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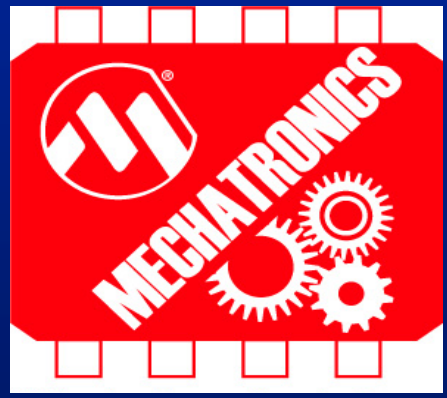
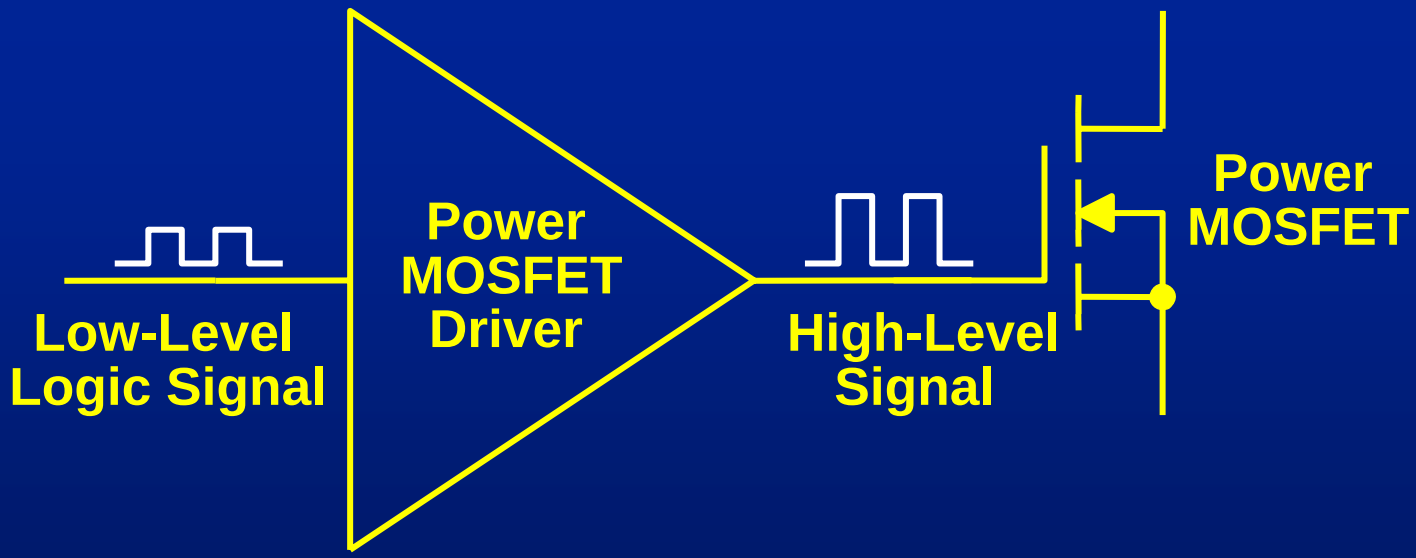
Mechatronics WIB
Selecting Power MOSFET Drivers



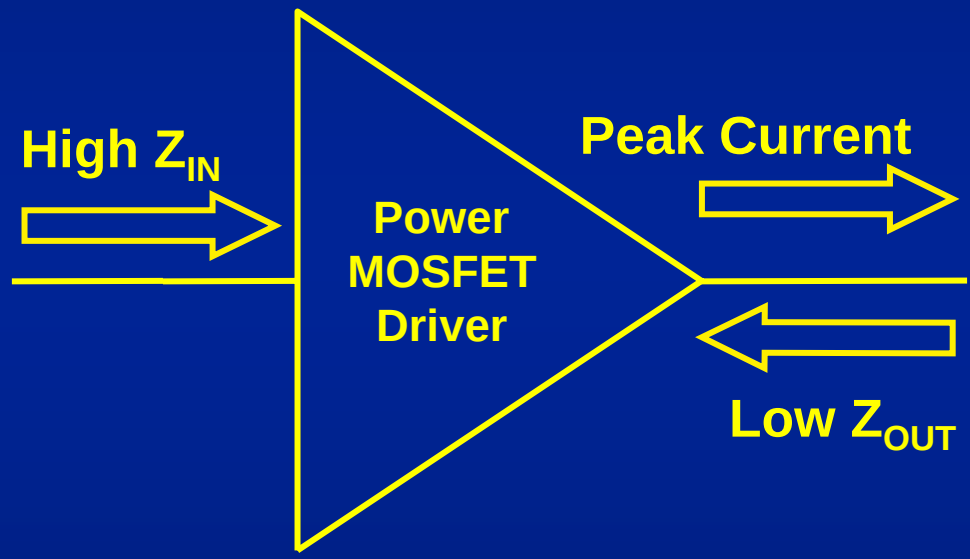
What is a Power MOSFET Driver?

- Power MOSFET Drivers Transform
  - Low-Level Logic Signal
  - High-Level Signal
  - Capable of Driving Power MOSFETs



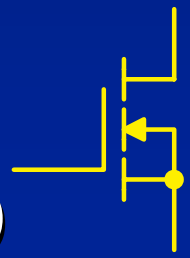
Power MOSFET Driver Key Characteristics

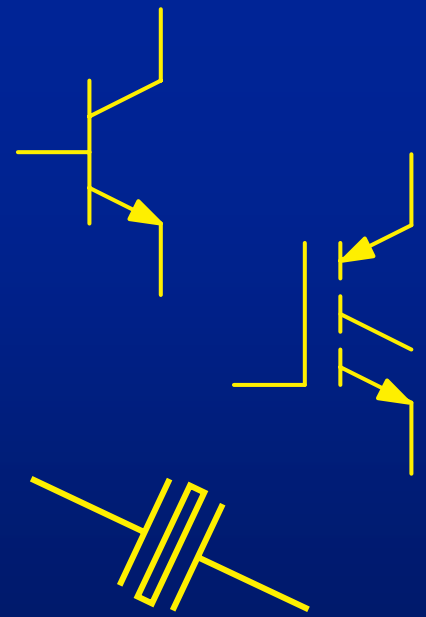
- High Input Impedance
- Low Output Impedance
- Provide Large Peak Currents
- Low Internal Delays
- Fast Output Rise & Fall Times
- Minimize Shoot-Through Currents



What Do Power MOSFET Drivers Drive?

- Power MOSFETs
  - Known Under Various Tradenames
    - VMOS
    - TMOS
    - Vertical DMOS
    - HEXFET
- BJTs (Bipolar Junction Transistor)
- IGBTs (Insulated Gate Bipolar Transistor)
- Piezo Electric Transducers

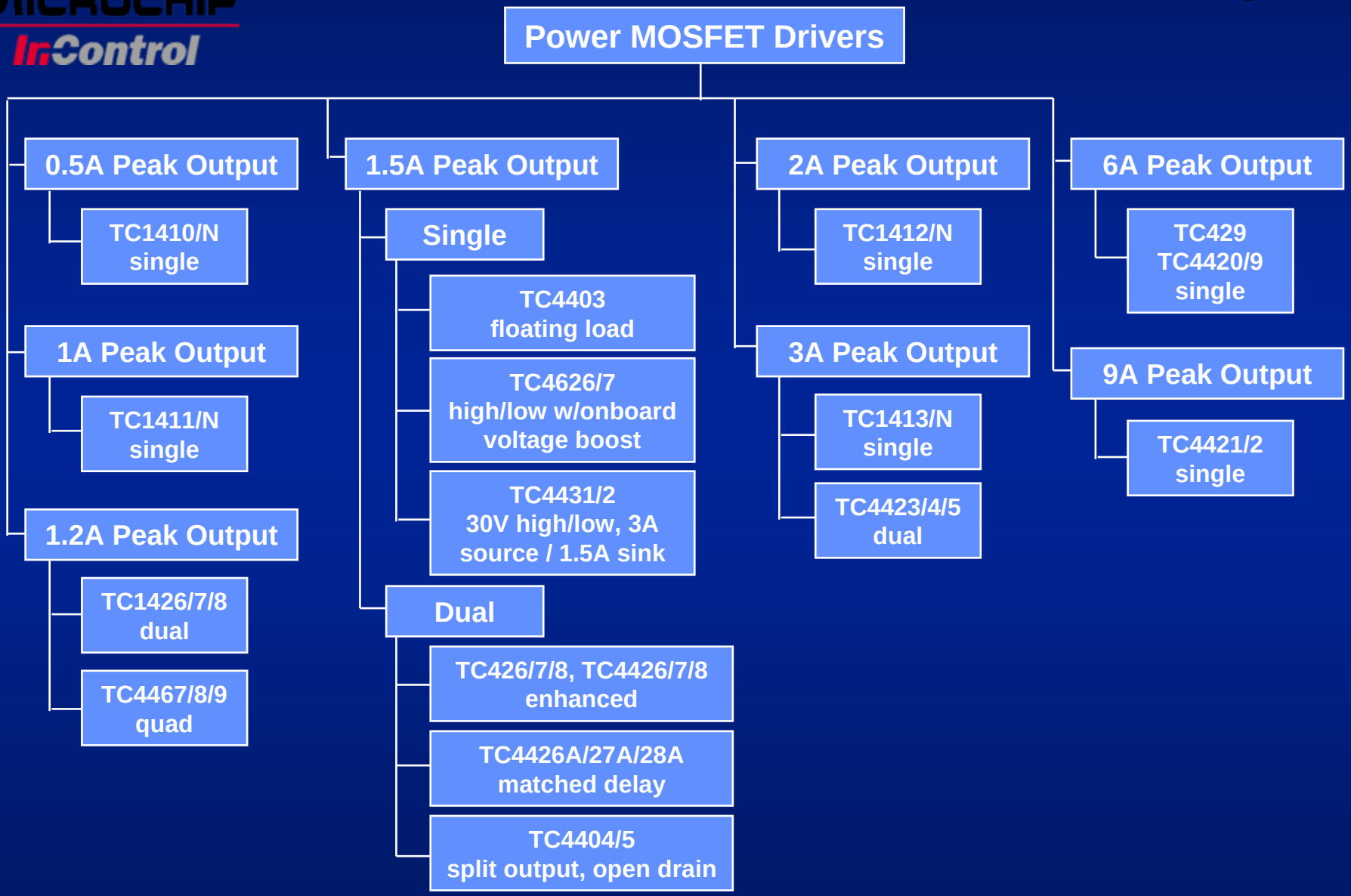




Power MOSFET Driver Applications

- Motors
- Relays and Solenoids
- Switch Mode Power Supply (SMPS)
- CCDs
- Inductive Loads
- Transducers
- Visual Indicators

MOSFET Driver Offering



Microchip MOSFET Driver Key Features

- Broad operating voltage range: 4.5V to 30V
- Broad peak current capability: 0.5A to 12A
- Input / output delay: 30 to 75 ns
- Low power dissipation
- Single, dual, quad packages
- Special features
  - Superior ESD & latch-up protection
  - TTL compatible
  - Operating junction temperature to 150°C

Power MOSFET Driver Key Parameters By Application

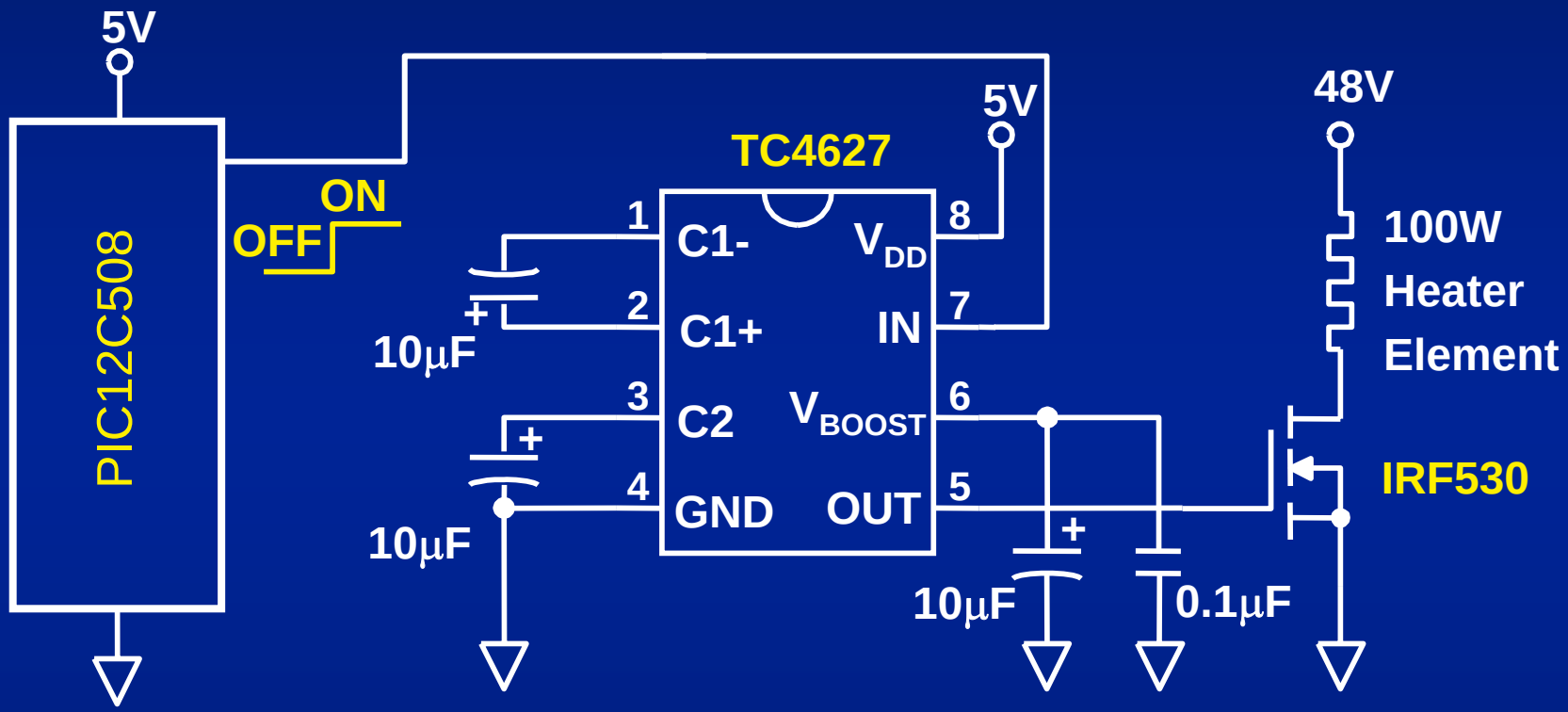
Low Speed Applications:

- Key Parameters: V_{OH}, V_{OL}
  - Level Shifters
  - H-Bridge Motor Controllers
  - Voltage Inverters.

High Speed Applications:

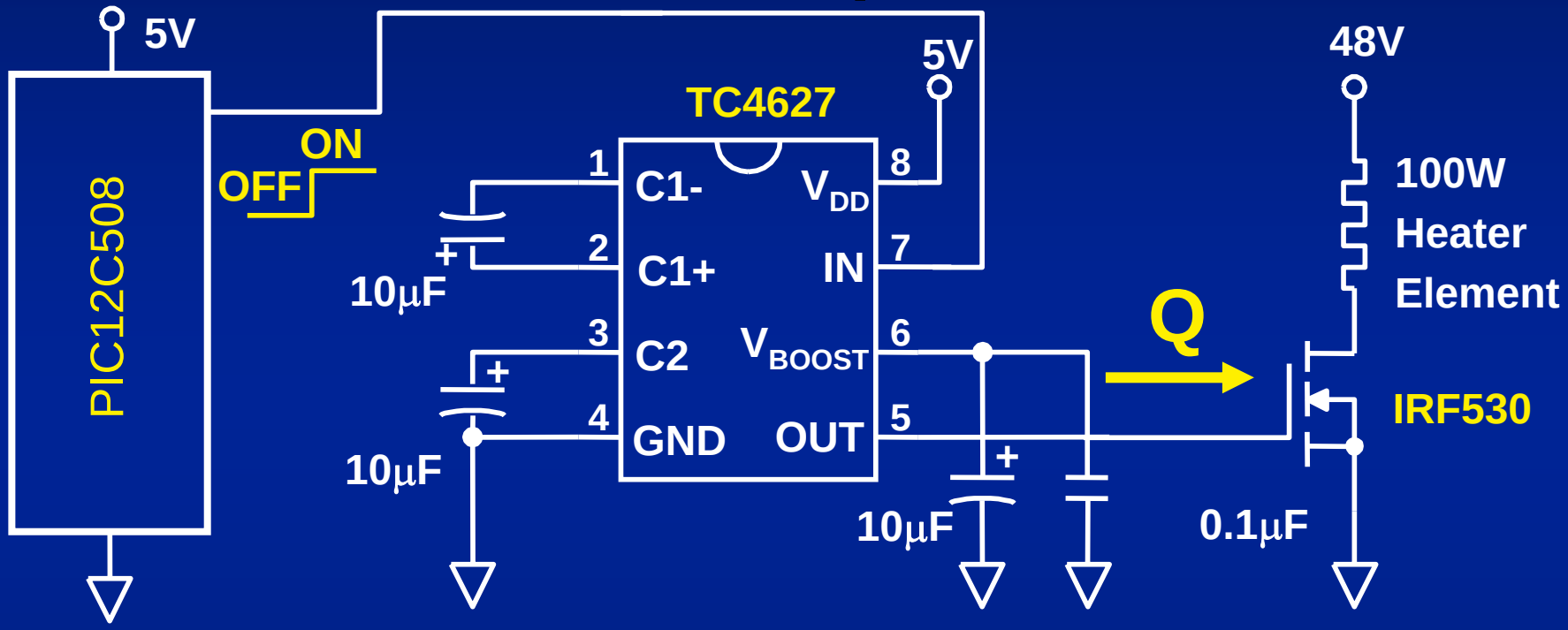
- Key Parameters: V_{OH}, V_{OL}, I_{PK}, t_R, t_F, t_{D1}, t_{D2}
  - Switch Mode Power Supplies

Low Speed Power MOSFET Driver Application



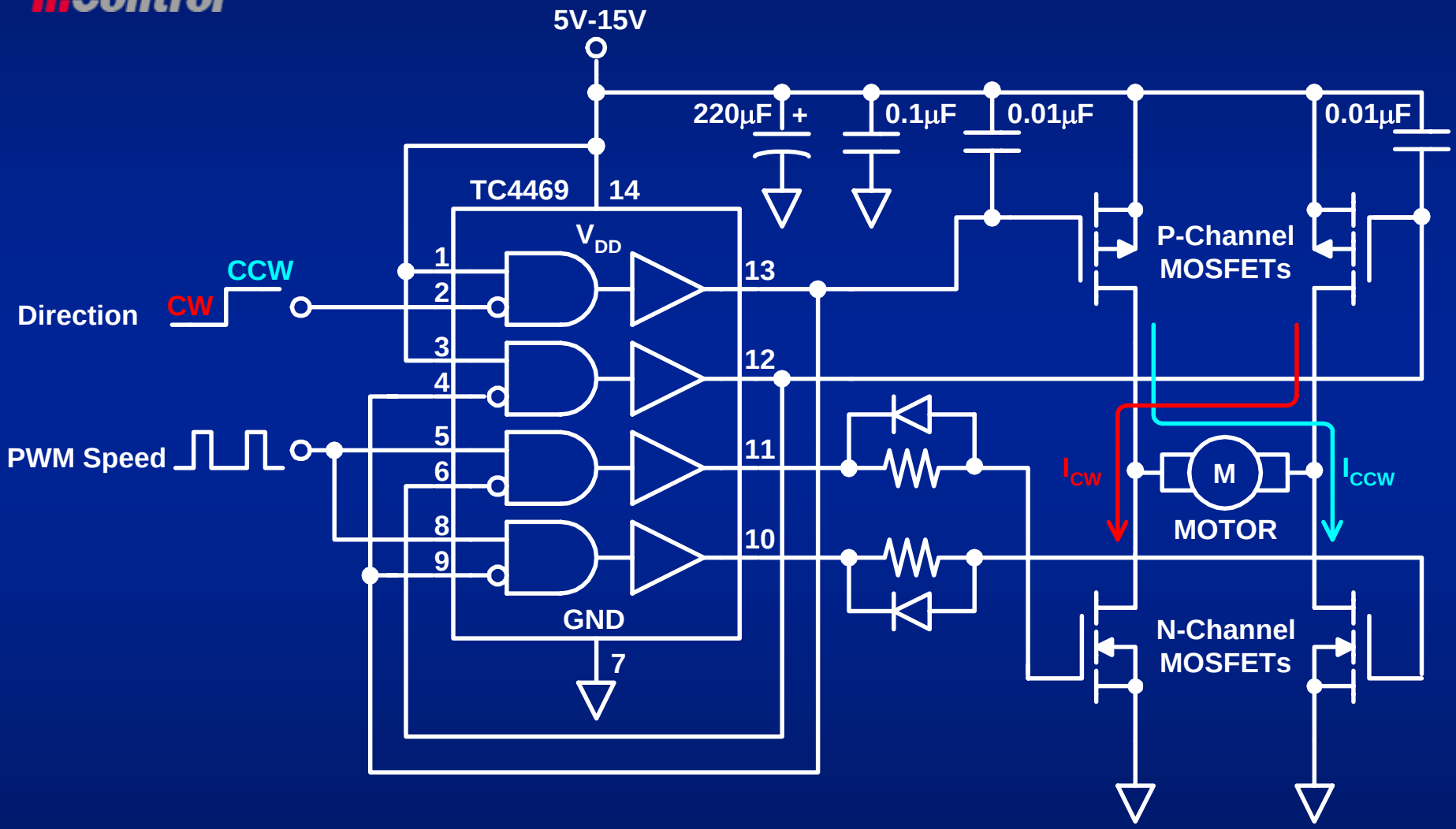
- IRF530
  - Requires Gate-to-Source Drive Voltage of ≥10V
- TC4627
  - Provides Output Voltage of 15V

Driver / MOSFET Requirements

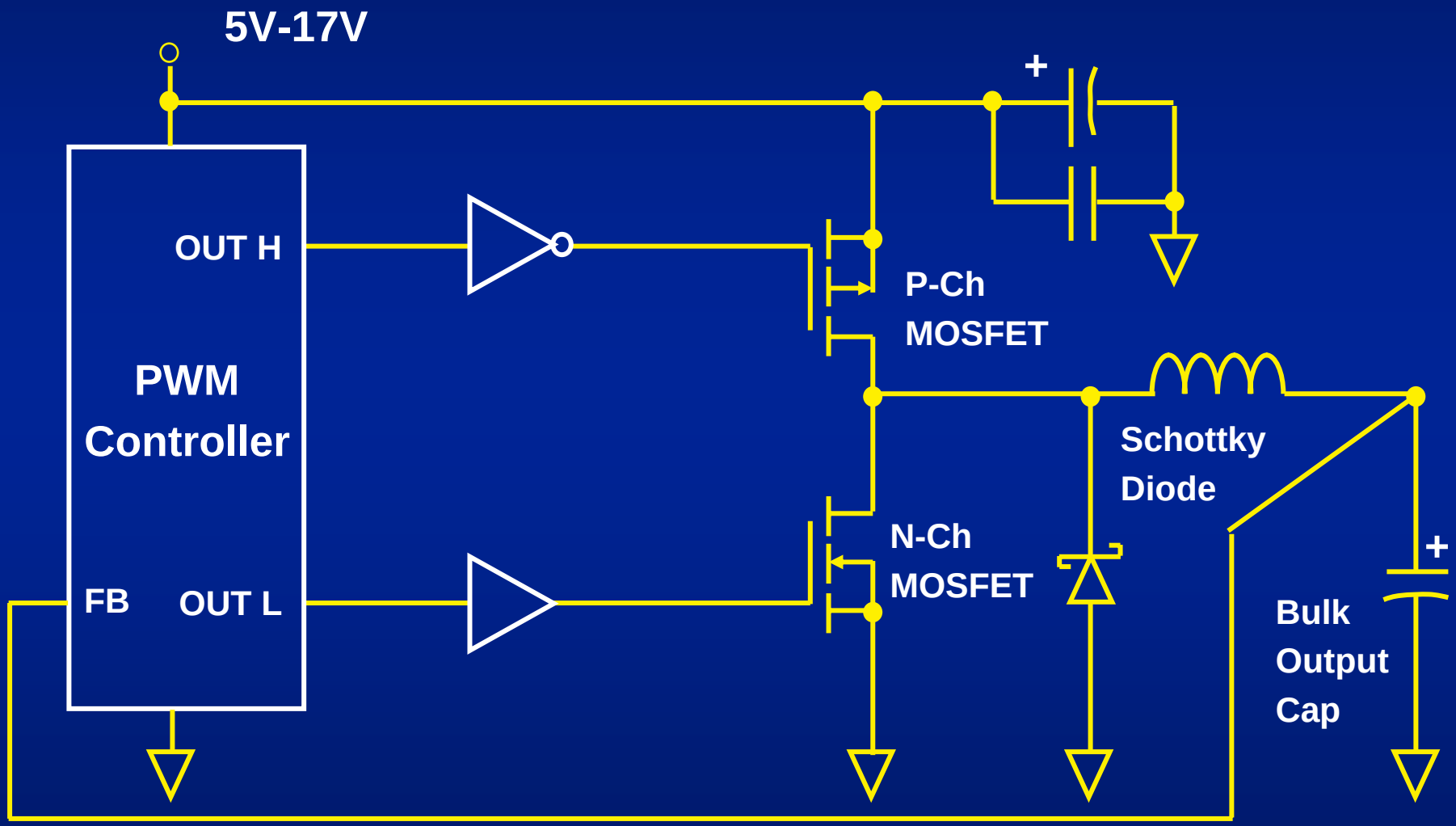


- Gate-to-Source Drive Voltage = 15V
- Specifications Not Important For This Application:
  - Total Gate Charge (Q_G) from Driver ≥ 37nC
  - Switch Time ≤ 0.1µs=$TC4627_{DELAY}$+$TC4627_{RISE\ TIME}$+ $IRF530_{SWITCH\ TIME}$
  - I_{PK} = 1.5A

H-Bridge Driver Application

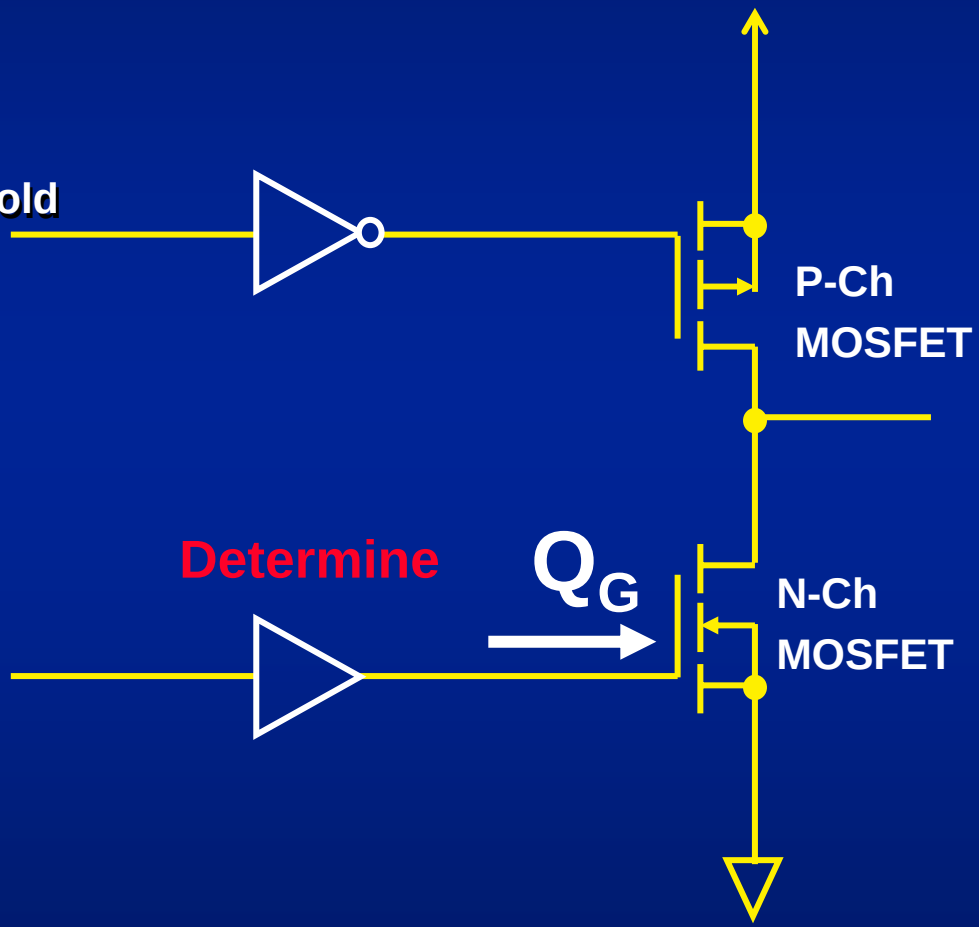


High Speed Switch-Mode Power Supply (SMPS) Application



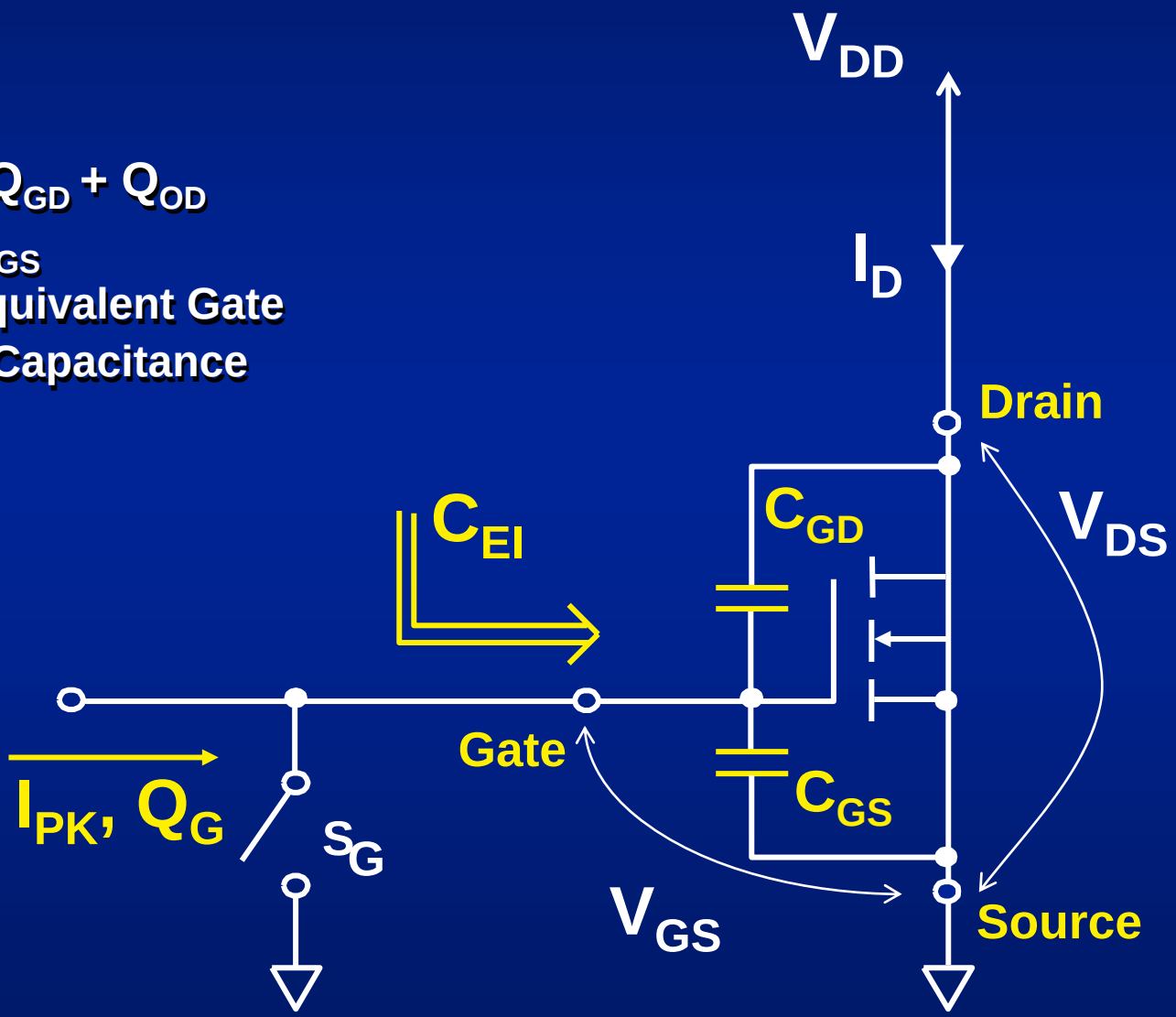
MOSFET Interface Key Issues

- MOSFET
  - Total Required Gate Charge, Q_G
  - Gate-to-Source Threshold Voltage, $V_{GS(TH)}$
- Driver
  - Output Swing
    - V_{OH} and V_{OL}
  - Peak Output Current, I_{PK}
  - Rise and Fall Times
    - t_R, t_F
  - Delay Times
    - t_{D1}, t_{D2}



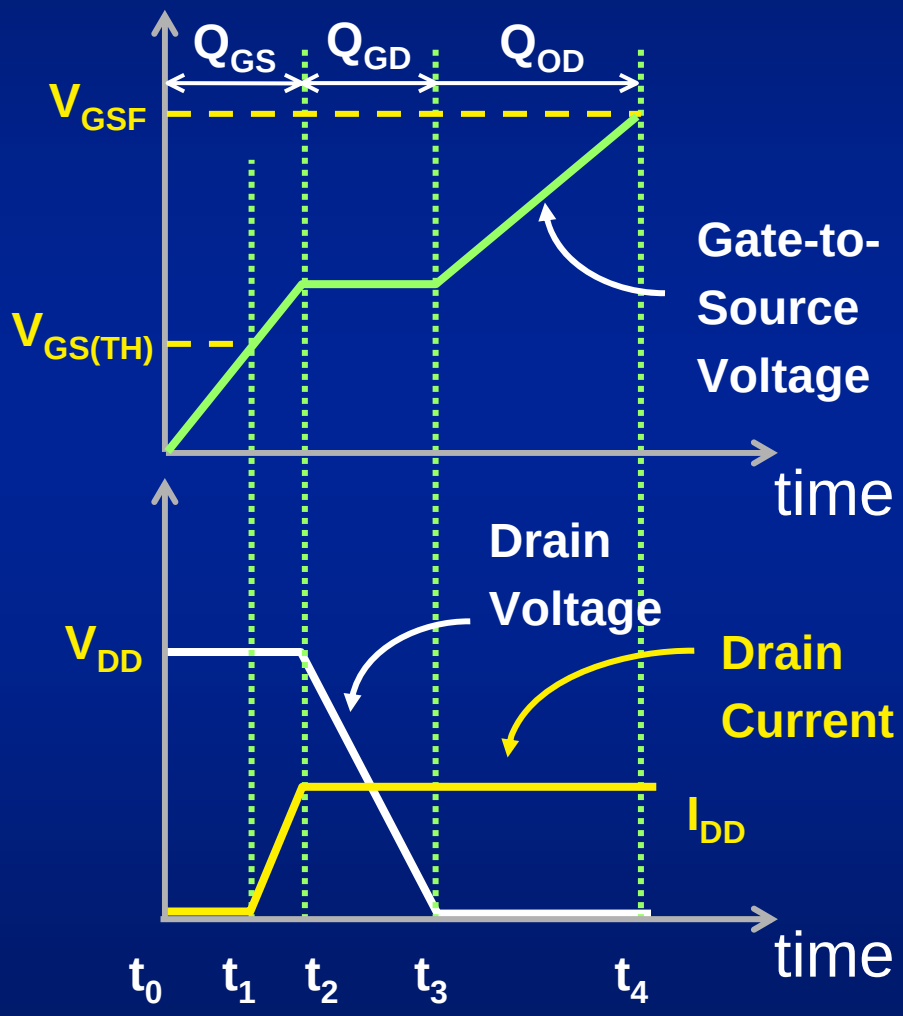
MOSFET Driver Design Equations

- $Q_G = t \times I_{PK}$
- $Q_G = Q_{GS} + Q_{GD} + Q_{OD}$
- $Q_G = C_{EI} \times V_{GS}$
  - C_{EI} = Equivalent Gate Capacitance

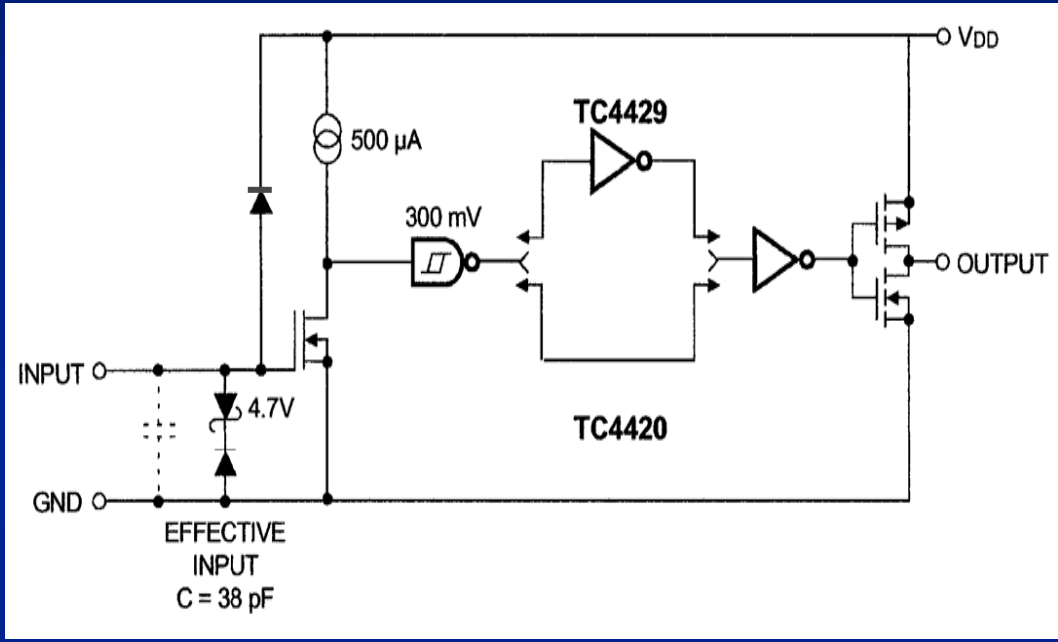


MOSFET Gate / Drain Waveforms

- $Q_G = t \times I_{PK}$
- $Q_G = Q_{GS} + Q_{GD} + Q_{OD}$
- $Q_G = C_{EI} \times V_{GS}$
  - C_{EI} = Equivalent Gate Capacitance

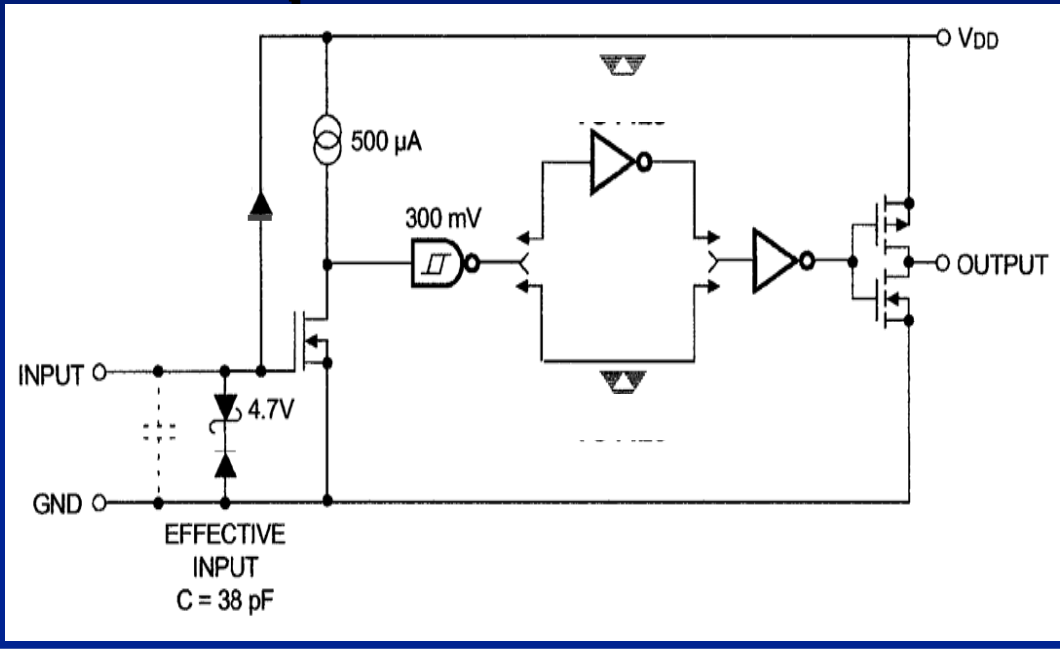


Power MOSFET Driver
Input Electrical Characteristics



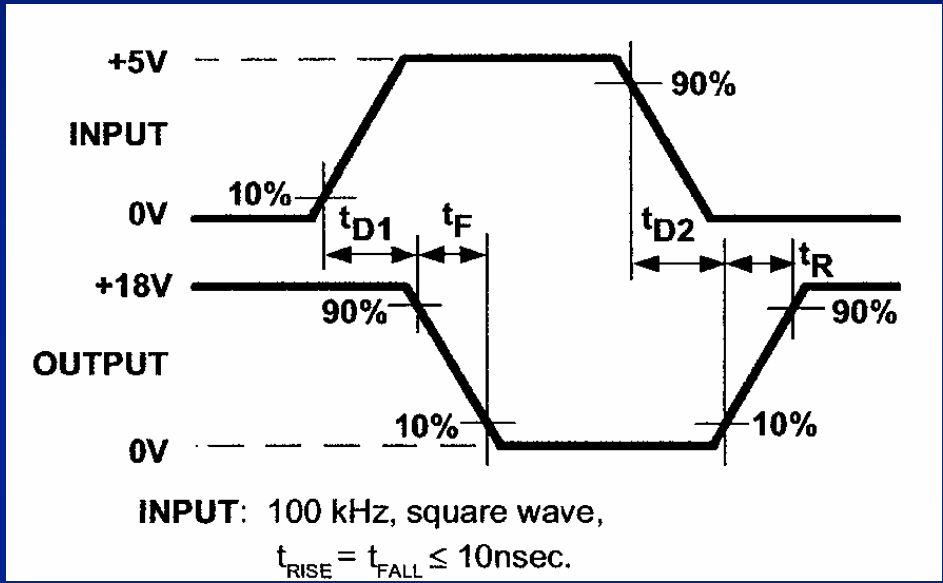
Symbol	Parameter	Min	Max
V_{IH}	Logic High Input Voltage	2.4V	–
V_{IL}	Logic Low Input Voltage	–	0.8V
$V_{IN(MAX)}$	Input Voltage Range	–5V	VDD + 0.3V
I_{IN}	Input Current	–10µA	10µA

Power MOSFET Driver
Output Electrical Characteristics



Symbol	Parameter	Min	Typ	Max
V_{OH}	High Output Voltage	V_{DD} - 0.025V	–	–
V_{OL}	Low Output Voltage	–	–	0.025V
R_O	Output Resistance	–	1.5Ω	2.8Ω
I_{PK}	Peak Output Current	–	6.0A	–
I_{REV}	Reverse Current	1.5A	–	–

Power MOSFET Driver
Switching Time Characteristics



Symbol	Parameter	Min	Max
t_R	Rise Time	–	35nsec
t_F	Fall Time	–	35nsec
t_{D1}	Delay Time 1	–	75nsec
t_{D2}	Delay Time 2	–	75nsec

Key Driver Output Voltage Considerations

- Equivalent Input Gate Capacitance, C_{EI}
  - Must Be Charged Up Beyond Gate-to-Source Threshold Voltage, $V_{GS(TH)}$
    - $V_{GSF} >> V_{GS(TH)}$
      - $V_{GSF} = Q_G/C_{EI}$
      - V_{GSF} Typically Equals V_{OH} of Driver

Key Driver Timing Considerations

- MOSFET Driver's Peak Output Current, I_{PK}
  - Determines Time Required to Charge Up C_{EI} to V_{GSF}
    - $t_R = Q_G / I_{PK}$
- MOSFET Driver's Output Impedance, R_O
  - Limits Peak Output Current, I_{PK}

Good Design Practices

- V_{GSF} >> $V_{GS(TH)}$ - Good Design Practice
  - Assures Channel of MOSFET is Fully Enhanced
  - $V_{GS(TH)}$ = 2V min. to 4V max. For IRFR120N
- Have $R_{DS(ON)}$ of MOSFET as Low as Possible
  - MOSFET Manufacturers Specify Static Drain-to-Source on Resistance, $R_{DS(ON)}$
  - $R_{DS(ON)}$ = 0.21Ω max. @ V_{GS} = 10V For IRFR120N

Power MOSFET Driver Selection Example

- Select MOSFET for Application
- Identify Important Design Parameters
  - Application
  - MOSFET
  - Driver
- Determine Total Required Gate Charge of MOSFET
- Calculate Required Driver Peak Output Current
- Select Driver

Power MOSFET Driver Selection Example

- **Step 1:** Select MOSFET for Application
  MOSFET = IRFR120N

- **Step 2:** Identify Important Design Parameters
  MOSFET Voltage : V_{DS} = 12V
  MOSFET Gate Voltage: V_{GSF} = 12V
  Required Rise Time in Application: t_R = 15ns

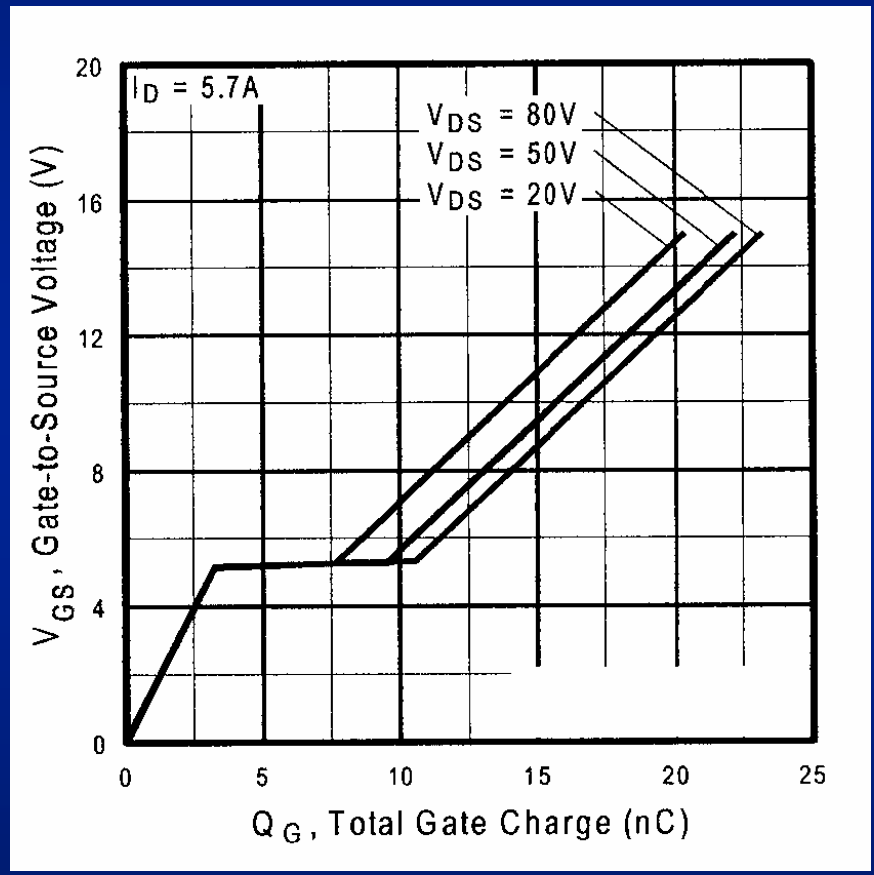
Power MOSFET Driver Determining Gate Charge

- **Step 3:** Using MOSFET Curve V_{GS} vs Q_G
  - Curve Closest to V_{DS} = 12V
    - Use V_{DS} = 20V Curve

- **Step 4:** Determine Total Gate Charge, Q_G
  - Necessary to Charge Up C_{EI} to V_{GSF} = 12V

$Q_G \cong 16.25nC$

(Typical Number)



IRFR120N

Power MOSFET Driver Selection Example *(Continued)*

- **Step 5:** Calculate Power MOSFET Driver Required Peak Output Current
  - $I_{PK} = Q_G/t_r$
    - Q_G = Total Gate Charge
    - t_r = Desired Rise Time

- Using Q_G From IRFR120N V_{GS} vs. Q_G Curve
  - $I_{PK} = Q_G/t_r$ = 16.25nC/15ns = 1.08A

Power MOSFET Driver Selection Example *(Continued)*

- **Step 6:** Select a Power MOSFET Driver
  - Key Parameters:
    - Supply Voltage = $V_{DD} \cong V_{OH}$ = 12V
    - Peak Output Current = I_{PK} > 1.08A
  - Use Power MOSFET Driver Selection Guide
    - Good Candidate Would Be TC1412
      - Supply Voltage Range = 4.5V - 16V
      - Peak Output Current = 2A
      - Delay Time = 35ns

Technical Information

Microchip Application Notes (www.microchip.com)

- AN-22: Considerations For Driving Power MOSFETs in High-Current Switch Mode Regulators.
- AN-25: TC4426/27/28 System Design Practice.
- AN-28: TC4420/4429 Universal Power MOSFET Interface IC.
- AN-30: Matching MOSFET Drivers to MOSFETs.
- AN-40: Switched Attenuation to Improve Current Sensing.
- AN-42: Low-Cost DC Motor Speed Control With CMOS ICs.

Technical Information *(Continued)*

International Rectifier Application Notes (www.irf.com)

- **AN-937 (v.Int): Gate Drive Characteristics and Requirements for HEXFET® s.**
- **AN-944 (v.Int): Use Gate Charge to Design the Gate Drive Circuit for Power MOSFETs and IGBTs.**
- **AN-957 (v.Int): Measuring HEXFET® Characteristics.**
- **AN-983 (v.Int): IGBT Characteristics.**

International Rectifier Technical Papers (www.irf.com):

- ***Power MOSFET Basics* by Vrej Barkhordarian.**
- ***IGBT or MOSFET: Choose Wisely* by Carl Blake and Chris Bull.**

Conclusions

- Identify Key Parameters For Application
  - Low Speed Application Key Parameters:
    - V_{OH}, V_{OL}
  - High Speed Application Key Parameters:
    - V_{OH}, V_{OL}, I_{PK}, t_R, t_F, t_{D1}, t_{D2}
- Proper Matching of Power MOSFET Driver to MOSFET & Application Yields:
  - Best Efficiency
  - Optimum Performance
  - Lowest Cost

BACK