# 直流伺服驅動器的模擬~從系統到元件

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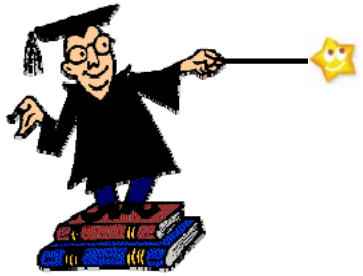
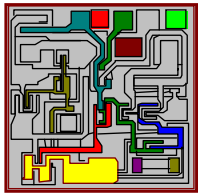
# Why do we need to know the detailed characteristics of these basic components?



You may do experiment by try and error, or you can do experiment intuitively to compare with design-oriented analysis, modeling and simulation!



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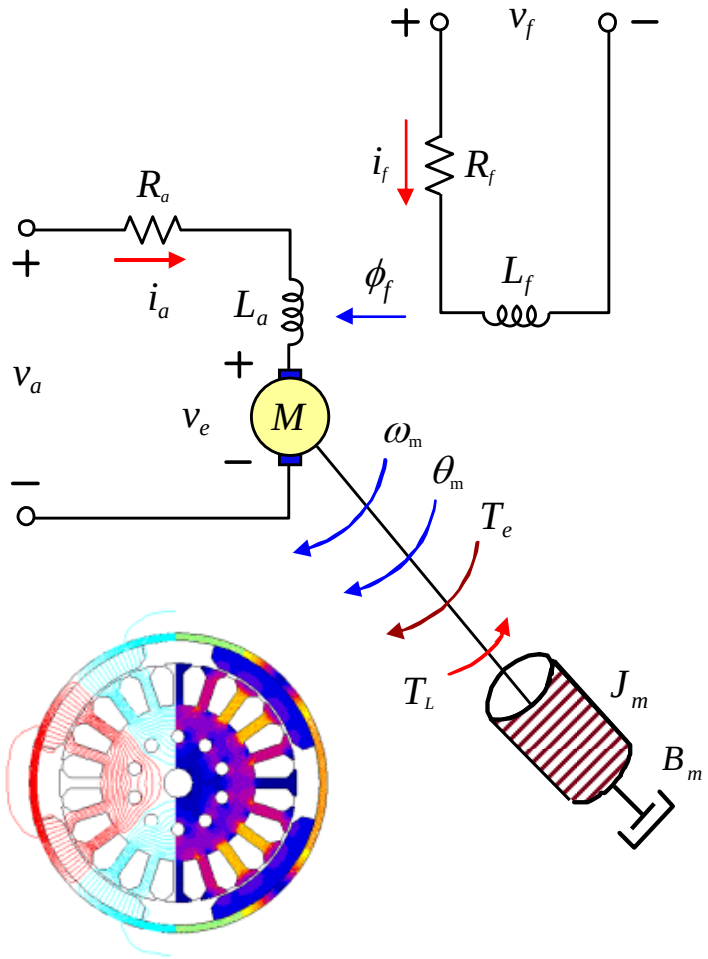
# Modeling of a Separately Excited DC Motor

## From Equivalent Circuit to Differential Equations




electrical equation: $v_a = i_a R_a + L_a \frac{di_a}{dt} + v_{emf}$

$v_f = i_f R_f + L_f \frac{di_f}{dt}$

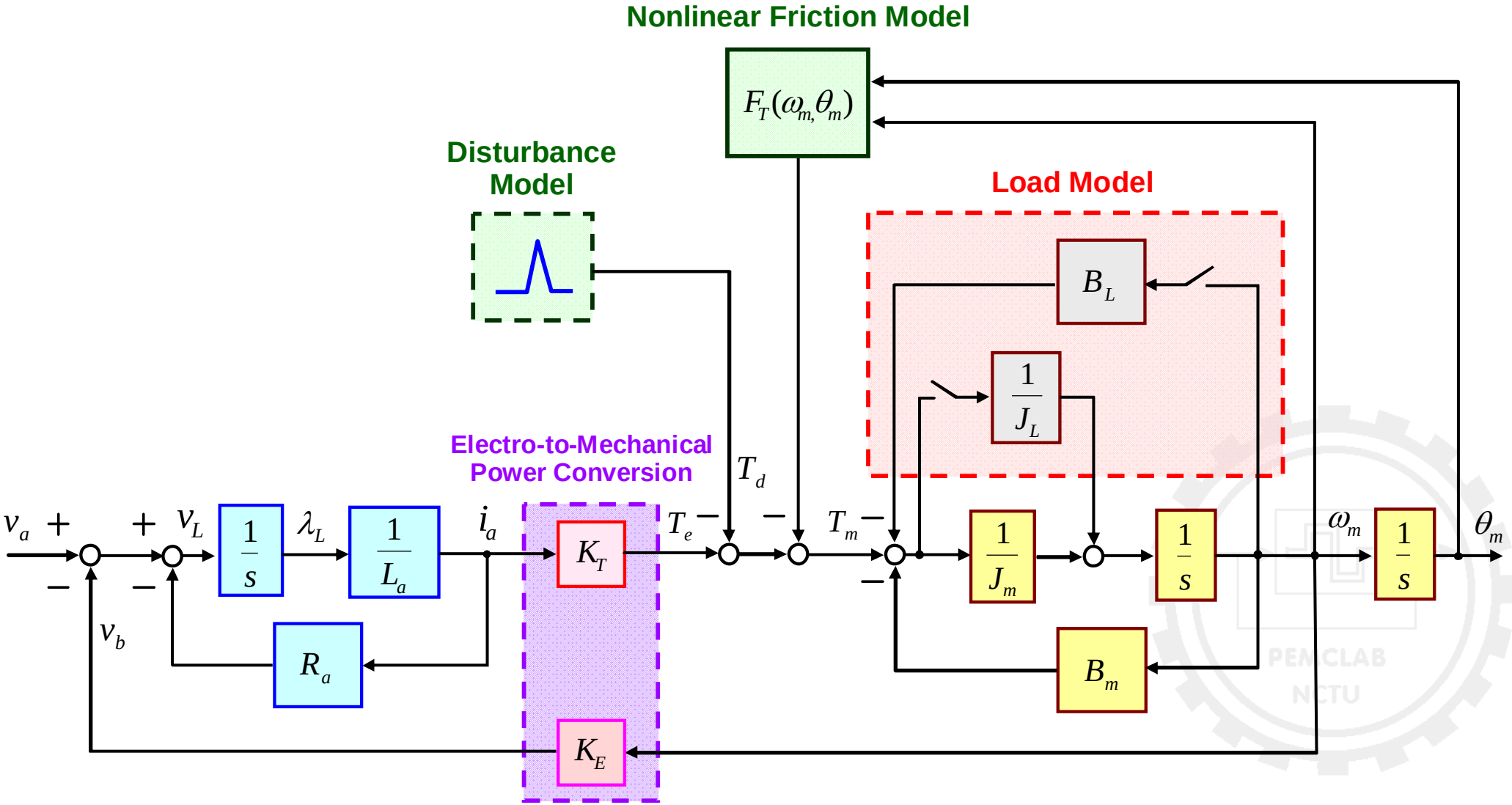
back *emf* equation: $v_{emf} = K_f \varphi_f \omega_m$

torque equation: $T_e = K_f \varphi_f i_a$

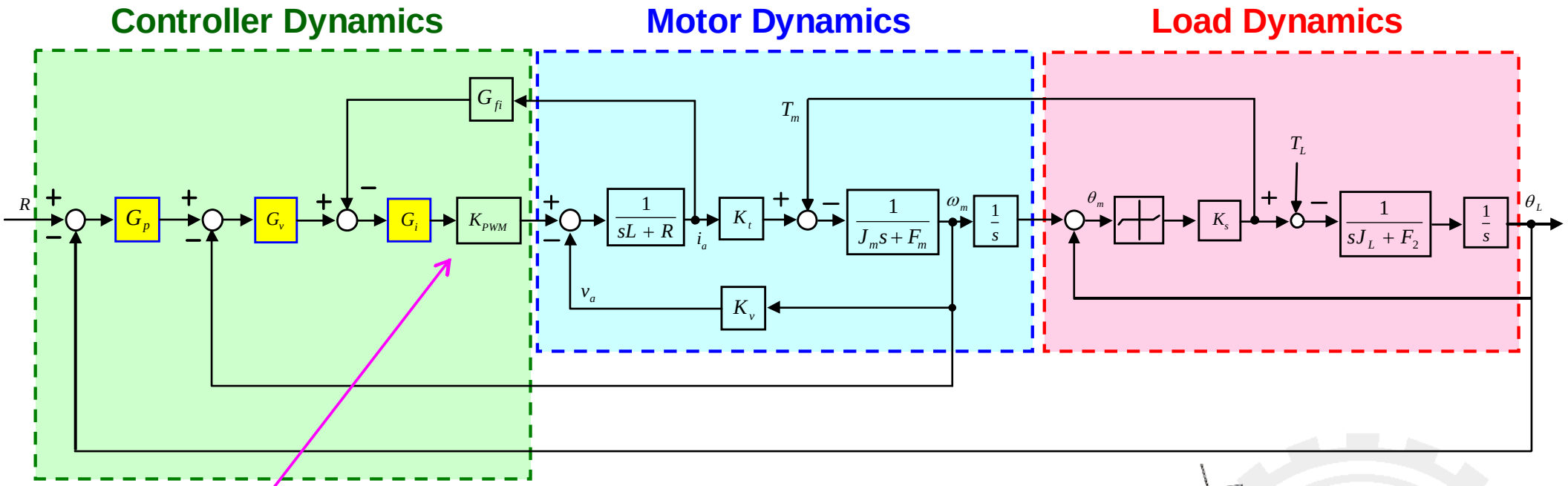
mechanical equation: $T_e = T_f + T_L + J_m \frac{d\omega_m}{dt} + B_m \omega_m$

$\omega_m = \frac{d\theta_m}{dt}$

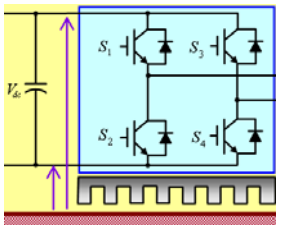
# Block Diagram Representation of a PM DC Motor

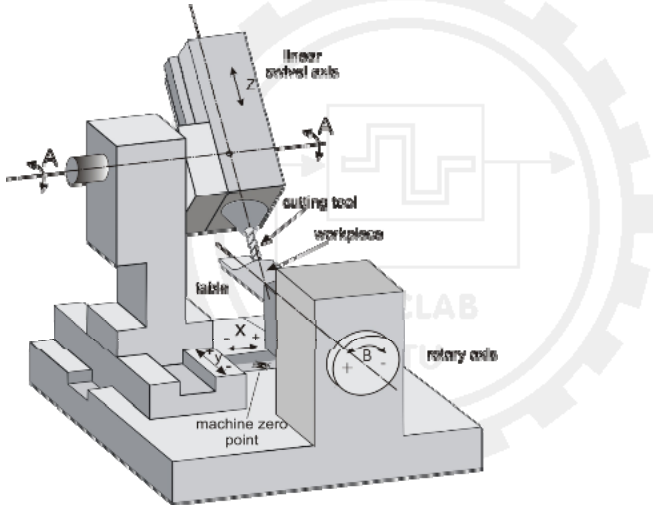


# Modeling of a DC Servo Drive with Load Dynamics

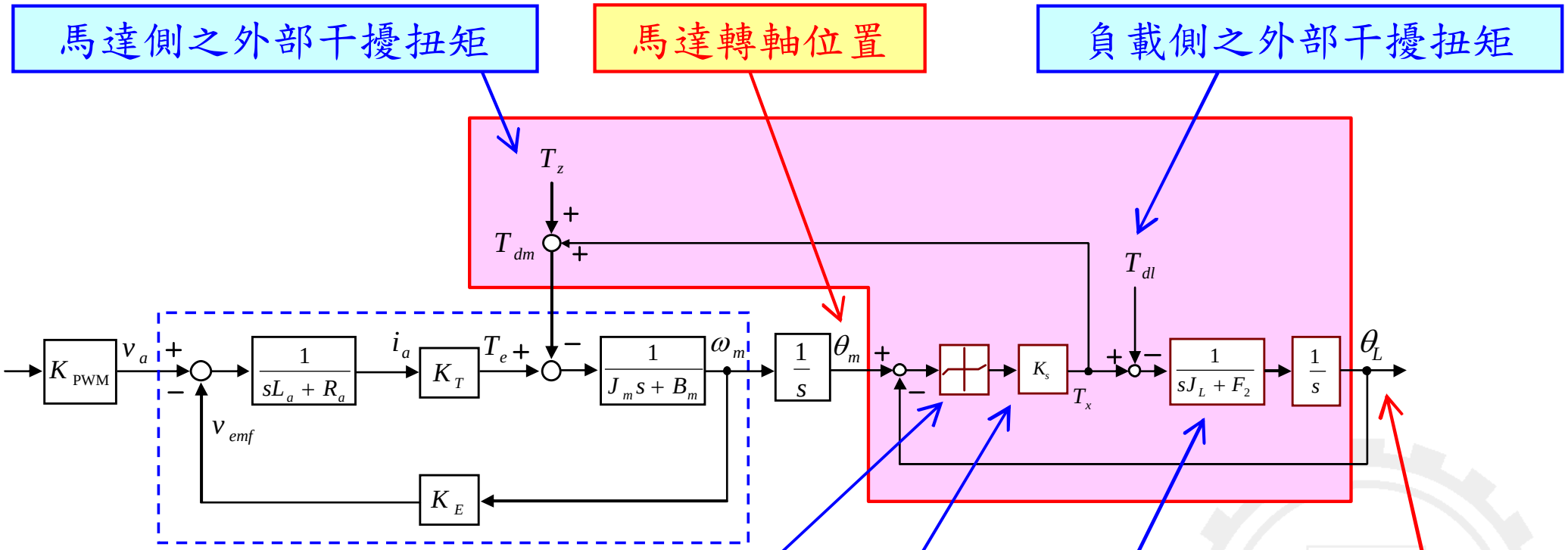



Nonlinearity of PWM Amp.

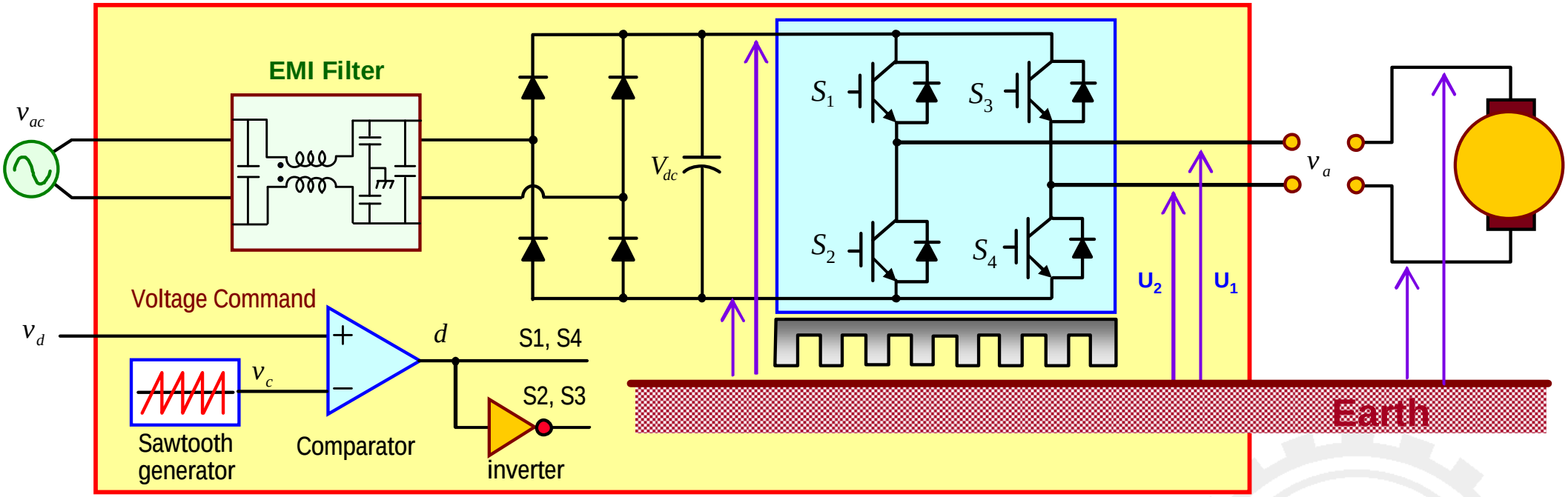


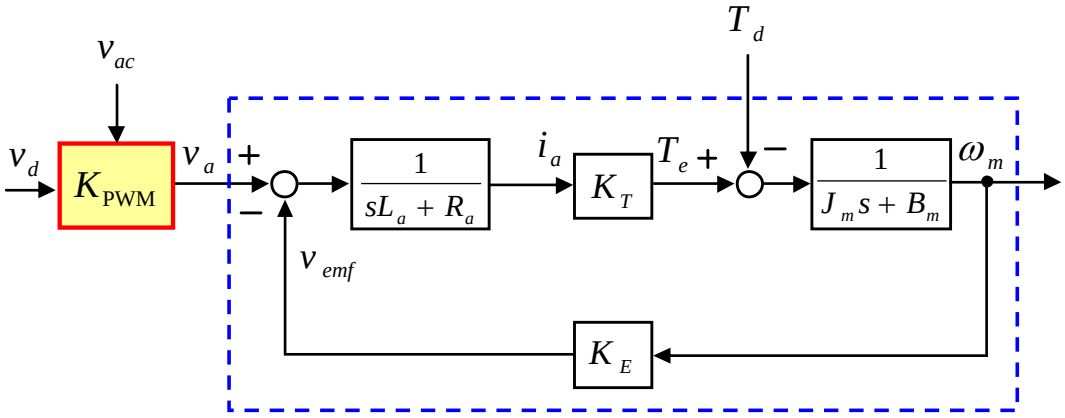


# Modeling of Load Dynamics and Disturbances



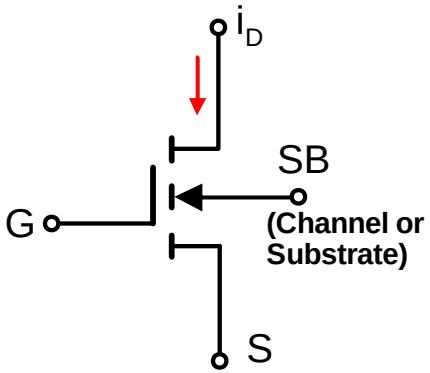
# Modeling the PWM Amplifier



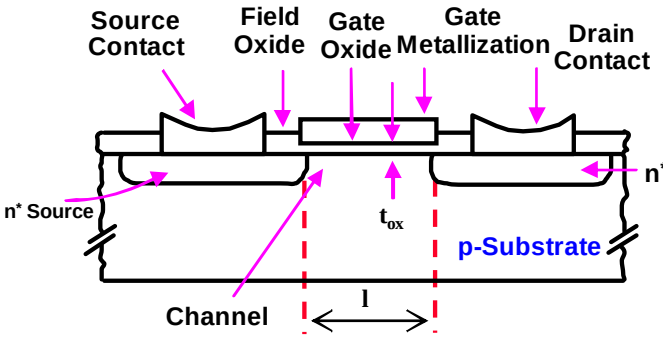




- Line Voltage Variations (±20%)
- Voltage Fall Due to Acceleration
- Voltage Rise Due to Regeneration
- PWM Modulation Schemes
- Dead-Time Effect
- Motor Parameters Variation
- Turn-On & Turn-Off Time & Slew Rate Control
- Common-Mode Noises

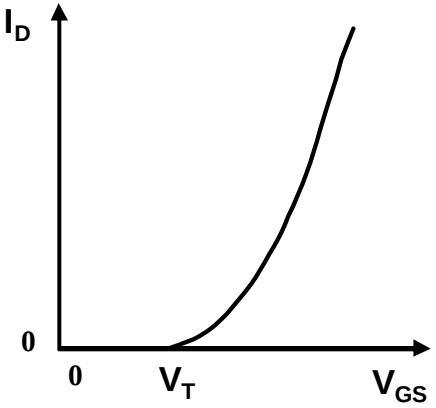
# Characteristics of N-Channel MOSFET



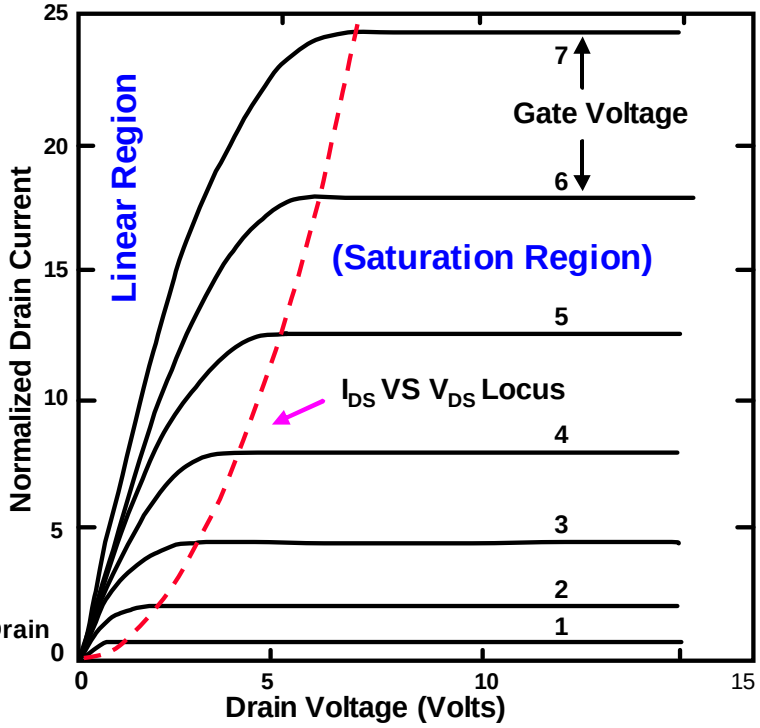

Symbol (N-Channel)



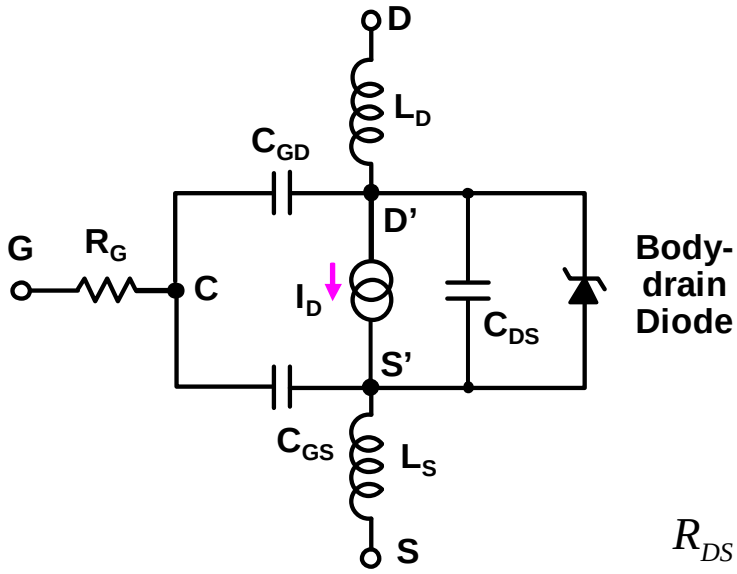

Schematic



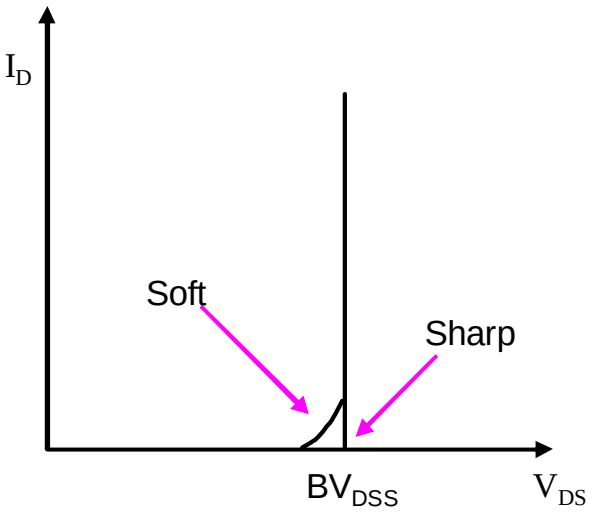

Transfer Characteristics



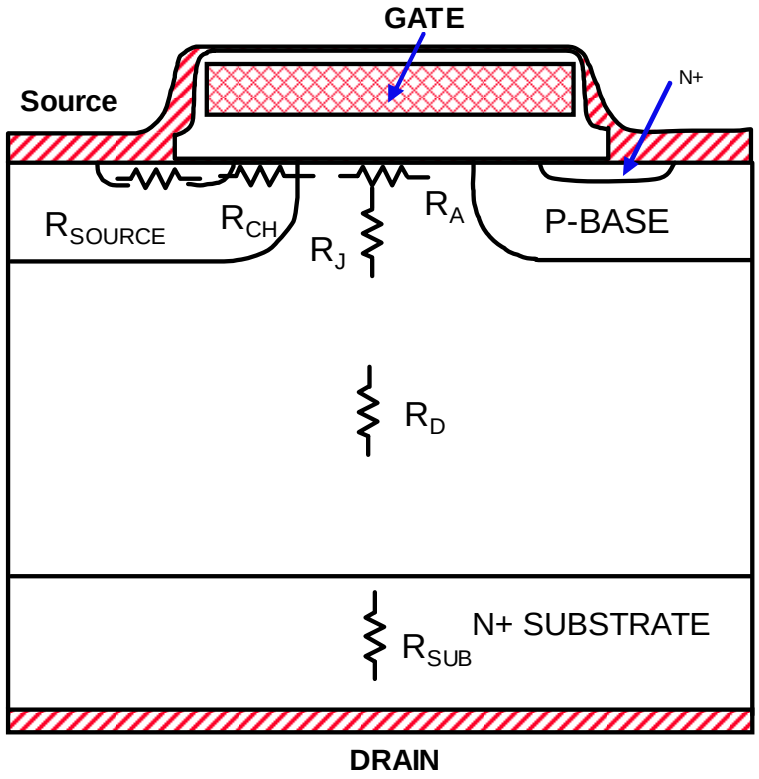

Current-Voltage Characteristics




Equivalent circuit




Breakdown Characteristics



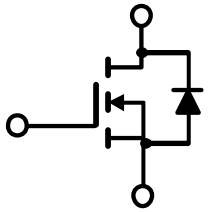

$$R_{DS(on)} = R_{source} + R_{ch} + R_A + R_J + R_D + R_{sub} + R_{wcml}$$

Origin of Internal Resistance

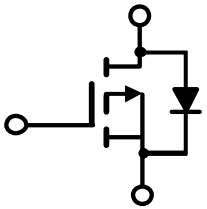
# MOSFET Device Model (PSIM)

Linear switches, which can operate in three states, include npn and pnp BJT, and n-channel and p-channel MOSFET. BJT devices can operate in either cut-off, linear, or saturation state. MOSFET devices can operate in either cut-off, active, or ohmic state.

MOSFET (n-channel)



MOSFET (p-channel)



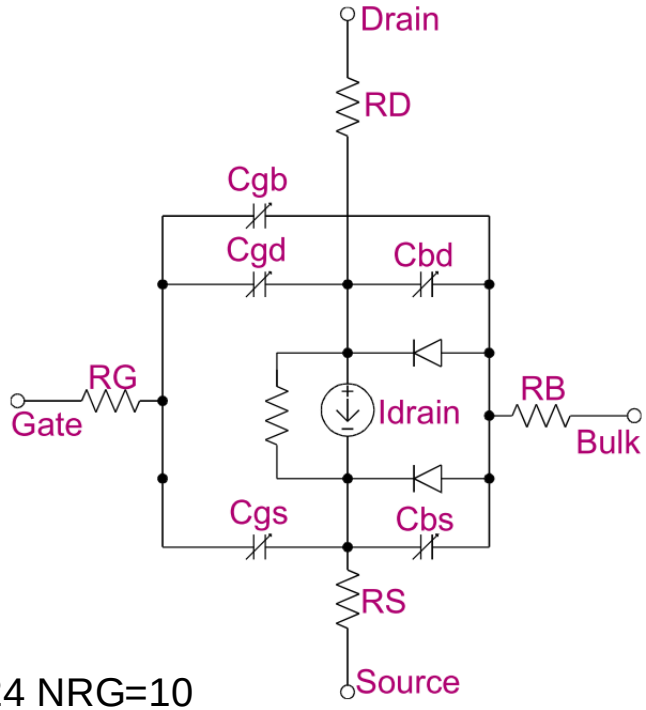
| Parameters | Descriptions |
|---|---|
| On Resistance | On resistance $R_{ds(on)}$ of the MOSFET, in Ohm. |
| Threshold Voltage $V_{gs(th)}$ | Threshold voltage of the gate-to-source voltage, in V, beyond which the MOSFET starts to conduct. |
| Transconductance $g_m$ | Transconductance $g_m$ of the MOSFET. |
| Diode Voltage Drop | Forward conduction voltage drop of the anti-parallel diode, in V. |

Warning: It has been found that linear switch models for BJT and MOSFET work well in simple circuits, but may not work in complex circuits. Please use these models with caution.

# MOSFET Device Model (PSPICE)

**General form**

M<name> <drain node> <gate node> <source node>
+ <bulk/substrate node> <model name>
+ [L=<value>] [W=<value>]
+ [AD=<value>] [AS=<value>]
+ [PD=<value>] [PS=<value>]
+ [NRD=<value>] [NRS=<value>]
+ [NRG=<value>] [NRB=<value>]
+ [M=<value>] [N=<value>]




**Examples**

M1 14 2 13 0 PNOM  L=25u W=12u
M13 15 3 0 0 PSTRONG
M16 17 3 0 0 PSTRONG M=2
M28 0 2 100 100 NWEAK L=33u W=12u
+ AD=288p AS=288p PD=60u PS=60u NRD=14 NRS=24 NRG=10

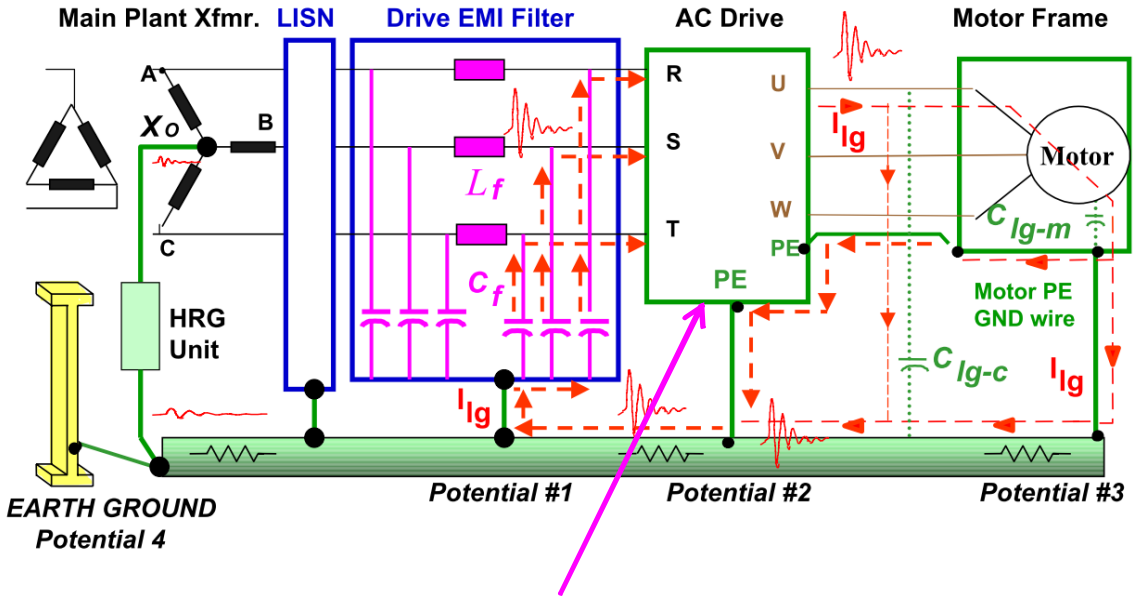
**Model form**

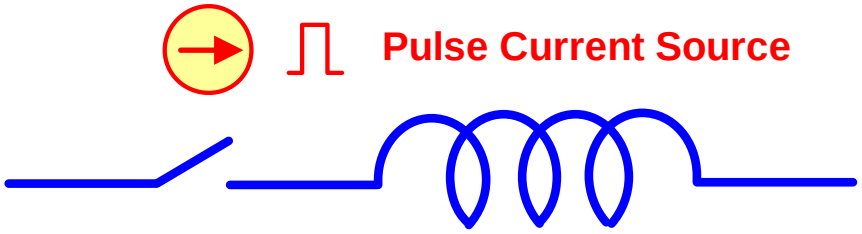
.MODEL <model name> NMOS [model parameters]
.MODEL <model name> PMOS [model parameters]

**Description**

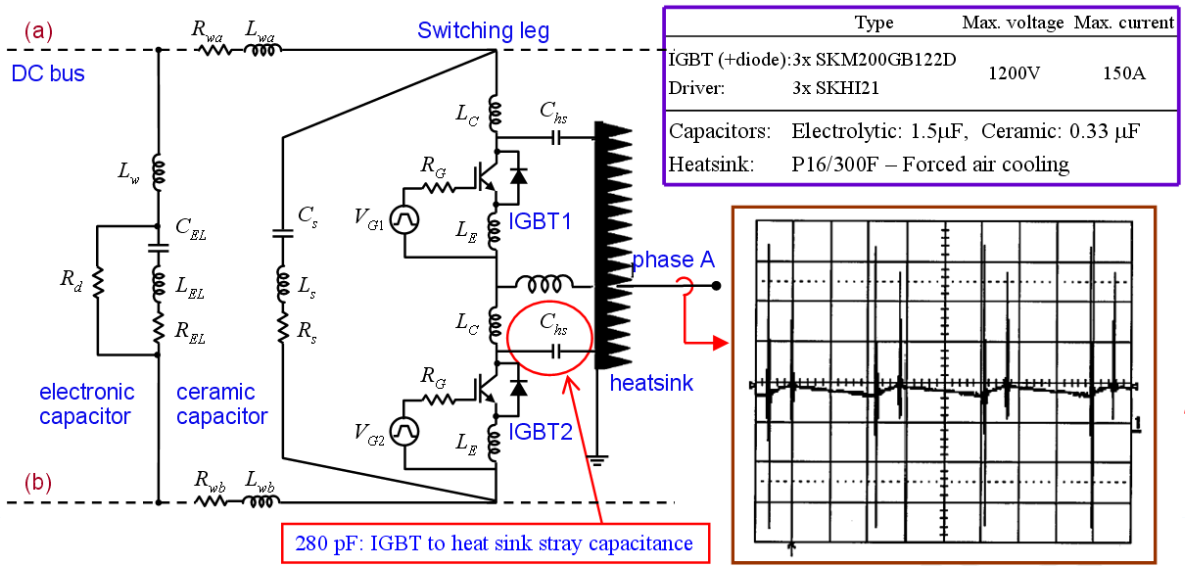
The MOSFET is modeled as an intrinsic MOSFET using ohmic resistances in series the with drain, source, gate, and bulk (substrate). There is also a shunt resistance (RDS) in parallel with the drain-source channel.

# Modeling of EMI Source in PWM Motor Drives



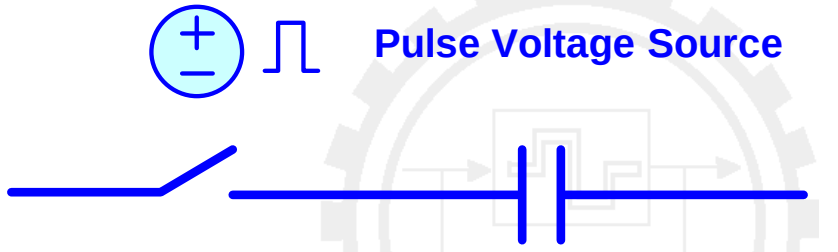




$$v = L\frac{di}{dt} \quad \Rightarrow \quad \Delta V = L\frac{\Delta I}{\Delta T}$$




| | Type | Max. voltage | Max. current |
|---|---|---|---|
| IGBT (+diode): | 3x SKM200GB122D | 1200V | 150A |
| Driver: | 3x SKHI21 | | |
| Capacitors: | Electrolytic: 1.5μF, Ceramic: 0.33 μF | | |
| Heatsink: | P16/300F – Forced air cooling | | |






$$i = C\frac{dv}{dt} \quad \Rightarrow \quad \Delta I = C\frac{\Delta V}{\Delta T}$$