Power (1)

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Contents

- Introduction
- Dynamic Power
- Static Power

Same Battery Capacity

Talk Time : 22.9 Hours

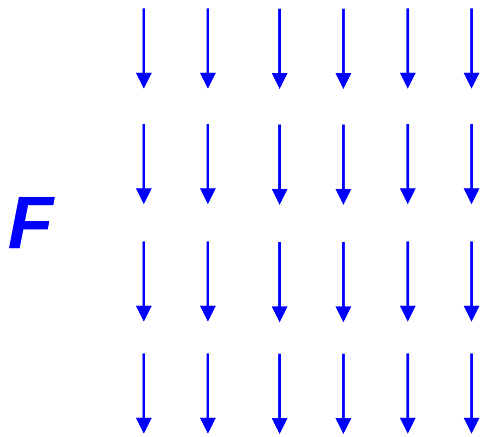
Talk Time : 24.5 Hours

Introduction

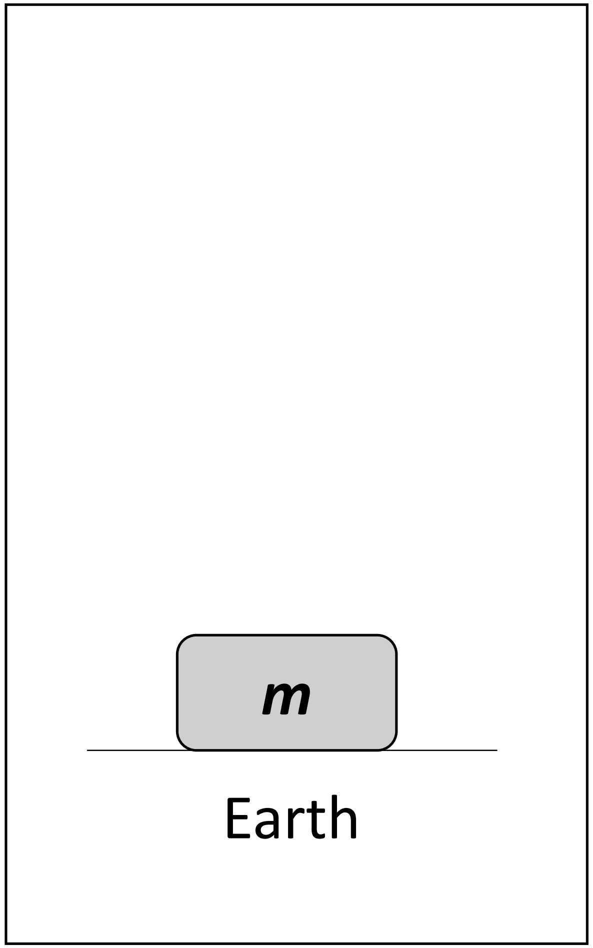
- ✓ What is power? Why is it important? How is it determined?

Work & Energy in Physics

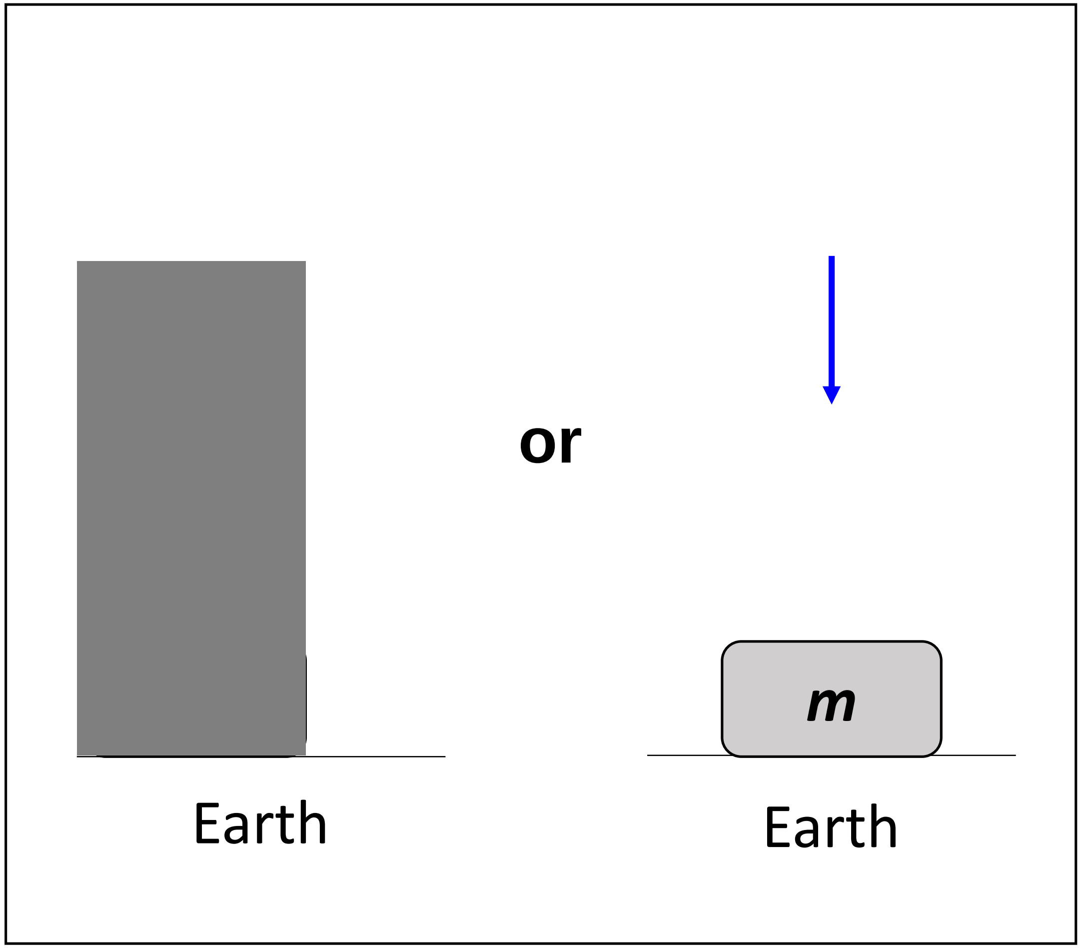
- **Work**? ➔ $W = \int F ds$ *or* $W = Fs$ (when F is fixed over s)
- **Energy** is the capacity for doing **work**.
- We can say **"energy" is dissipated or consumed** to do something we can call "work"



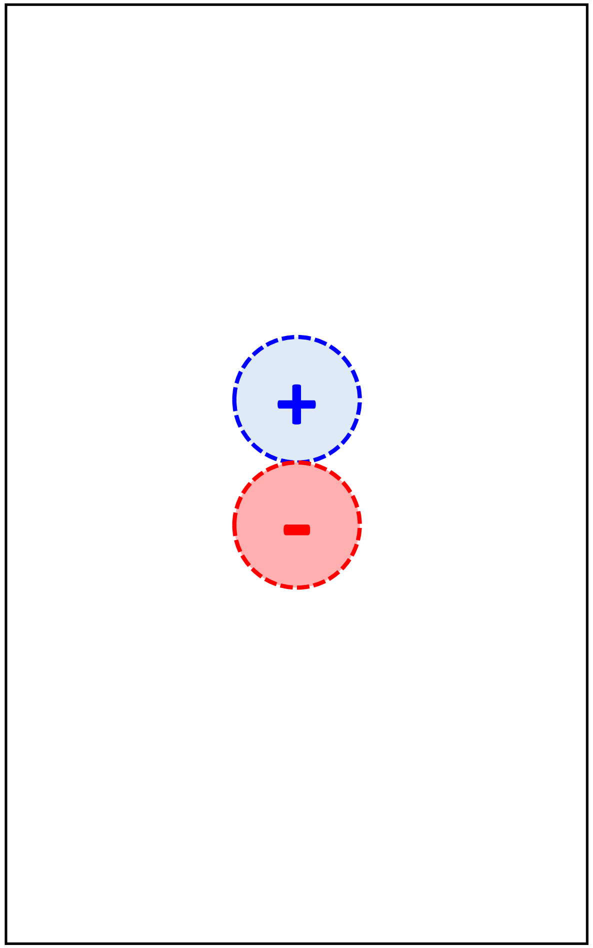
Which is More Natural? Or
Which Does Have More Energy?



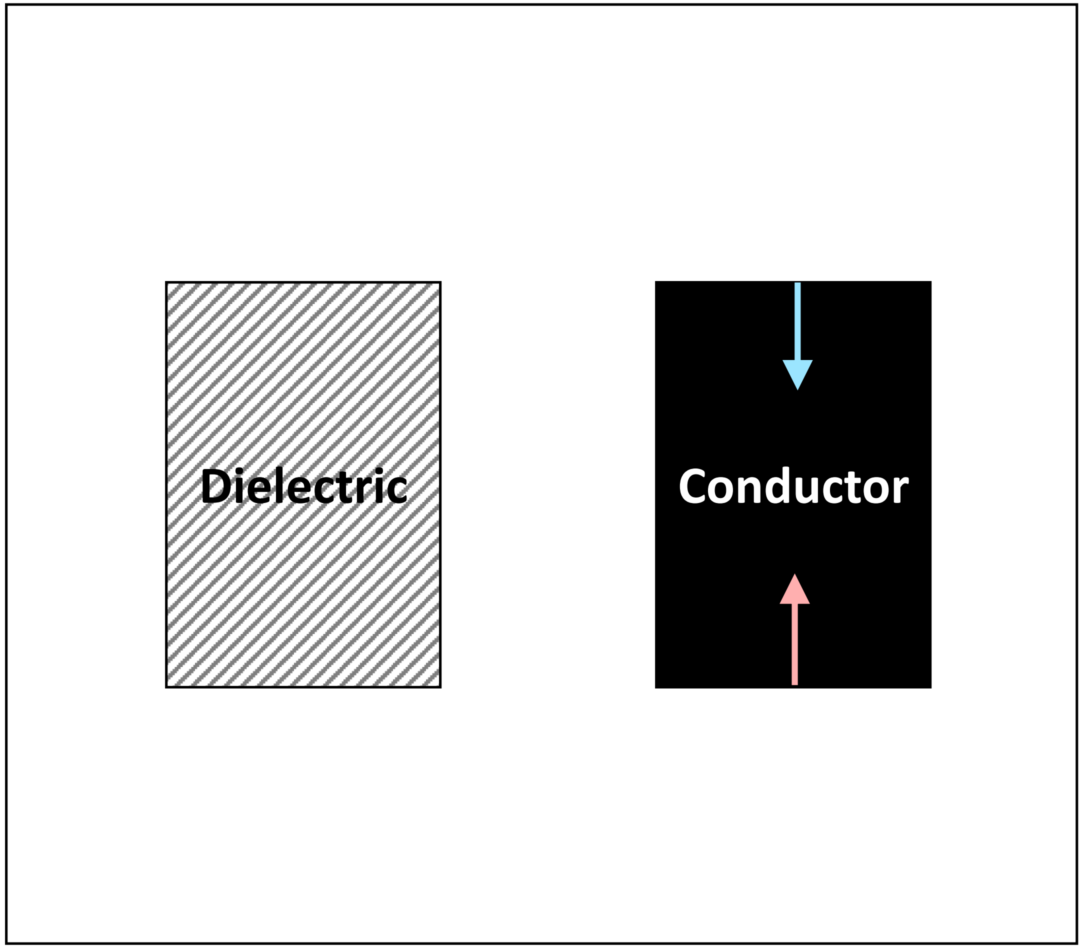
vs.



Again, Which is More Natural?
or Which Does Have More Energy?

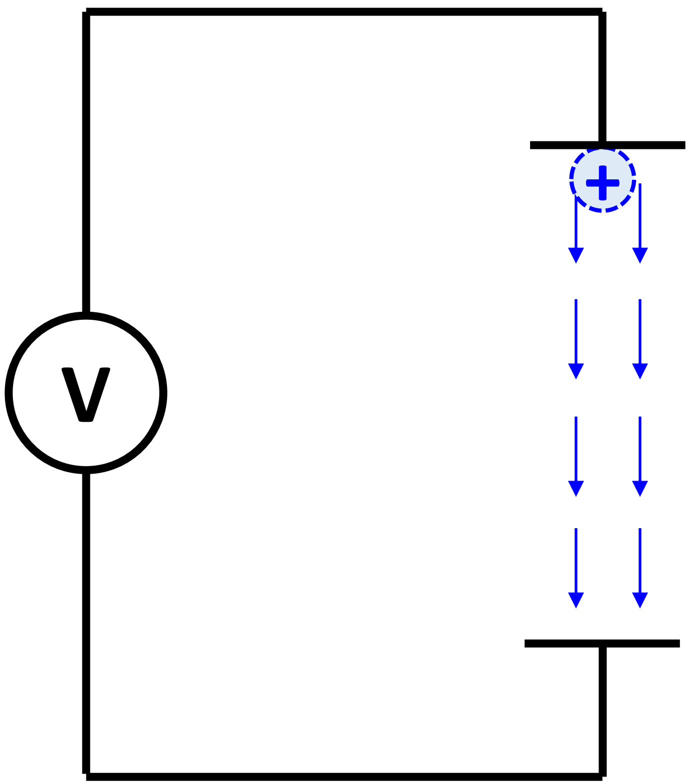


vs.



More Familiar/Simple Situation; Applying "Field" ➔ Charge Moves

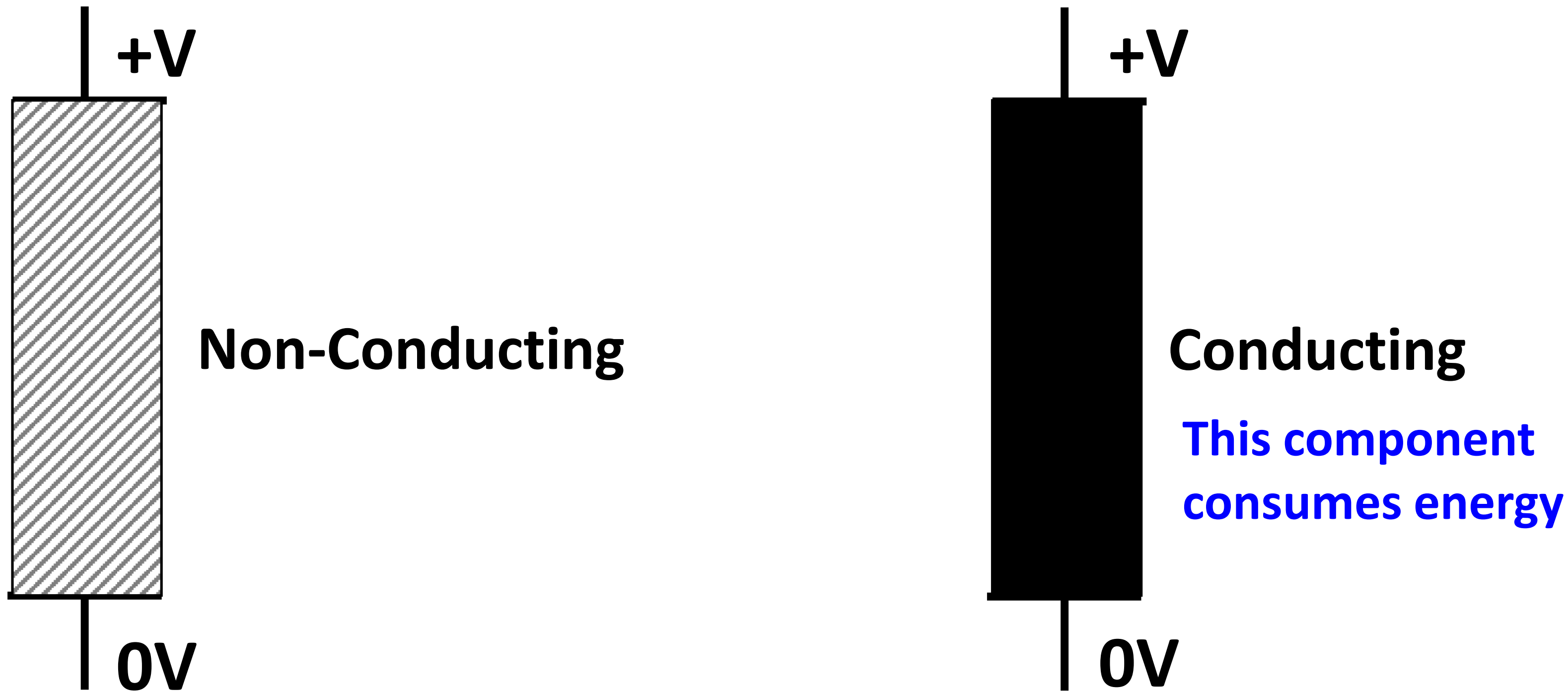
- Voltage is given ➔ Electric field is applied
- Then, charge becomes capable of moving, responding to the field



Meaning of Charge Movement for Voltage

- Potential of charge is decreased
- Corresponding amount of the energy is converted to something else

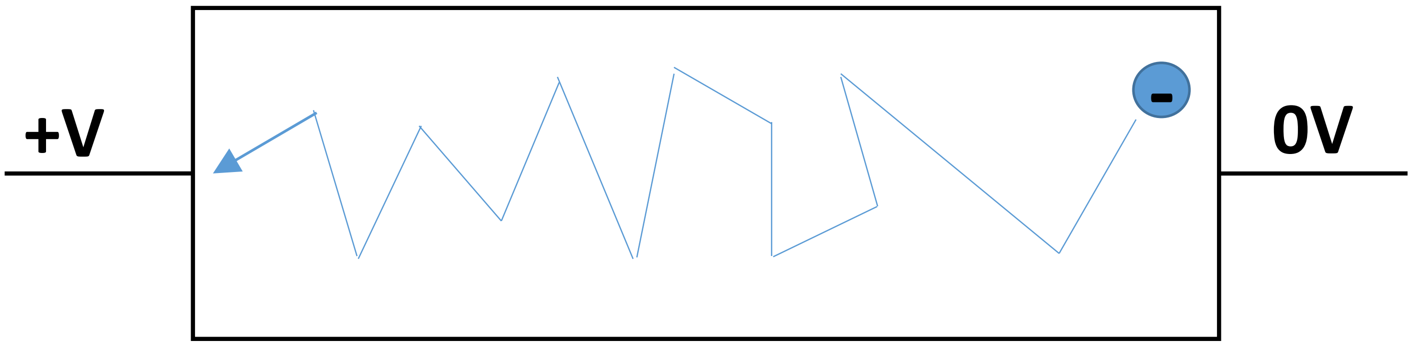
➔ We can say the energy is consumed by the component.



Dominant Energy Consumption Source in Conduction; Drift

- You remember drift current?

$$v = \mu E$$



Conducting Drift Current Means Energy Dissipation

- By how much? Consider the definition of voltage
- Then how can you relate it with **current**?

$$E_{consumed} = \Delta W = QV = IVt$$

Power

= Energy per time

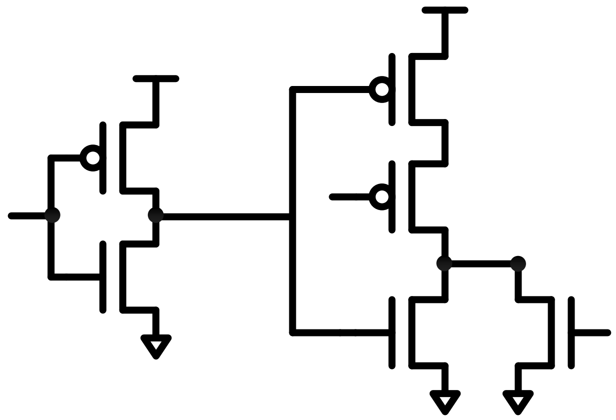
= $I \times V$

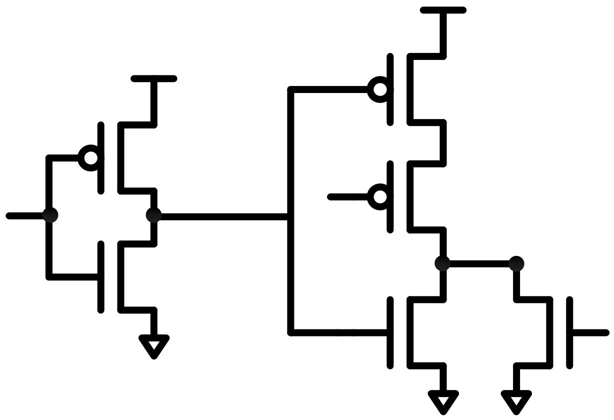
Conducting

This component consumes energy

Electrical Energy in Digital Circuit

- Charging & discharging nodes to VDD and GND, respectively.
  ➔ Key operation of digital circuits





Formal Definitions

- Instantaneous power consumed or supplied at time *t*

$$P(t) = I(t)V(t)$$

- Energy consumed or supplied over some time interval *T*,

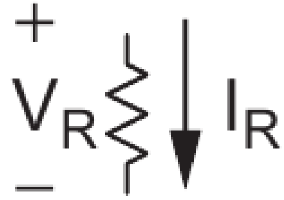
$$E = \int_0^T P(t)\,dt$$

- Average power over the interval

$$P_{\text{avg}} = \frac{E}{T} = \frac{1}{T}\int_0^T P(t)\,dt$$

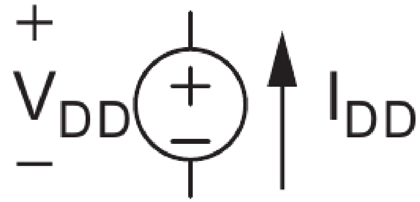
Examples

- The power dissipated in the resistor is



$$P_R(t) = \frac{V_R^2(t)}{R} = I_R^2(t) R$$

- The power supplied by the voltage source is

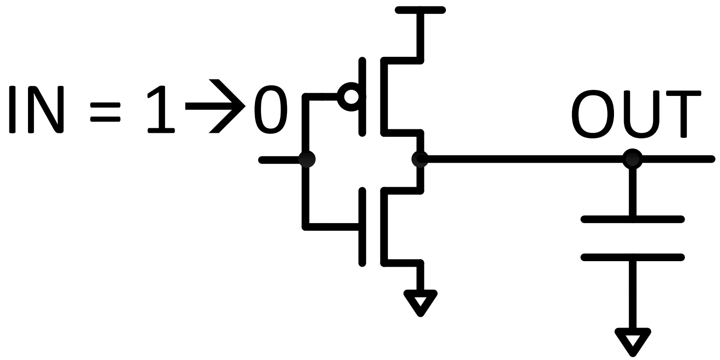


$$P_{VDD}(t) = I_{DD}(t) V_{DD}$$

- When the capacitor is charged from 0 to V_C, how much energy stored?

CMOS Inverter

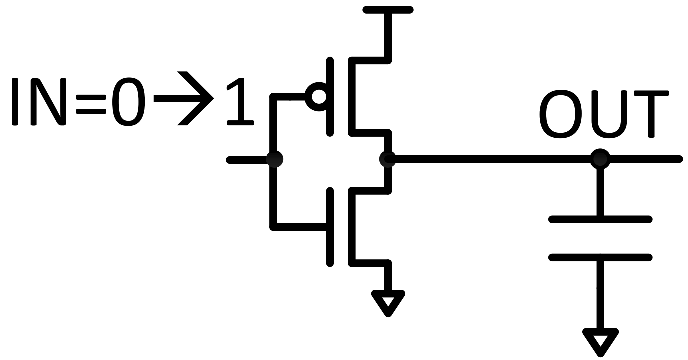
- Suppose that the output capacitance is C_{out}.
- What if IN falls? How about IN rises?



C_{out} : 0 → V_{DD} ➔ E_C?

Power Supplied from V_{DD}?

pMOS dissipates :



C_{out} : V_{DD} → 0 ➔ E_C?

nMOS dissipates :

➔ Short-circuit current path exist. Why?

Dynamic Power & Static Power

- Dynamic power is power required for switching the load capacitors.
- Even when the gate is not switching, it draws some static power.

➔ Because an OFF transistor is leaky, a small amount of current I static flows between power and ground, resulting in a static power dissipation

Sources of Power Dissipation

- Dynamic power dissipation come from:
  1) Charging and discharging load capacitances as gates switch
  2) "short-circuit" current while both pMOS and nMOS stacks are partially ON

$$P_{\text{dynamic}} = P_{\text{switching}} + P_{\text{short circuit}}$$

- Static power dissipation come from:
  1) Subthreshold leakage through OFF transistors
  2) Gate leakage through gate dielectric
  3) Junction leakage from source/drain diffusions
  4) Contention current in ratioed circuits

$$P_{\text{static}} = \left(I_{\text{sub}} + I_{\text{gate}} + I_{\text{junct}} + I_{\text{contention}}\right)V_{DD}$$

$$P_{\text{total}} = P_{\text{dynamic}} + P_{\text{static}}$$