ترانزيستور ماسفت قدرت
Power MOSFET

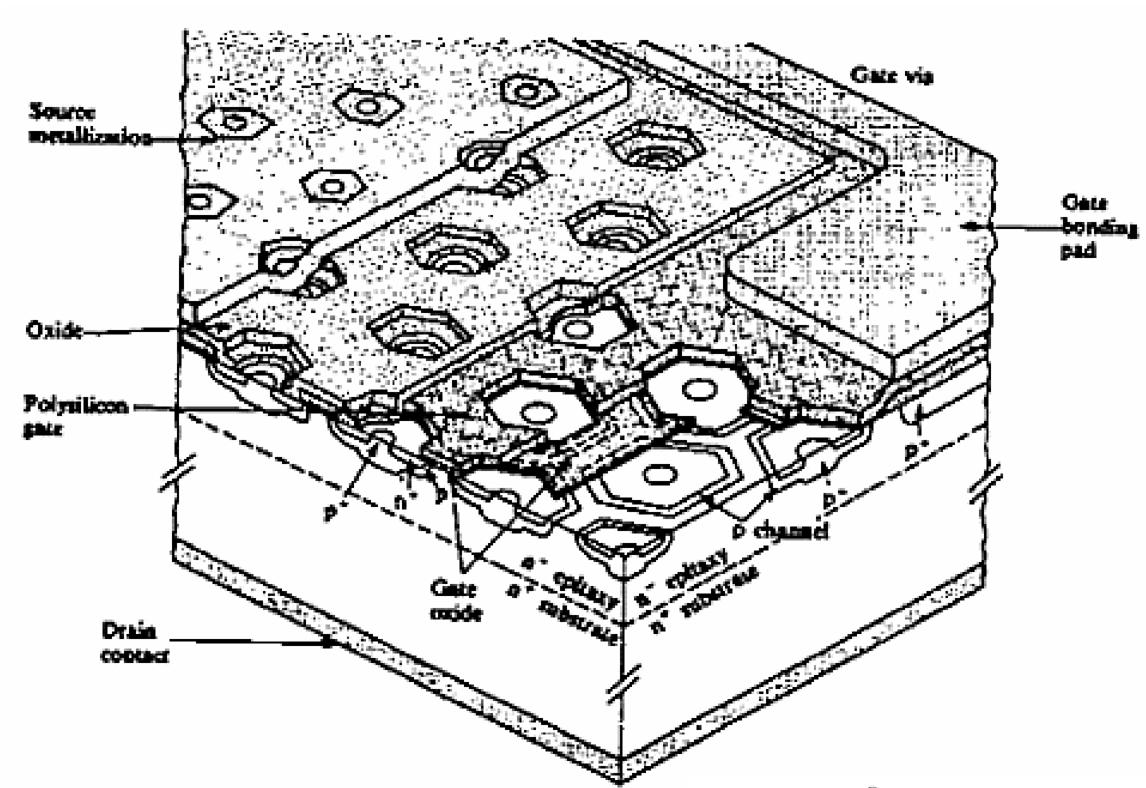
- تاريخچه
- ساختمان و اصول كار
- مشخصه ها
- مدارهاي راه انداز

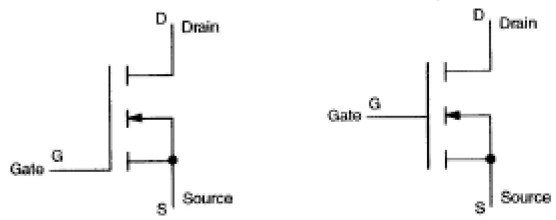
تاريخچه و ويژگي ها

- پيدايش: ۱۹۸۰
- اولين سازنده: شرکت International Rectifier
- سريعترين کليد الکترونيک قدرت
- تفاوت عمده با ماسفت سيگنال: ماسفت قائم VMOS
- دقت فن آوري ساخت: رده LSI
- محدوده قدرت قطع: چند وات تا حدود صد کيلو وات

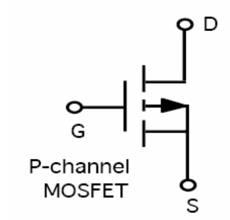
ساختمان

- ساختار سلولي
- پياده سازي قائم
- اتصال سورس در رو
- اتصال درين در زير



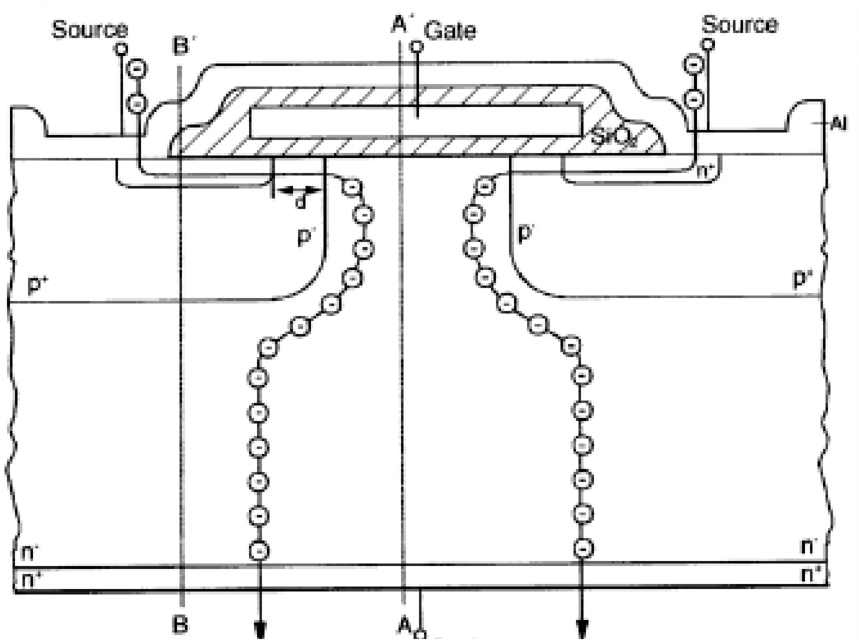


نماد ماسفت کانال n



نماد ماسفت کانال p

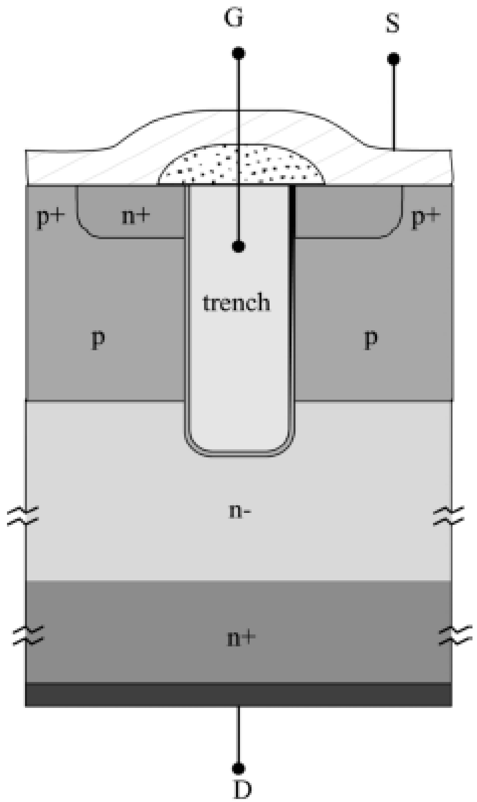
نمايش مقطعي يک سلول در دو نوع ماسفت قدرت



Power MOSFET (SIPMOS planar gate structure)

d: length of channel

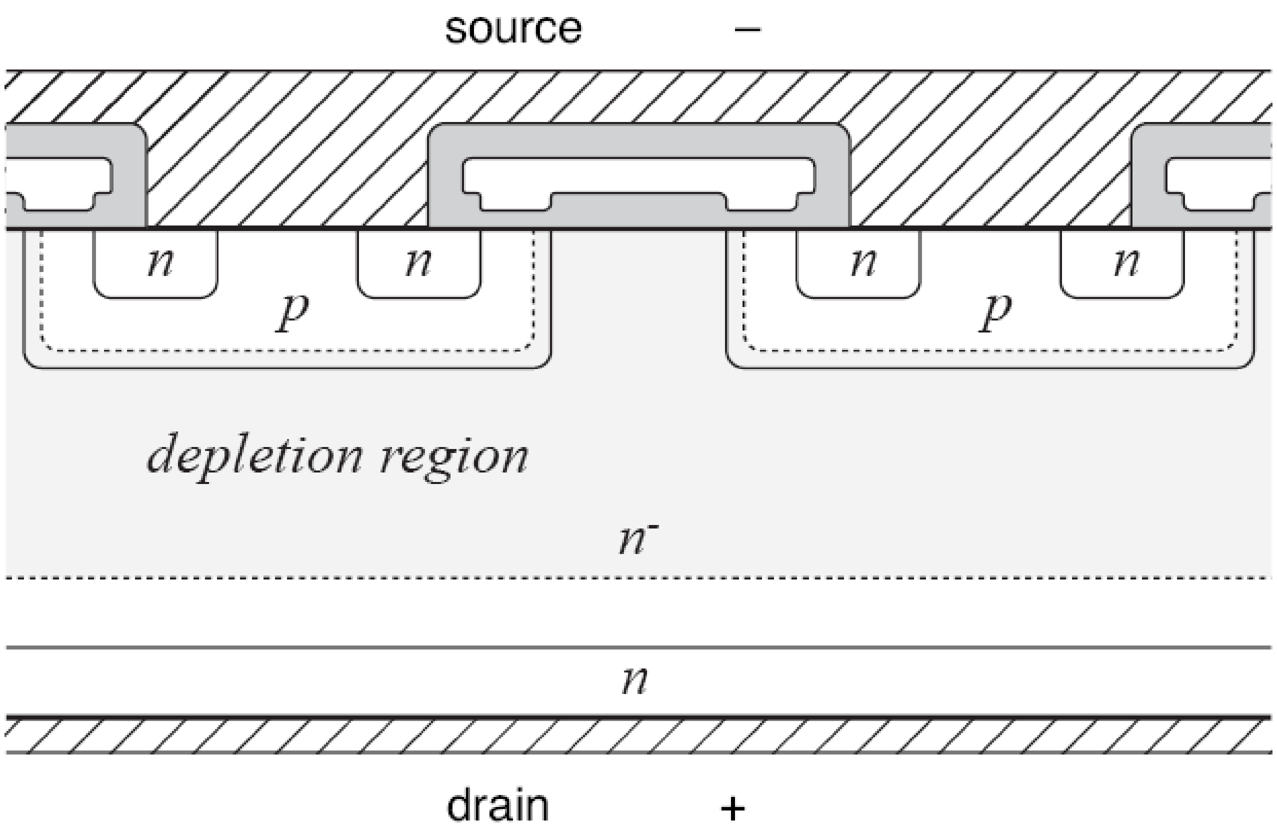
ساختارماسفت قدرت با گيت سطحي (ساختار متعارف)



c) MOSFET with trench gate structure

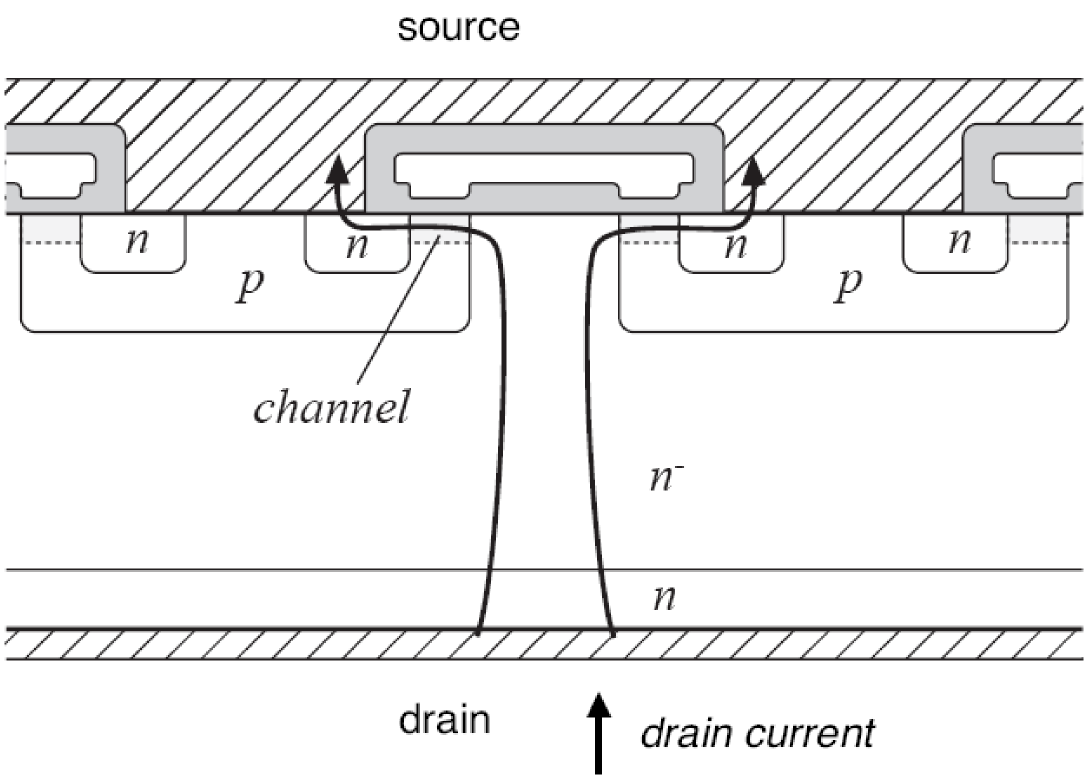
ساختار ماسفت با گيت به صورت كانال عميق

مکانیسم تحمل ولتاژ



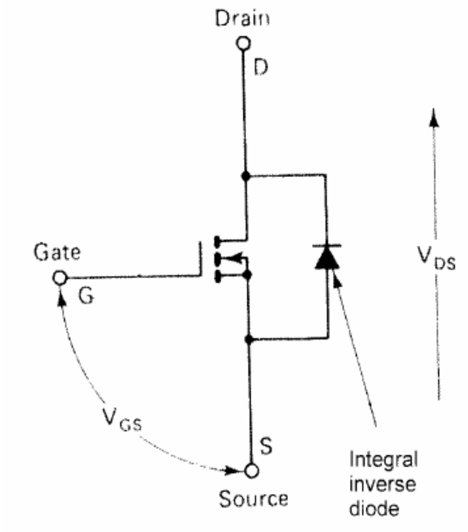
- p-n^- junction is reverse-biased
- off-state voltage appears across n^- region

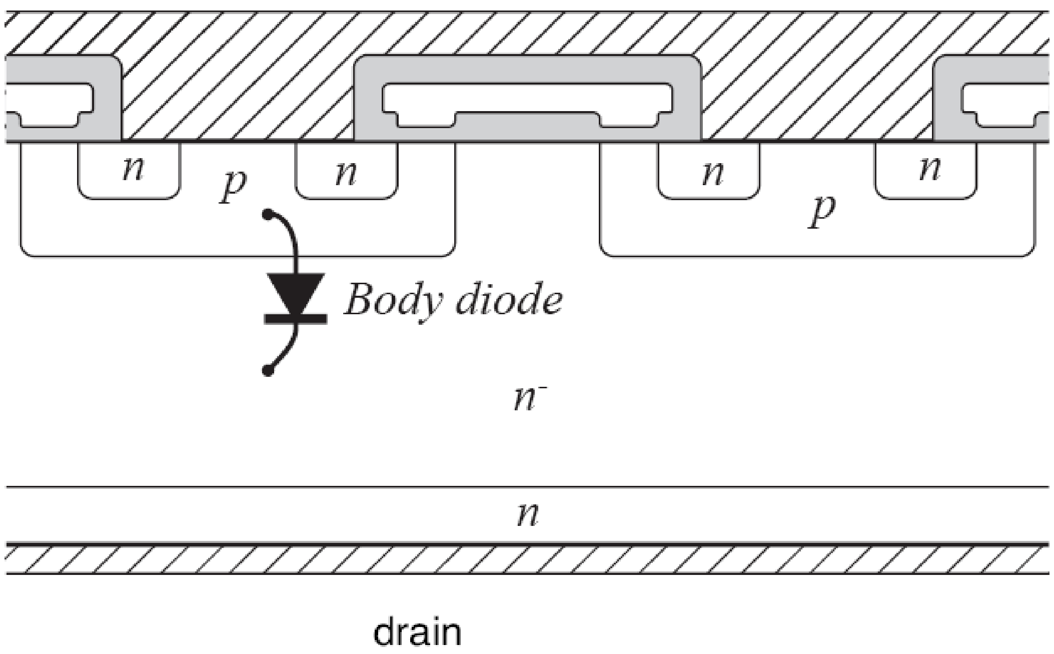
مکانیسم عبور جریان



- p-n^- junction is slightly reverse-biased
- positive gate voltage induces conducting channel
- drain current flows through n^- region and conducting channel
- on resistance = total resistances of n^- region, conducting channel, source and drain contacts, etc.

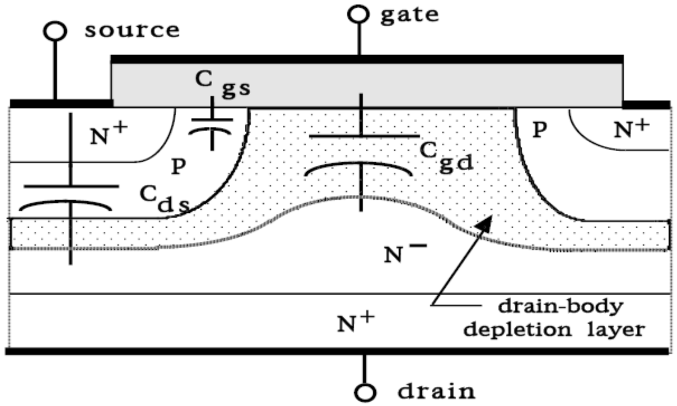
دیود بدنه در ماسفت قدرت

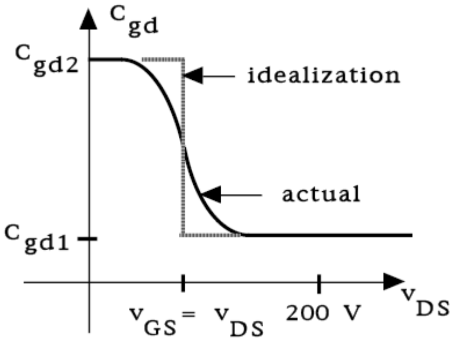


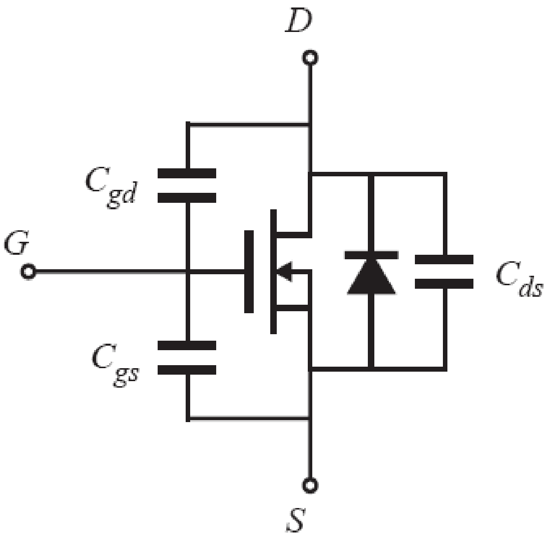


- p-n^- junction forms an effective diode, in parallel with the channel
- negative drain-to-source voltage can forward-bias the body diode
- diode can conduct the full MOSFET rated current
- diode switching speed not optimized —body diode is slow, Q_r is large

خازنهاي ماسفت





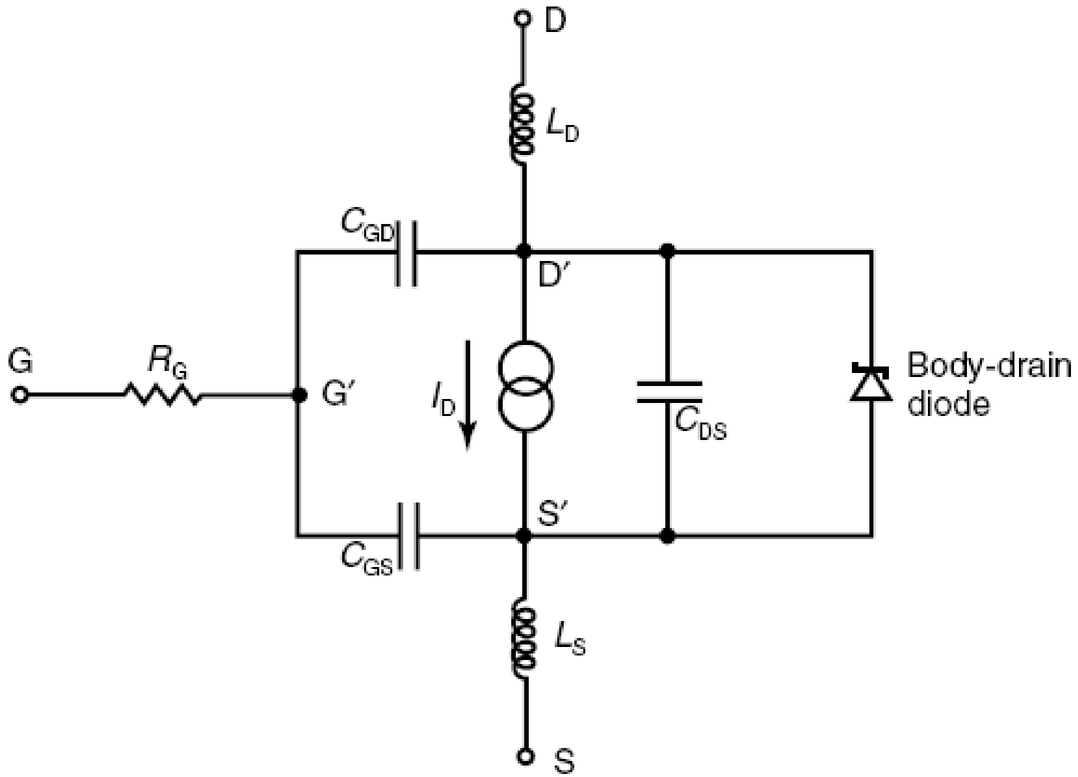


- C_{gs} : large, essentially constant
- C_{gd} : small, highly nonlinear
- C_{ds} : intermediate in value, highly nonlinear
- switching times determined by rate at which gate driver charges/discharges C_{gs} and C_{gd}

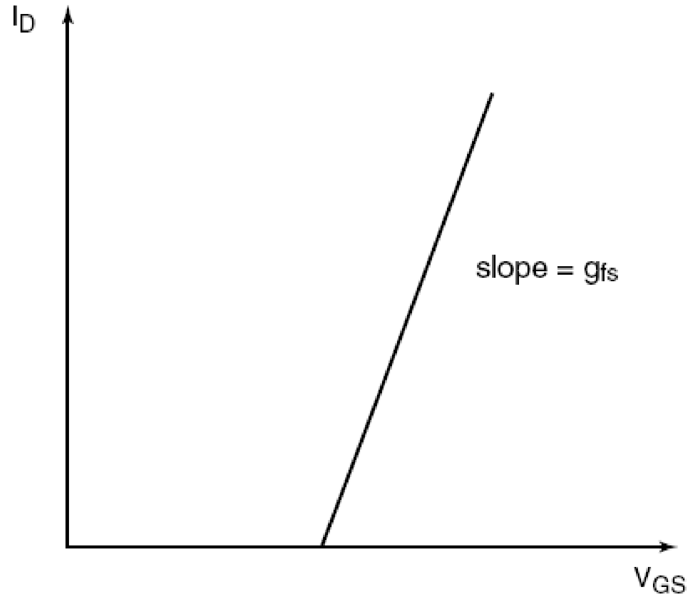
$$C_{ds}(v_{ds}) = \frac{C_0}{\sqrt{1+\frac{v_{ds}}{V_0}}}$$

$$C_{ds}(v_{ds}) \approx C_0\sqrt{\frac{V_0}{v_{ds}}} = \frac{C_0'}{\sqrt{v_{ds}}}$$

مدار معادل ديناميكي ماسفت

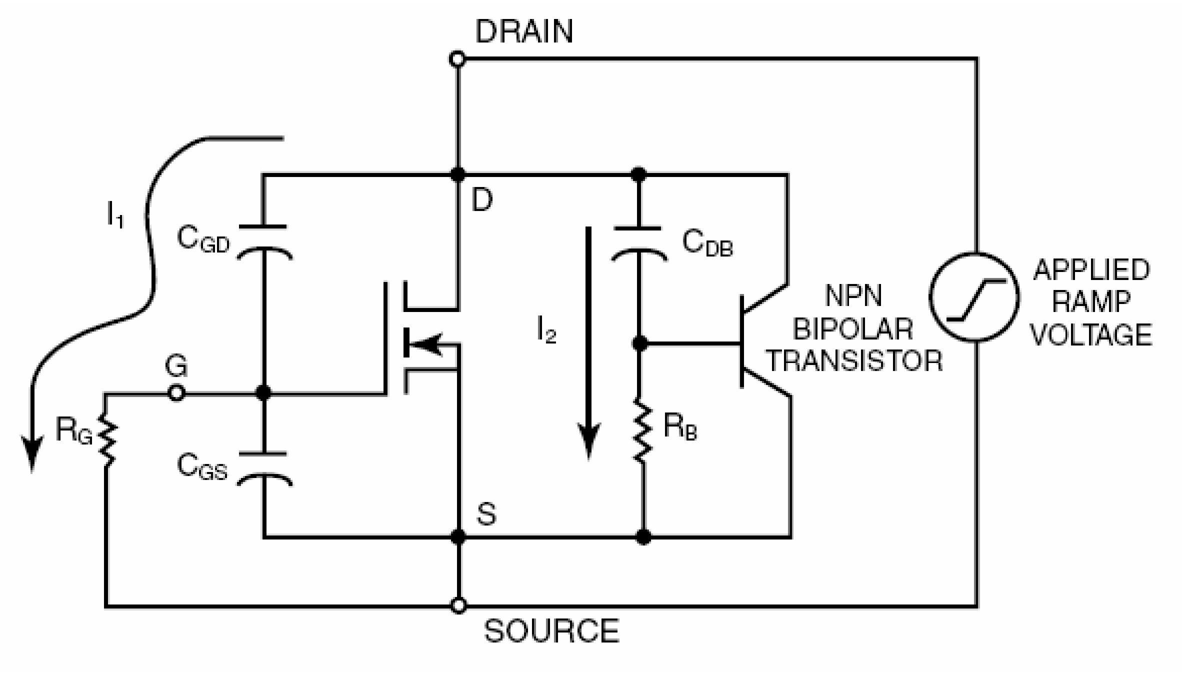


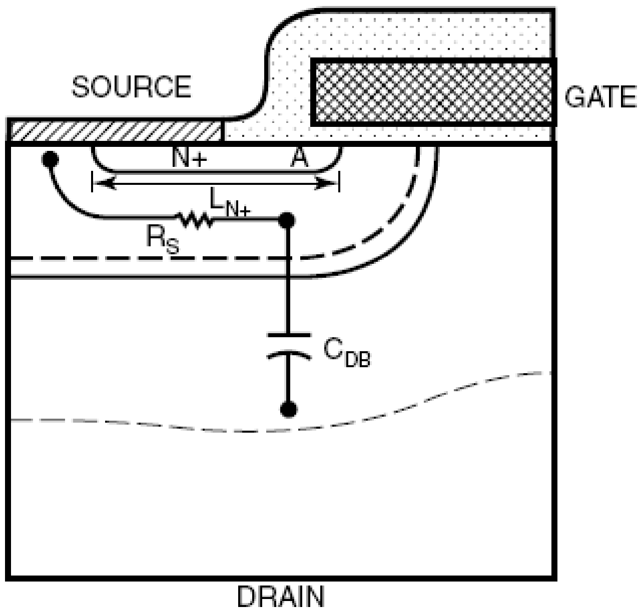
عناصر پارازيت در مدار معادل ماسفت



مشخصه انتقالي

محدودیت dV/dt در ماسفت





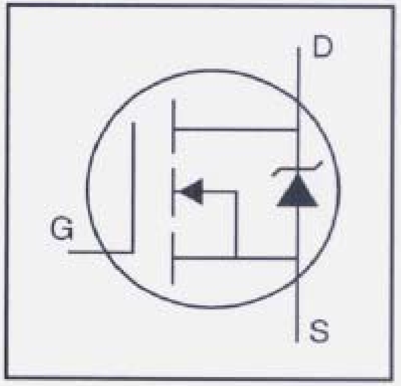
ويژگي هاي ماسفت قدرت

- A majority-carrier device: fast switching speed
- Typical switching frequencies: tens and hundreds of kHz
- On-resistance increases rapidly with rated blocking voltage
- Easy to drive
- The device of choice for blocking voltages less than 500V
- 1000V devices are available, but are useful only at low power levels (100W)
- Part number is selected on the basis of on-resistance rather than current rating

پارامترها و مشخصه هاي مهم ماسفت قدرت

IRFP150NPbF

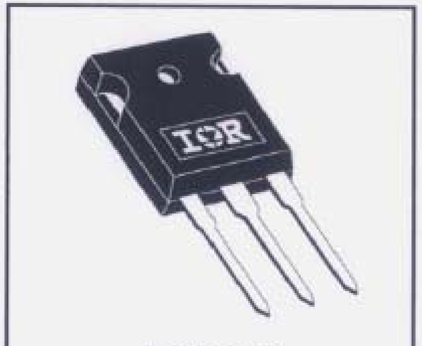
HEXFET® Power MOSFET



$V_{DSS} = 100V$

$R_{DS(on)} = 0.036\Omega$

$I_D = 42A$



TO-247AC

Absolute Maximum Ratings

	Parameter	Max.	Units
I_D @ T_C = 25°C	Continuous Drain Current, V_{GS} @ 10V	42	A
I_D @ T_C = 100°C	Continuous Drain Current, V_{GS} @ 10V	30	
I_{DM}	Pulsed Drain Current ①⑤	140	
P_D @T_C = 25°C	Power Dissipation	160	W
	Linear Derating Factor	1.1	W/°C
V_{GS}	Gate-to-Source Voltage	± 20	V

مشخصه خروجي

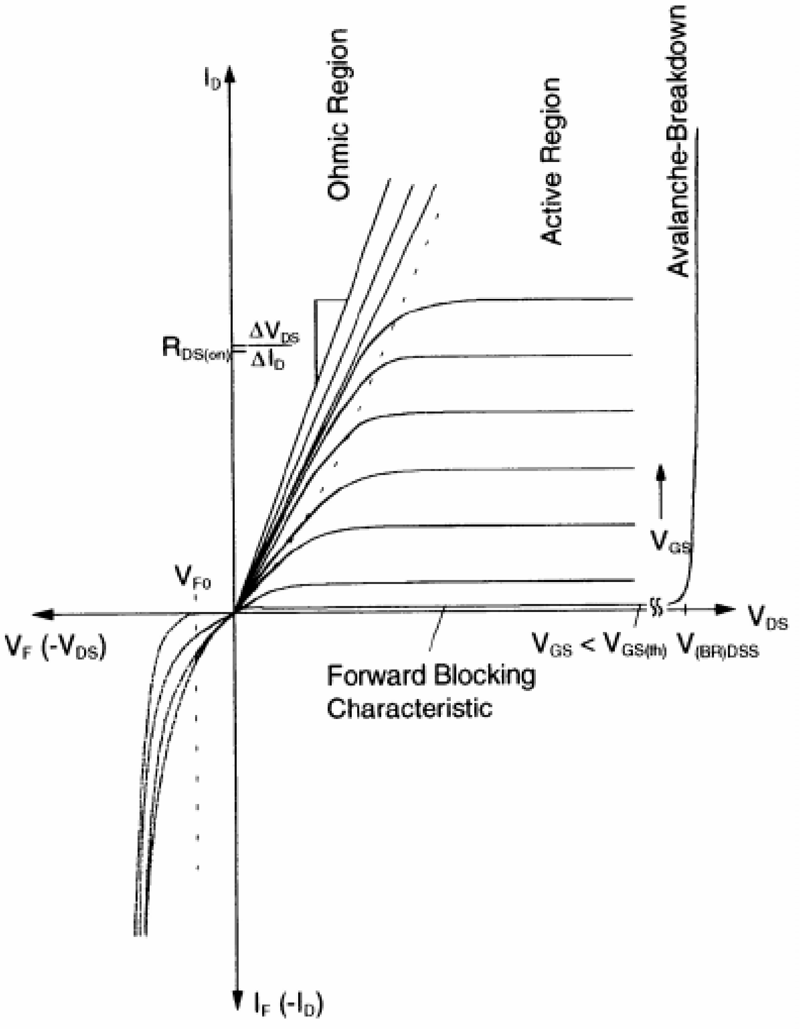


Fig. 3 a) Output characteristic of MOSFETs

مشخصه خروجي در برگه اطلاعات

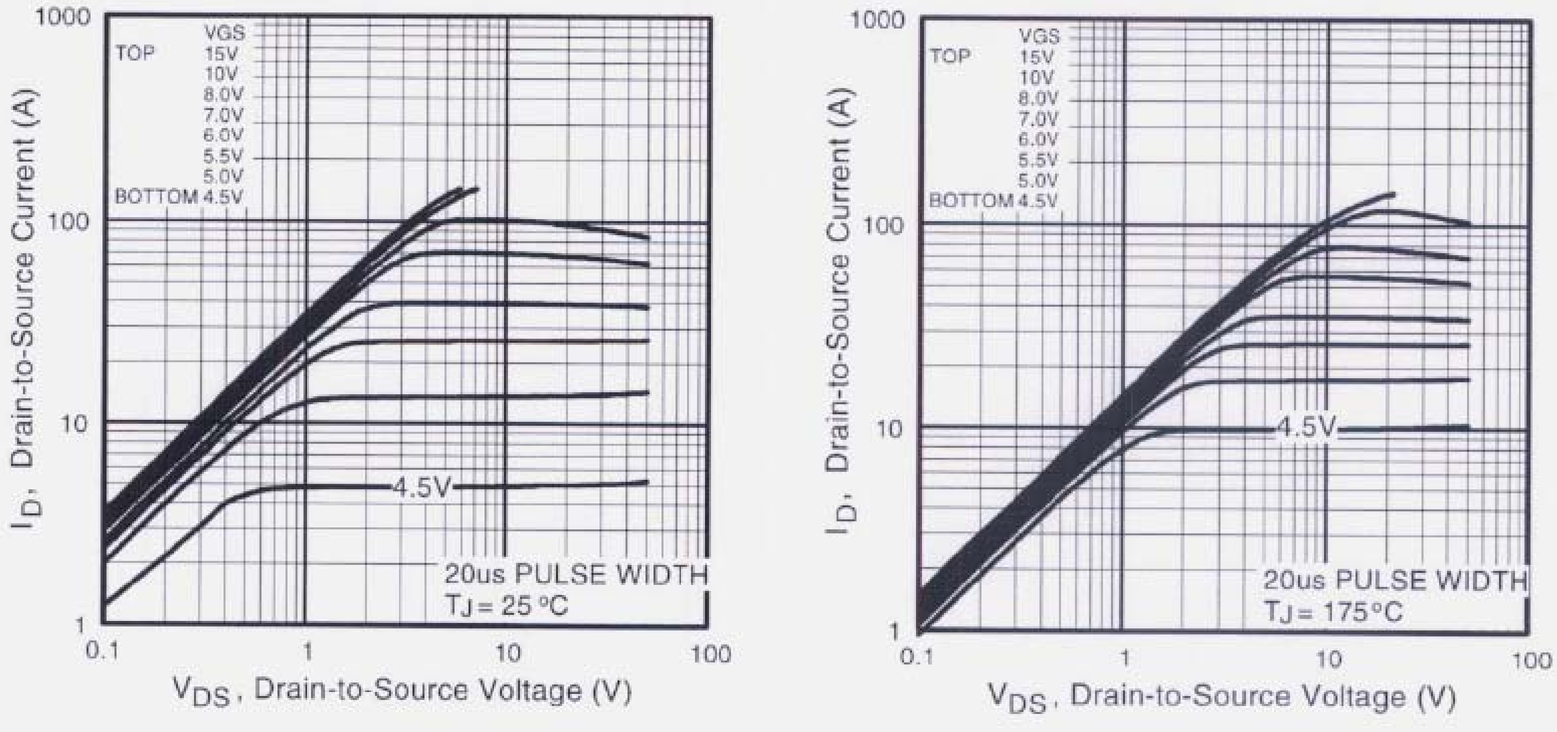
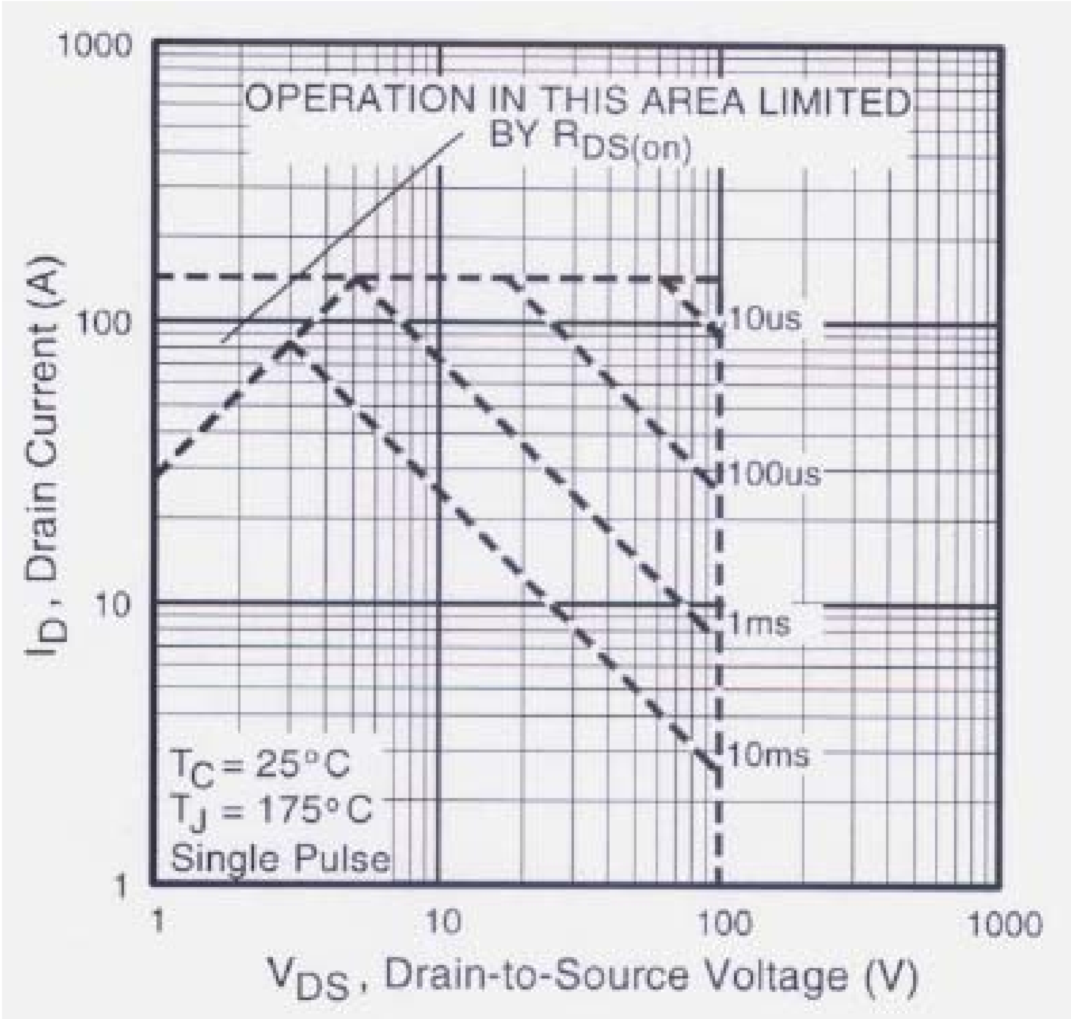


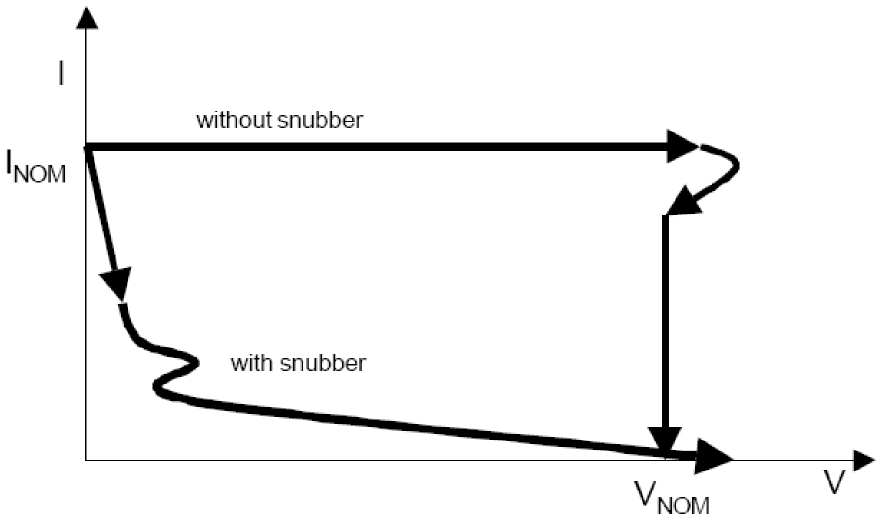
Fig 1. Typical Output Characteristics

Fig 2. Typical Output Characteristics

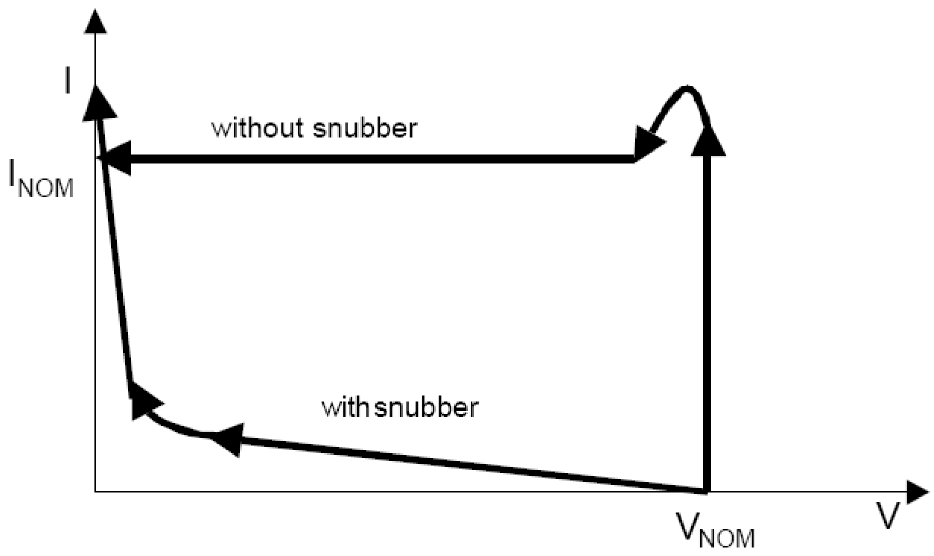
مشخصه ناحیه کار ایمن



مسیر نقطه کار ماسفت به هنگام وصل و قطع بار سلفي

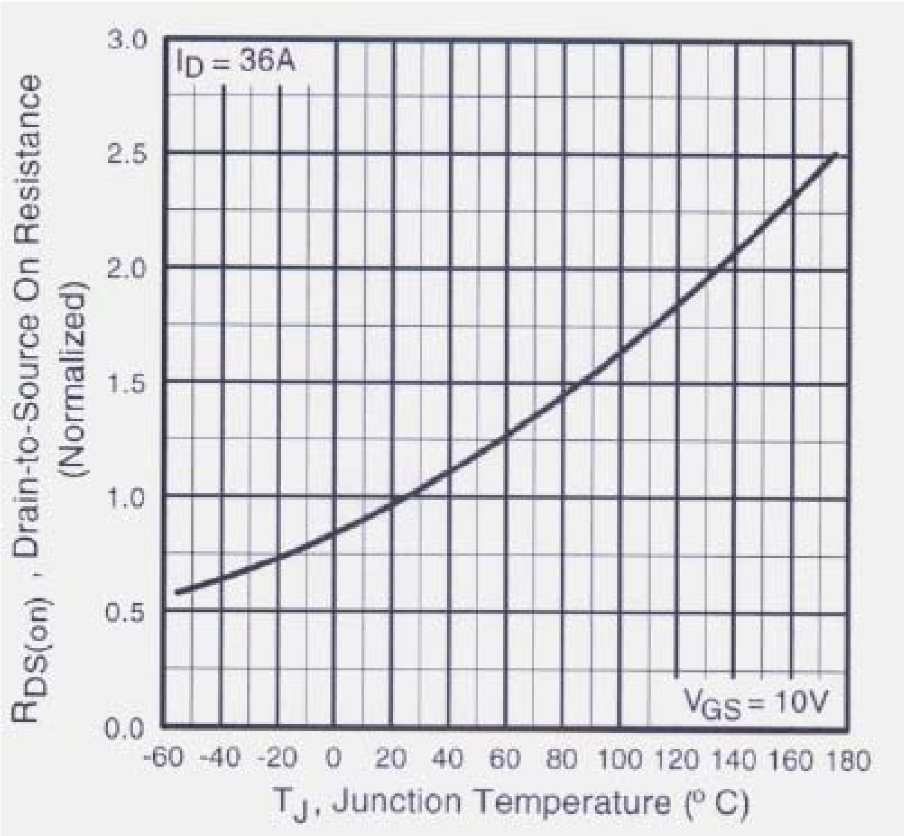


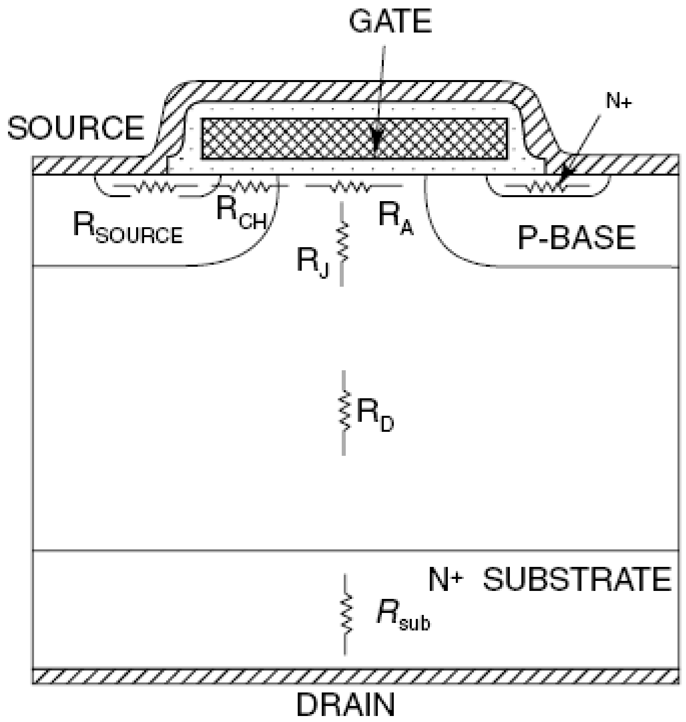
قطع شدن ماسفت بدون و با مدار ضربه گیر



وصل شدن ماسفت بدون و با مدار ضربه گیر

اجزاي $R_{DS(on)}$ – اثر دما بر مقاومت حالت وصل

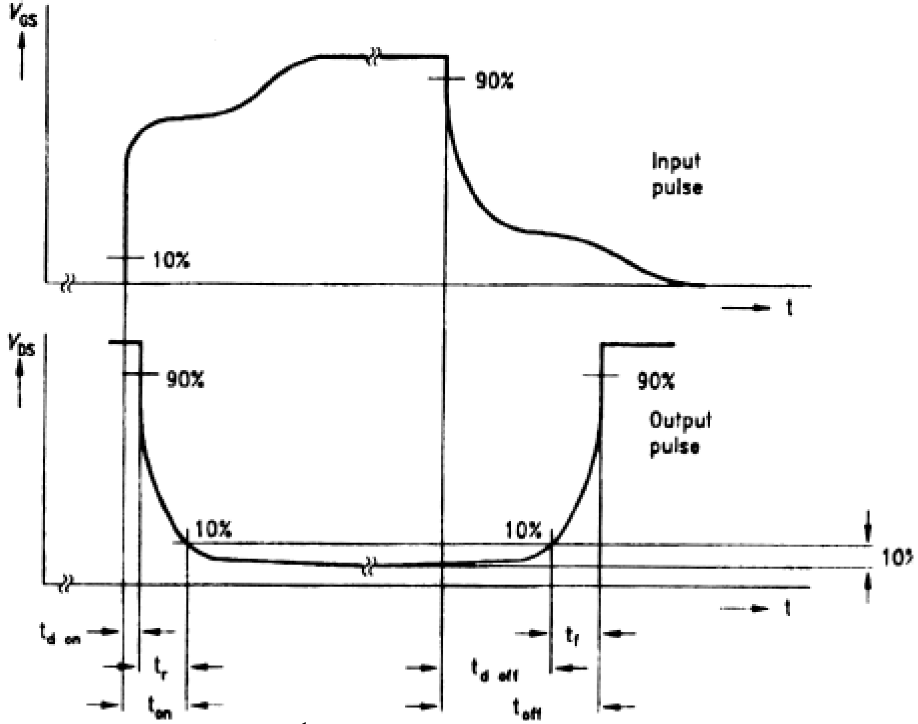




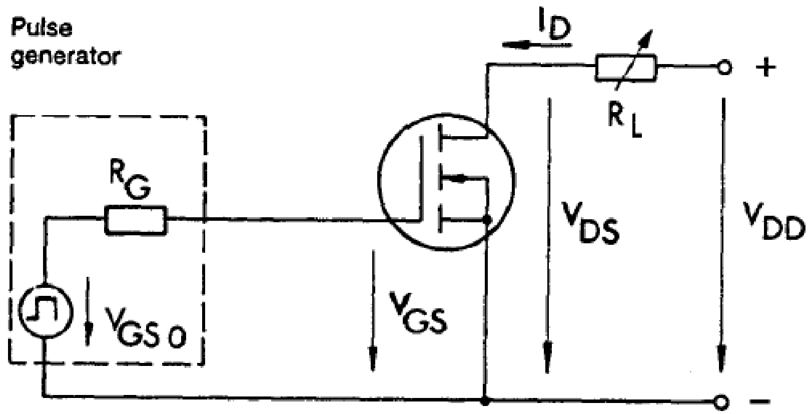
The origin of the internal resistances in a power MOSFET.

$$R_{dson} = R_{source} + R_{ch} + R_A + R_J + R_D + R_{sub} + R_{wcml}$$

زمانهاي كليدزني: تعريف و روش آزمايش



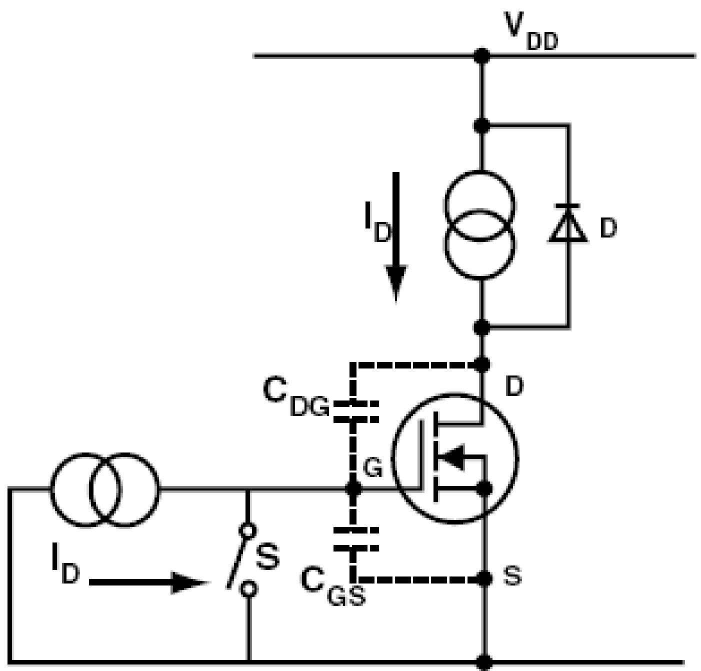
شكل موجهاي ولتاژ گيت و درين،
تعريف زمانهاي وصل وقطع



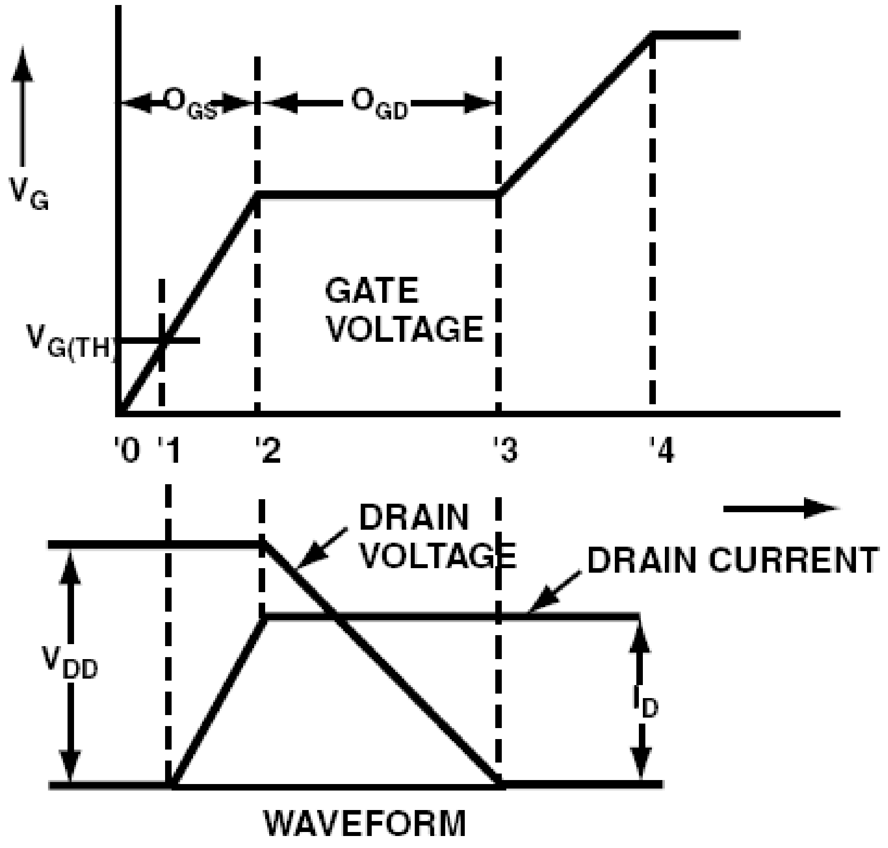
مدار آزمايش زمانهاي كليدزني

$t_{d(on)}$	Turn-On Delay Time	—	11	—	ns	V_{DD} = 50V
t_r	Rise Time	—	56	—		I_D = 22A
$t_{d(off)}$	Turn-Off Delay Time	—	45	—		R_G = 3.6W
t_f	Fall Time	—	40	—		R_D = 2.9W, See Fig. 10 ④⑤

وصل شدن با بار سلفي، ديود ايده ال و فرمان منبع جريان



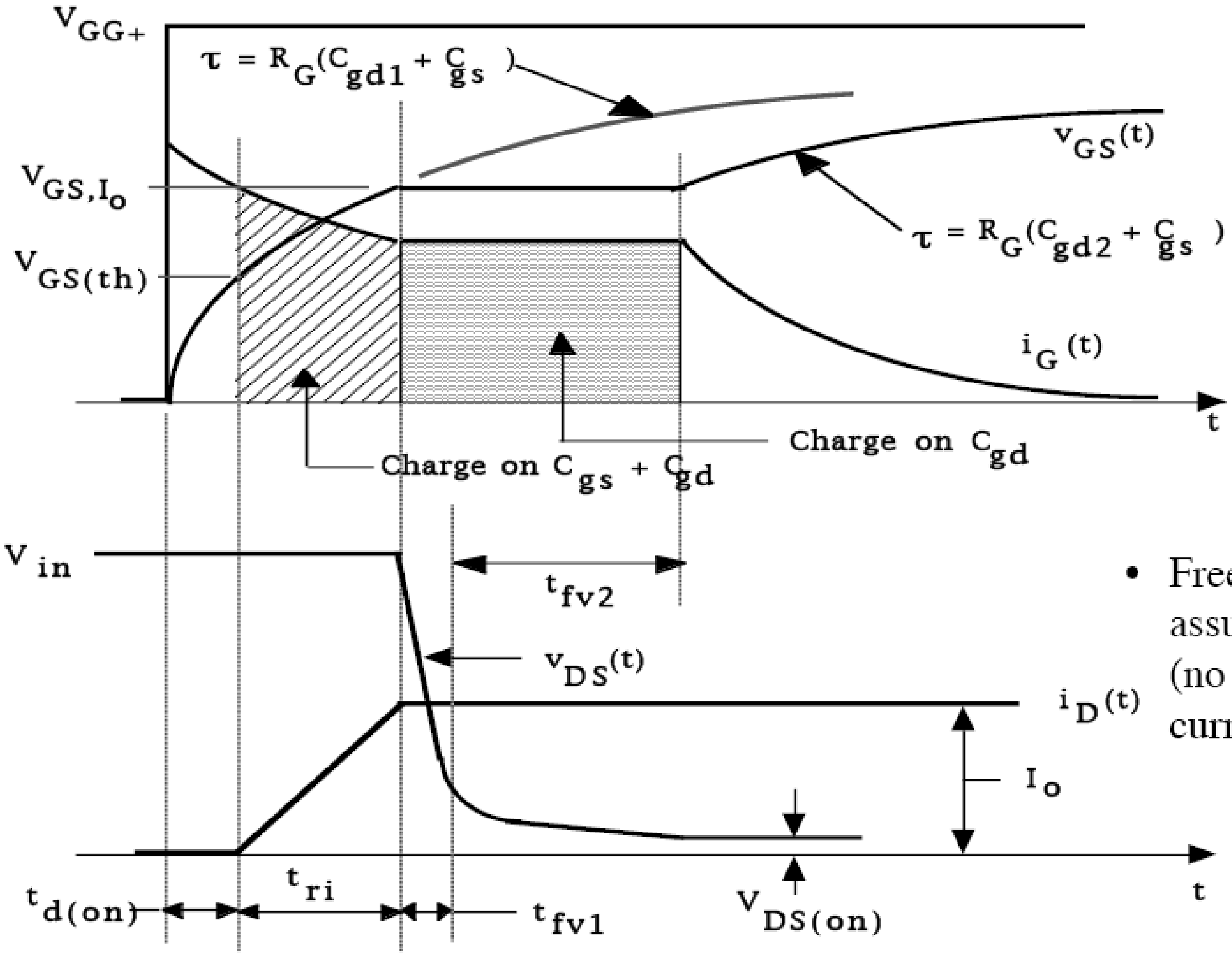
(a)



(b)

وصل شدن با بار سلفي، ديود ايده ال و فرمان منبع ولتاژ

MOSFET-based Buck Converter Turn-on Waveforms

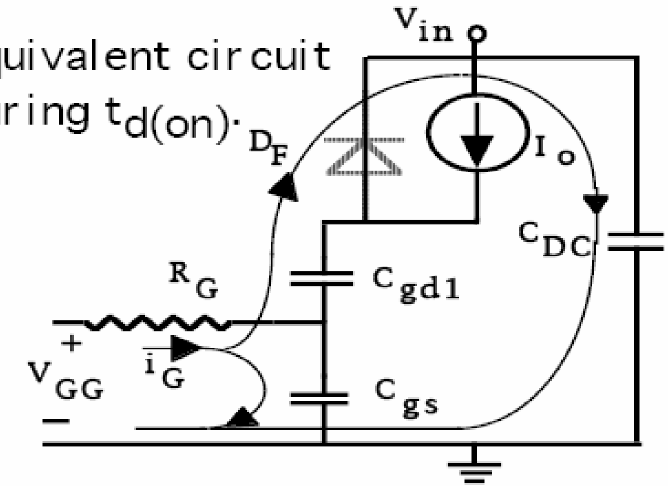


- Free-wheeling diode assumed to be ideal. (no reverse recovery current).

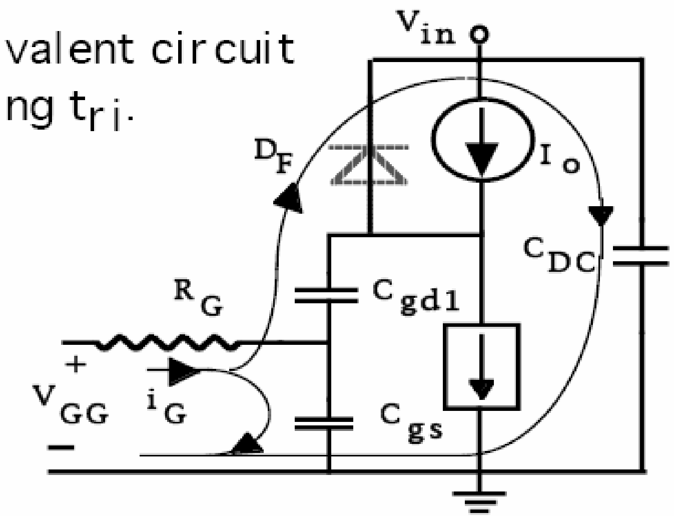
مدار معادل وصل شدن با بار سلفي با فرمان منبع ولتاژ

Turn-on Equivalent Circuits for MOSFET Buck Converter

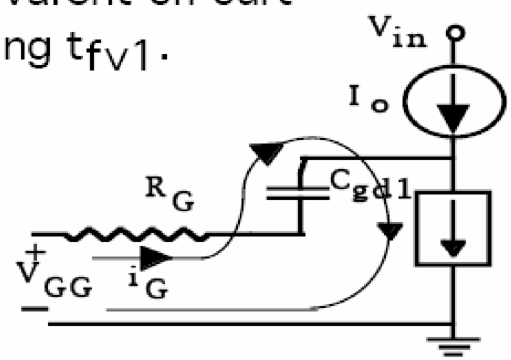
- Equivalent circuit during $t_{d(on)}$.



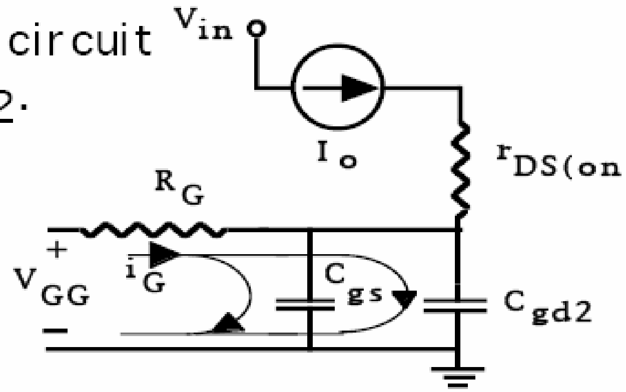
- Equivalent circuit during t_{ri}.



- Equivalent circuit during t_{fv1}.

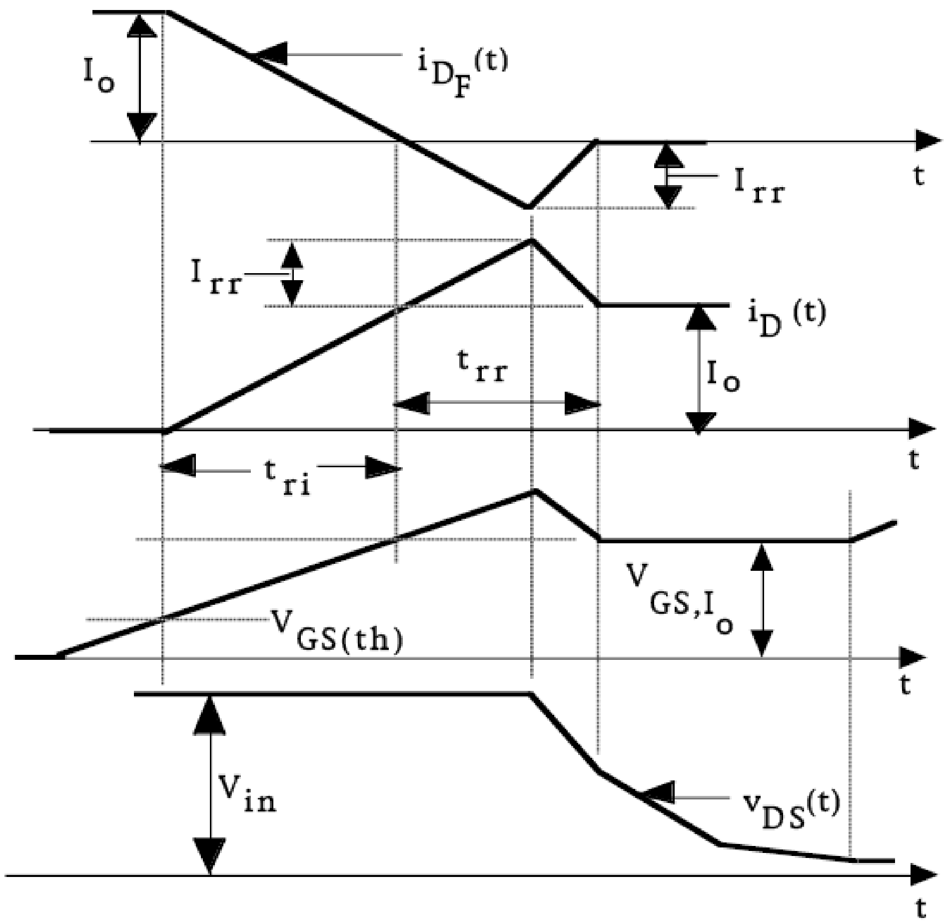


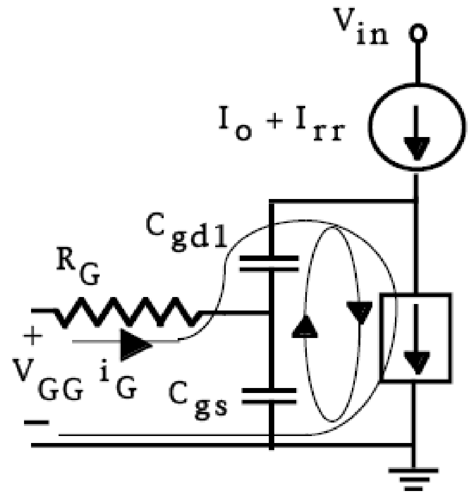
- Equivalent circuit during t_{fv2}.



وصل شدن با بار سلفي، ديود واقعي با فرمان منبع ولتاژ

Turn-on Waveforms with Non-ideal Free-wheeling Diode

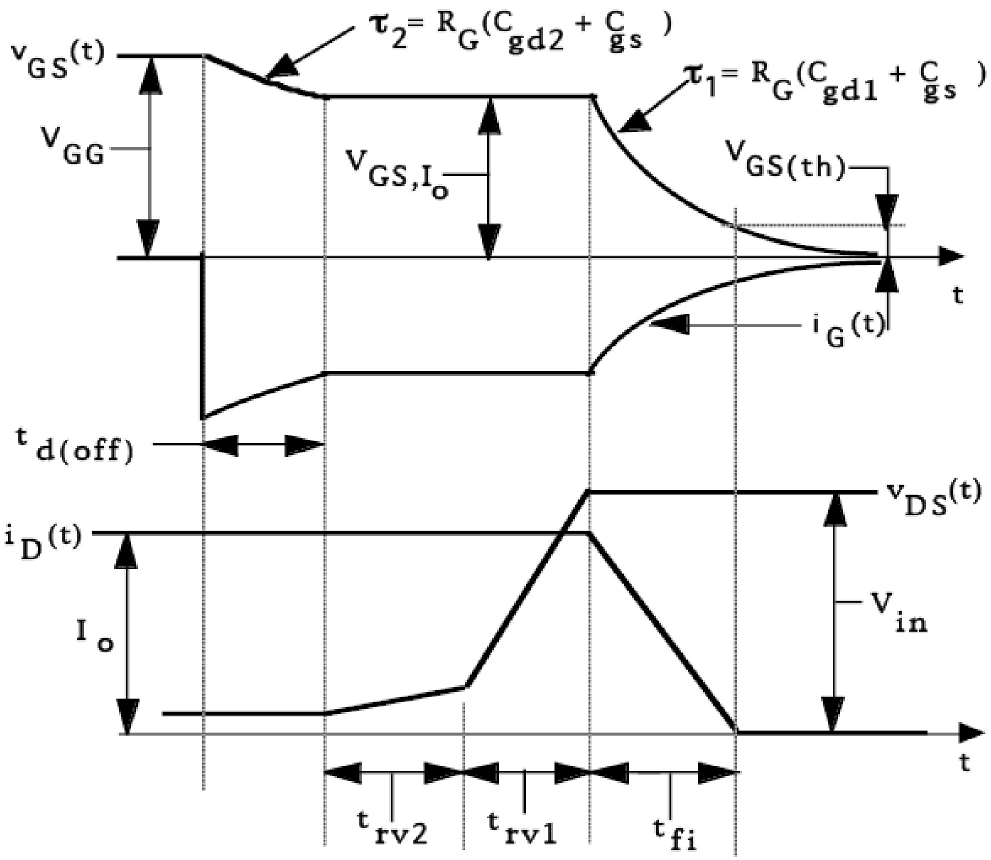




- Equivalent circuit for estimating effect of free-wheeling diode reverse recovery.

قطع شدن با بار سلفي و فرمان منبع ولتاژ

MOSFET-based Buck Converter Turn-off Waveforms



- Assume ideal free-wheeling diode.
- Essentially the inverse of the turn-on process.
- Model quanitatively using the same equivalent circuits as for turn-on. Simply use correct driving voltages and initial conditions

ملاحظات مدار راه انداز

Drive Circuit Design Considerations

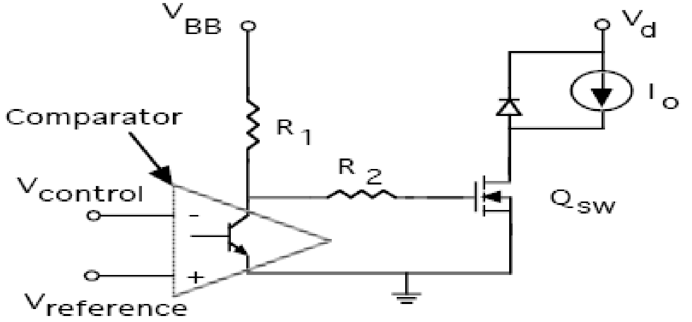
- Drive circuit topologies
  - Output signal polarity - unipolar or bipolar
  - AC or DC coupled
  - Connected in shunt or series with power switch
- Output current magnitude
  - Large I_{on} shortens turn-on time but lengthens turn-off delay time
  - Large I_{off} shortens turn-off time but lengthens turn-on delay time
- Provisions for power switch protection
  - Overcurrents
  - Blanking times for bridge circuit drives
- Waveshaping to improve switch performance
  - Controlled di_B/dt for BJT turn-off
  - Anti-saturation diodes for BJT drives
  - Speedup capacitors
  - Front-porch/backporch currents
- Component layout to minimize stray inductance and shielding from switching noise

Unipolar

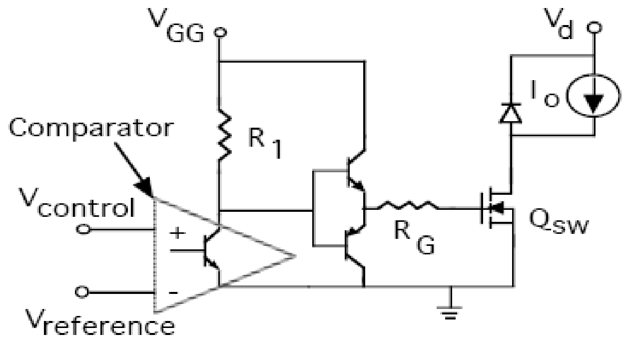
Bipolar

مدارهاي راه انداز با كوپلاژ مسقيم و تك قطبي

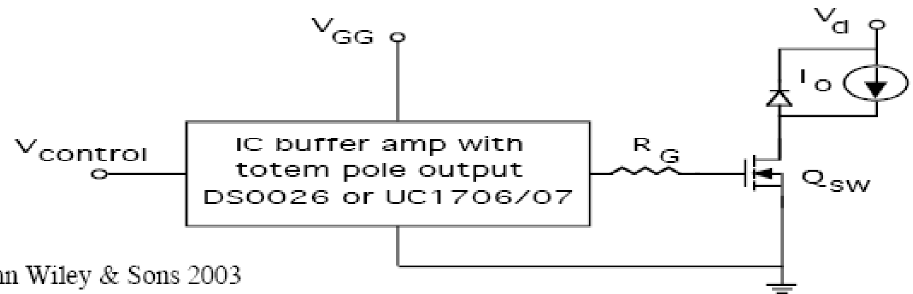
Unipolar DC-coupled Drive Circuits- MOSFET examples



- $V_{control} > V_{reference}$ comparator output high and Q_{sw} on
- $V_{control} < V_{reference}$ comparator output low and Q_{sw} off



- $V_{control} > V_{reference}$ comparator output high putting Q_{npn} on and thus Q_{sw} on
- $V_{control} < V_{reference}$ comparator output low putting Q_{pnp} on and thus Q_{sw} off



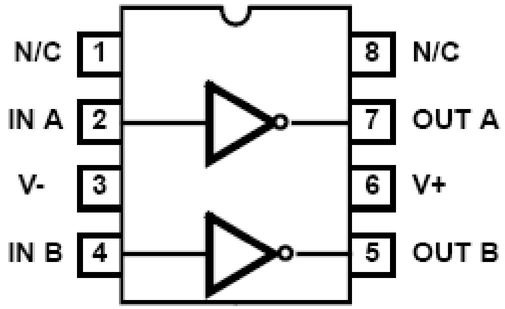
ICL7667 راه انداز ماسفت قدرت

Dual Power MOSFET Driver

Features

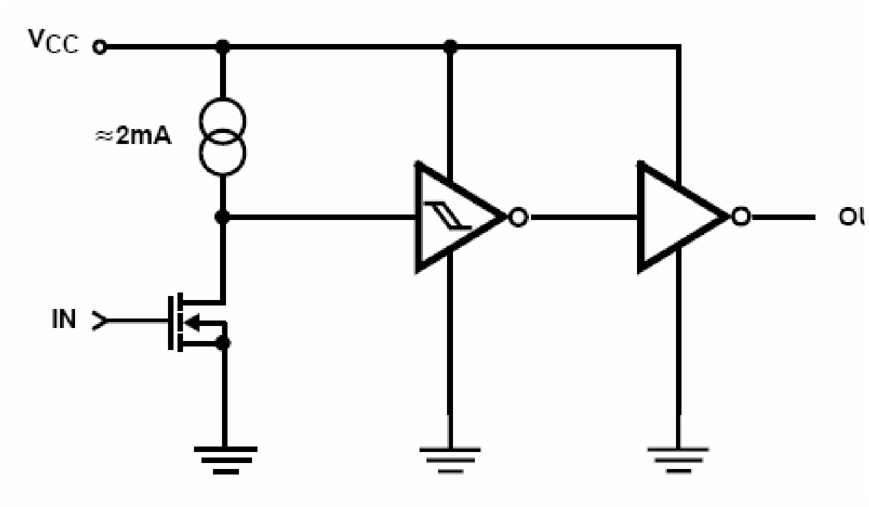
- Fast Rise and Fall Times – Typically 20ns with1000pF Load
- Wide Supply Range: V_{DD} = 4.5V to 17V
- Low Power Consumption:
  - 6mW with Inputs Low
  - 120mW with Inputs High
- TTL/CMOS Input Compatible
- Low R_{OUT} – Typically 4Ω
- Pin Equivalent to DS0026/DS0056, TSC426, SG1626/SG2626/SG3626

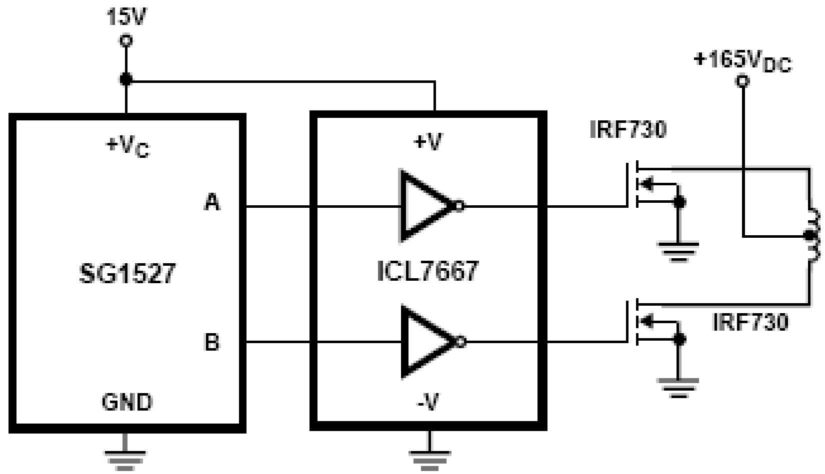
ICL7667



زمانهاي كليدزني و مدار نمونه ICL7667

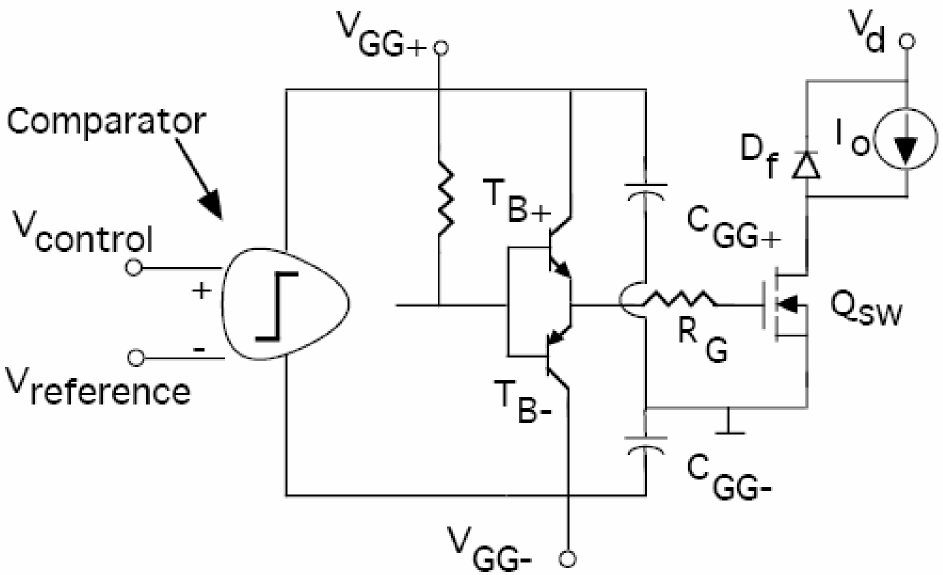
SWITCHING SPECIFICATIONS							
Delay Time	T_{D2}	35	50	-	-	60	ns
Rise Time	T_R	20	30	-	-	40	ns
Fall Time	T_F	20	30	-	-	40	ns
Delay Time	T_{D1}	20	30	-	-	40	ns



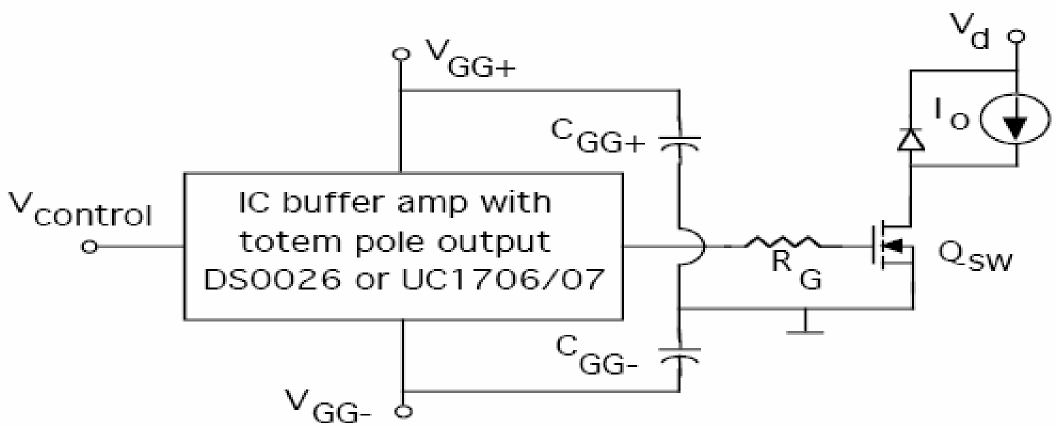


مدارهاي راه انداز با كوپلاژ مستقيم و دو قطبي

Bipolar DC-coupled Drive Circuit- MOSFET Example



- Bipolar drive with substantial output current capability



- Simple bipolar drive circuit with moderate (1 amp)output current capability

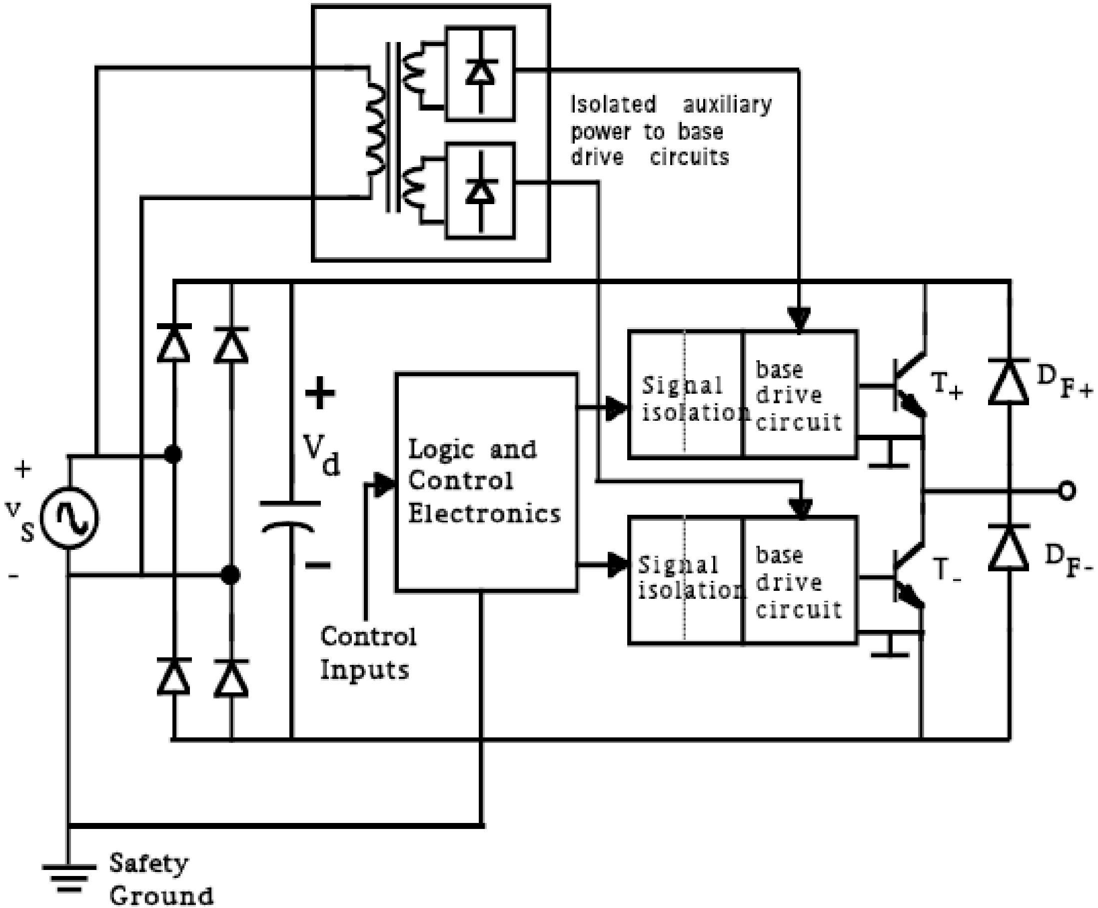
نياز به مدارهاي راه انداز با مجزاسازي

Need for Electrical Isolation of Drive Circuits

- Negative half cycle of $v_s(t)$ - positive dc rail near safety ground potential. T_- emitter potential large and negative with respect to safety and logic ground

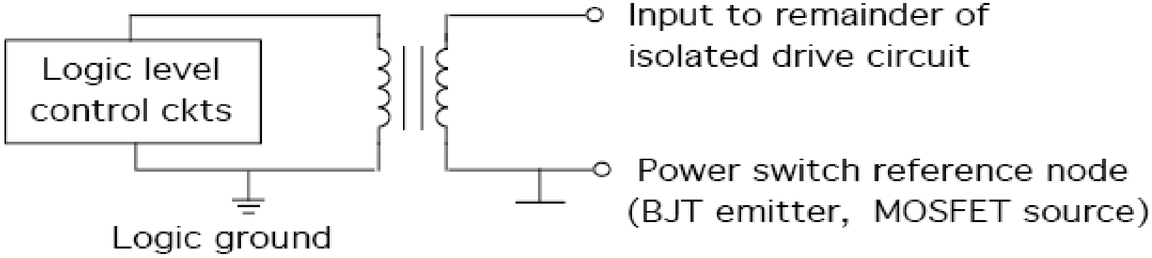
- Postive half cycle of $v_s(t)$ - negative dc rail near safety ground potential. T_+ emitter substantially positive with espect to safety ground if T_- is off

- Variation in emitter potentials with respect to safety and logic ground means that electrical isolation of emitters from logic ground is needed.

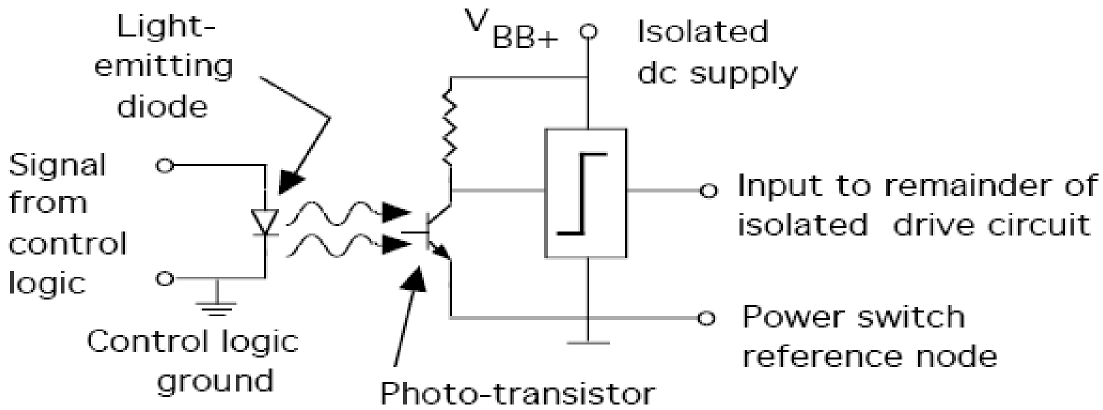


روشهاي مجزاسازي سيگنال راه اندازي گيت

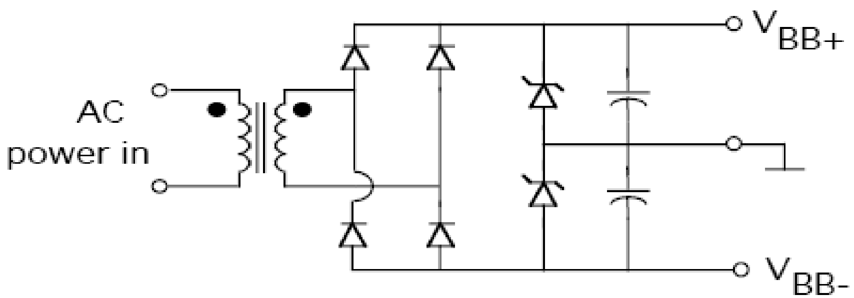
Methods of Control Signal Isolation



- Transformer isolation



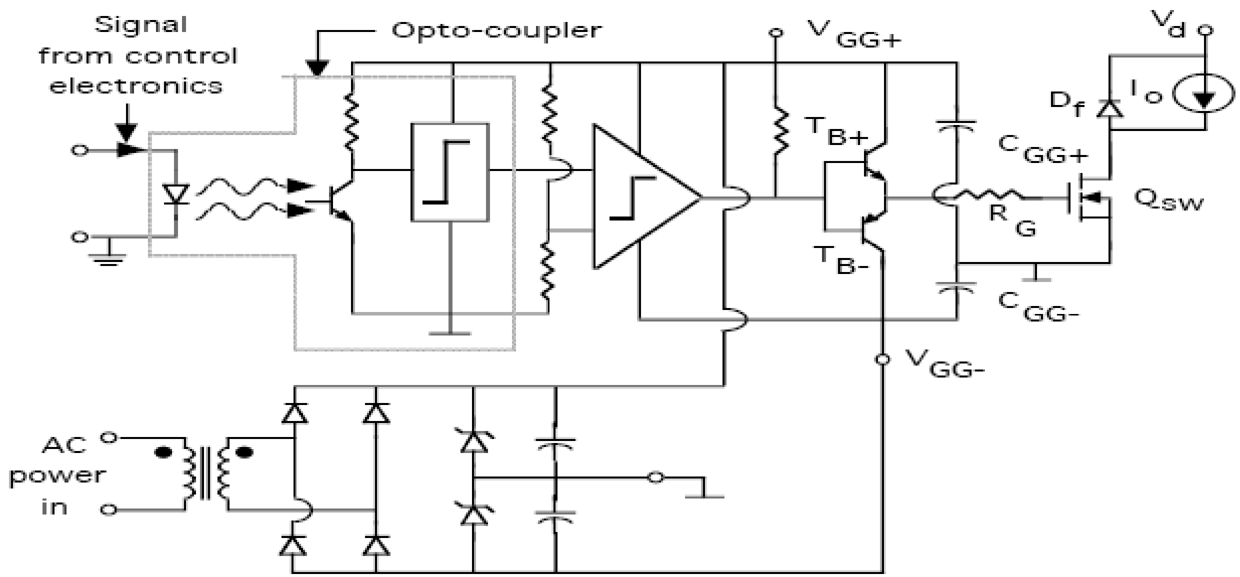
- Opto-coupler isolation

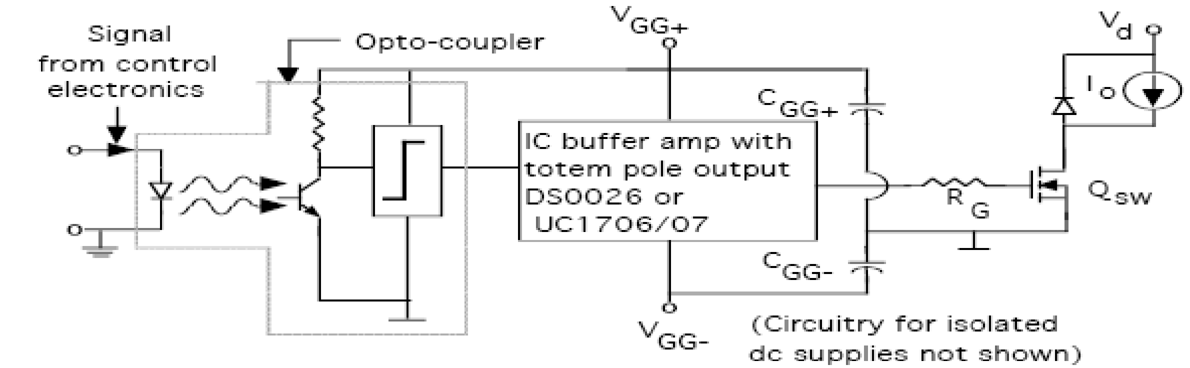


- Isolated dc power supplies for drive circuits

مجزاسازي سيگنال فرمان گيت با اپتوکوپلر

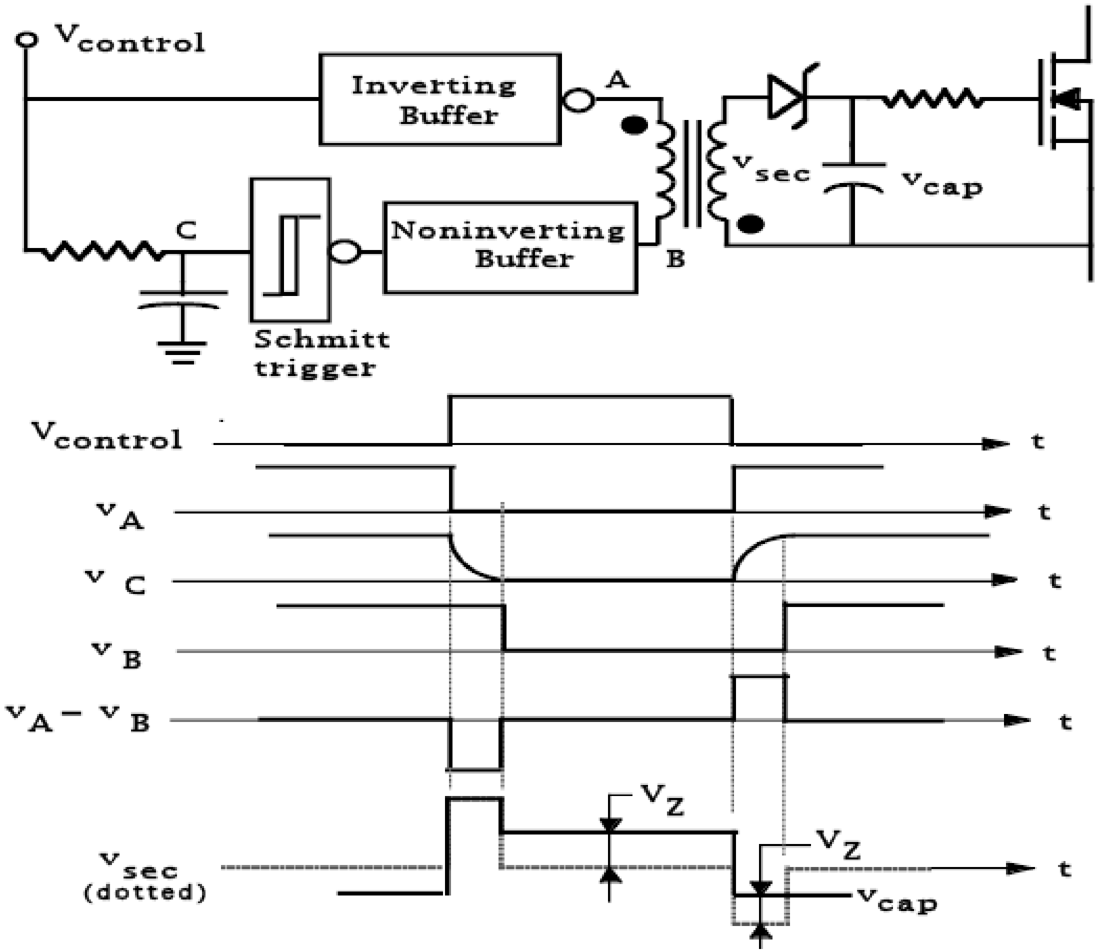
Opto-Coupler Isolated MOSFET Drives





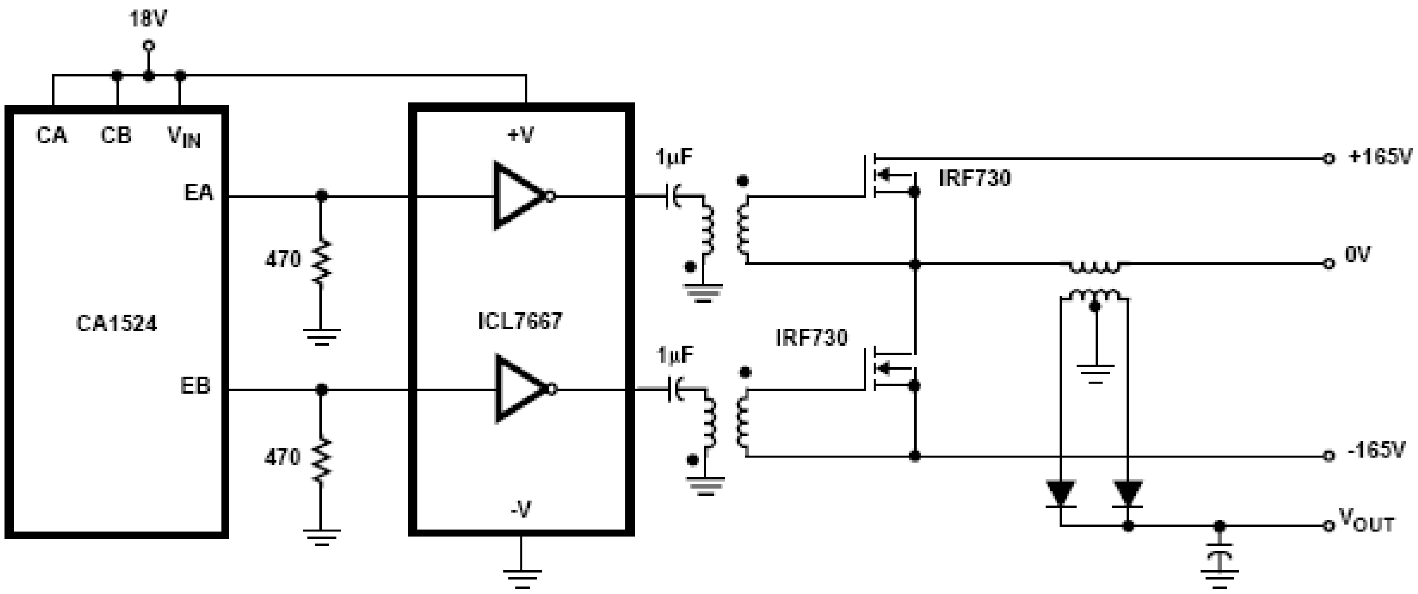
مجزاسازي سيگنال فرمان با ترانسفورماتور پالس

Isolated Drive Without Auxiliary DC Supplies - MOSFET Example



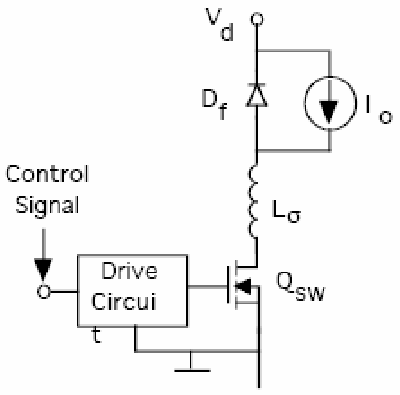
Zener diode voltage V_Z must be less than negative pulse out of transformer secondary or pulse will not reach MOSFET gate to turn it off.

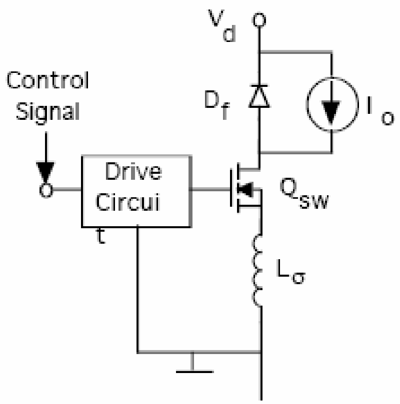
مجزاسازي سيگنال فرمان با ترانسفورماتور پالس



ملاحظات مدار راه انداز

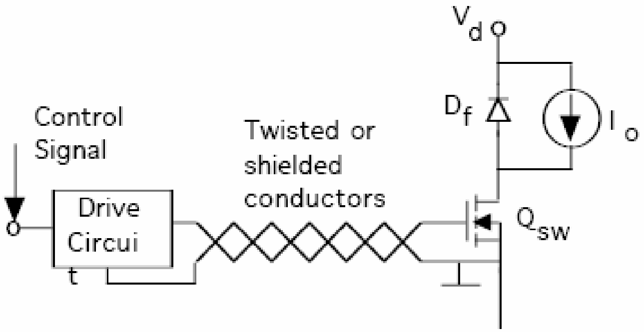
Circuit/Component Layout Considerations



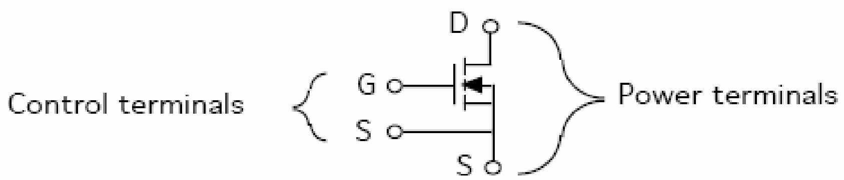


Prime consideration is minimizing stray inductance

- Stray inductance in series with high-voltage side of power device Q_{sw} causes overvoltage at turn-off.
- Stray inductance in series with low-voltage side power device Q_{sw} can cause oscill-ations at turn-on and turn-off.
- One cm of unshielded lead has about 5 nH of series inductance.
- Keep unshielded lead lengths to an absolute minimum.



Use shielded conductors to connect drive circuit to power switch if there must be any appreciable separation (few cm or more) between them



Some power devices provided with four leads, two input leads and two power leads, to minimize stray inductance in input circuit.