Implementing with SPST Switches

Step (1): Implement all switches w/ SPST

Non-trivial step

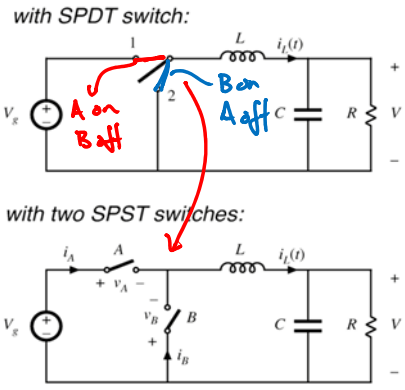
Now possible to have

X A on & B on → (shoot-through LARGE loss)

ok A off & B off → (dead time)

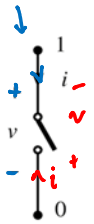
↳ used in discontinuous conduction mode (DCM) → Chapter 5

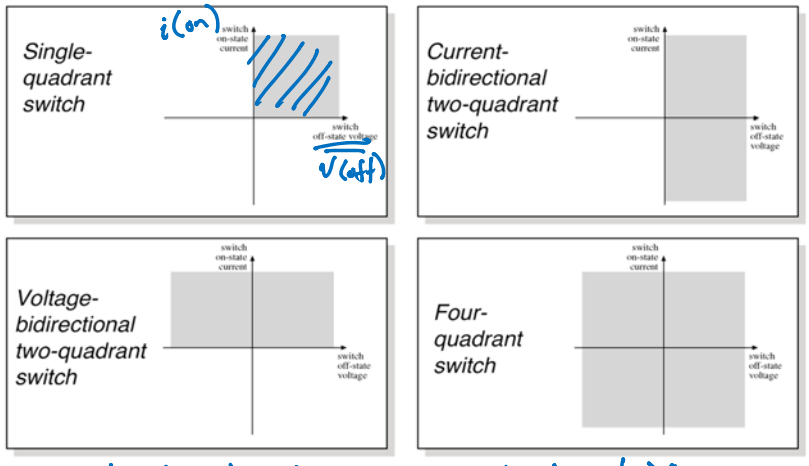
Buck converter



SPST Operating Quadrants

Step 2: Determine polarities of v(off) i(on) in the circuit



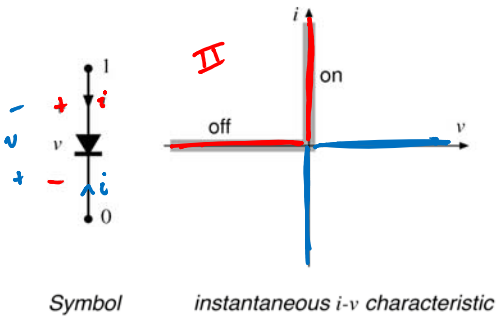


→ use Ch. 2/3 techniques

$N_{off}, i_{on} = f(V_g, R, D)$

know $V_g > 0$, $R > 0$, $0 < D < 1$

The Diode



Symbol instantaneous *i-v* characteristic

- *A passive switch*
- *Single-quadrant switch:*
- *can conduct positive on-state current*
- *can block negative off-state voltage*
- *provided that the intended on-state and off-state operating points lie on the diode i-v characteristic, then switch can be realized using a diode*

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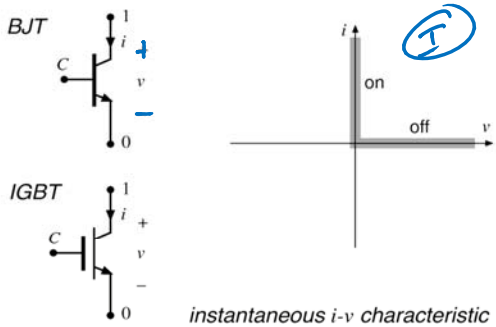
(Insulated Gate) Bipolar Junction Transistor



instantaneous *i-v* characteristic

- *An active switch, controlled by terminal C*
- *Single-quadrant switch:*
- *can conduct positive on-state current*
- *can block positive off-state voltage*
- *provided that the intended on-state and off-state operating points lie on the transistor i-v characteristic, then switch can be realized using a BJT or IGBT*

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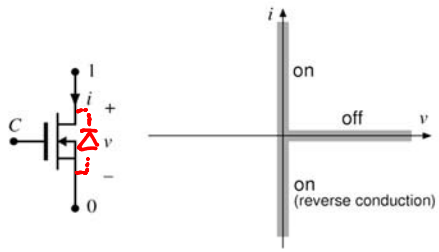
MOSFET

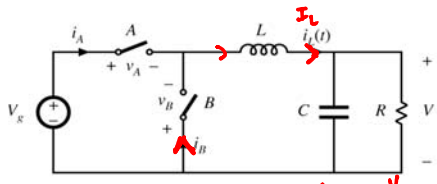
Body shorted to source



Symbol instantaneous i-v characteristic

- An active switch, controlled by terminal C
- Normally operated as single-quadrant switch:
- can conduct positive on-state current (can also conduct negative current in some circumstances)
- can block positive off-state voltage
- provided that the intended on-state and off-state operating points lie on the MOSFET i-v characteristic, then switch can be realized using a MOSFET

Buck Converter: Switch Realization



from previous analysis:

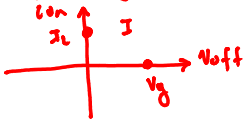
I_L

$0 \le V \le V_g$

$I_L > 0$

(A): $i_{A(on)} = I_L > 0$ $\left(I_L = \frac{V}{R} = \frac{DV_g}{R}\right)$

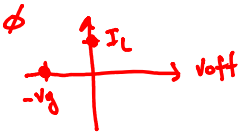
$v_{A(off)} = V_g > 0$



→ or or

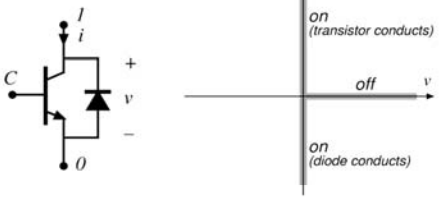
(B): $i_{B(on)} = I_L > 0$

$v_{B(off)} = -V_g < 0$



→

Current Bidirectional Two-Quadrant



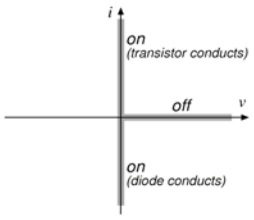
BJT / anti-parallel diode realization

instantaneous *i-v* characteristic

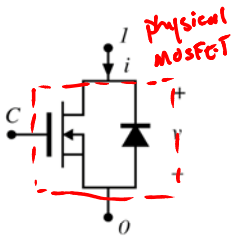
- *Usually an active switch, controlled by terminal C*
- *Normally operated as two-quadrant switch:*
- *can conduct positive or negative on-state current*
- *can block positive off-state voltage*
- *provided that the intended on-state and off-state operating points lie on the composite i-v characteristic, then switch can be realized as shown*

MOSFET Body Diode

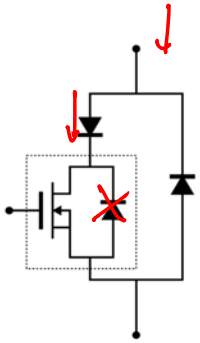
a bit outdated



Power MOSFET characteristics

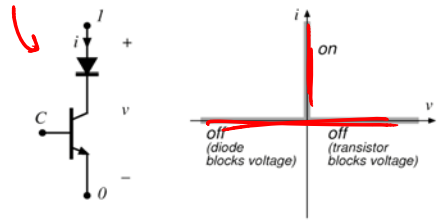


Power MOSFET, and its integral body diode



Use of external diodes to prevent conduction of body diode

Voltage-bidirectional Two-Quadrant

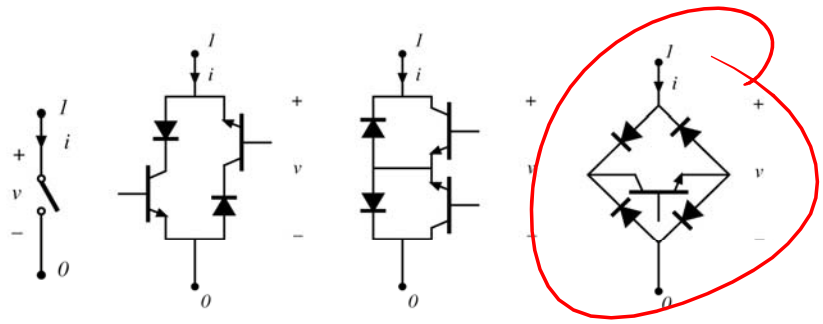


BJT / series diode realization

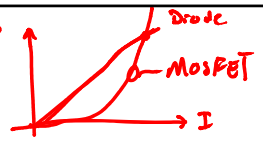
instantaneous *i-v* characteristic

- *Usually an active switch, controlled by terminal C*
- *Normally operated as two-quadrant switch:*
- *can conduct positive on-state current*
- *can block positive or negative off-state voltage*
- *provided that the intended on-state and off-state operating points lie on the composite i-v characteristic, then switch can be realized as shown*
- *The SCR is such a device, without controlled turn-off*

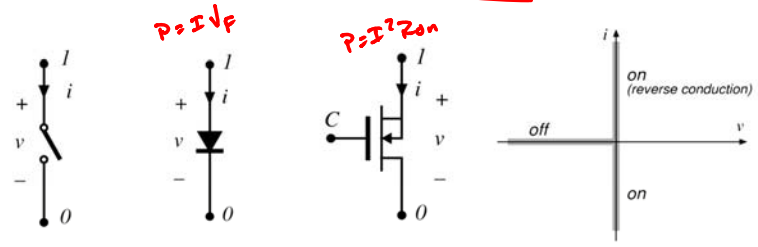
Four-Quadrant Switches



Synchronous Rectifiers



Replacement of diode with a backwards-connected MOSFET, to obtain reduced conduction loss



ideal switch | *conventional diode rectifier* | *MOSFET as synchronous rectifier* | *instantaneous i-v characteristic*

4.2: Survey of Power Semiconductor Devices

- Power diodes
- Power MOSFETs
- Bipolar Junction Transistors (BJTs)
- Insulated Gate Bipolar Transistors (IGBTs)
- Thyristors (SCR, GTO, MCT)

- On resistance vs. breakdown voltage vs. switching times
- Minority carrier and majority carrier devices

Switching Nonidealities