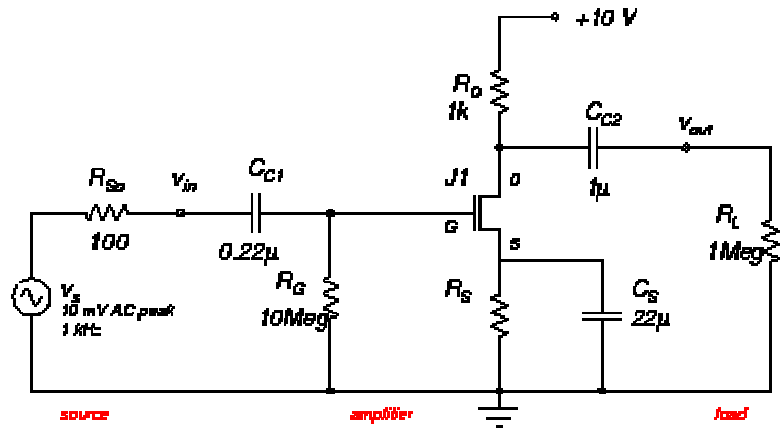


An FET Amplifier



Analysis

- The gate voltage is zero
- DC drain current flows through the source resistor raising the channel voltage till the current stabilizes



- An AC signal is superimposed on the gate
- The drain current now varies proportionally with the gate voltage causing the drain voltage to also vary.
- The AC components of the drain voltage passes through the coupling capacitor to the load resistor.

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 (Session 6b)

FET Comparison to Bipolar
(Amplifier)

Bipolar Transistor (NPN – Common Emitter)	N- channel FET (Common Drain)
Base Current Controlled	Gate Voltage Controlled
Low Input Impedance	High Input Impedance
Current Gain (β)	Almost infinite Current gain
High Voltage Gain	Small Voltage Gain
Low Output Impedance	Low Output Impedance

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