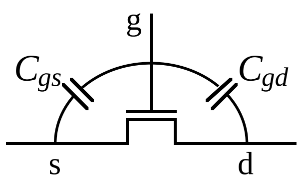
Charge Sharing

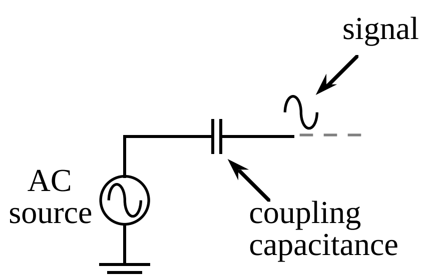
Dynamic circuits have nodes which retain charge. We must pay attention to how coupling capacitances between critical nodes can affect the charge stored on these nodes.

One set of coupling capacitances we need to worry about is C_{gs}, C_{gd}.

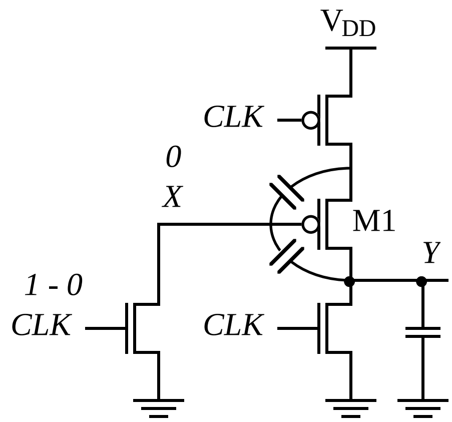


When channel is off, $C_{gs} = C_{gd} \approx 0$. When channel is (turned-on) in strong inversion, C_{gs} and/or C_{gd} are maximized (value varys depending on saturated or non-saturated device operation).

What is dynamic coupling?



What effects do we need to be worried about in dynamic structures?



Node *X* is precharged low when *CLK* = 1.

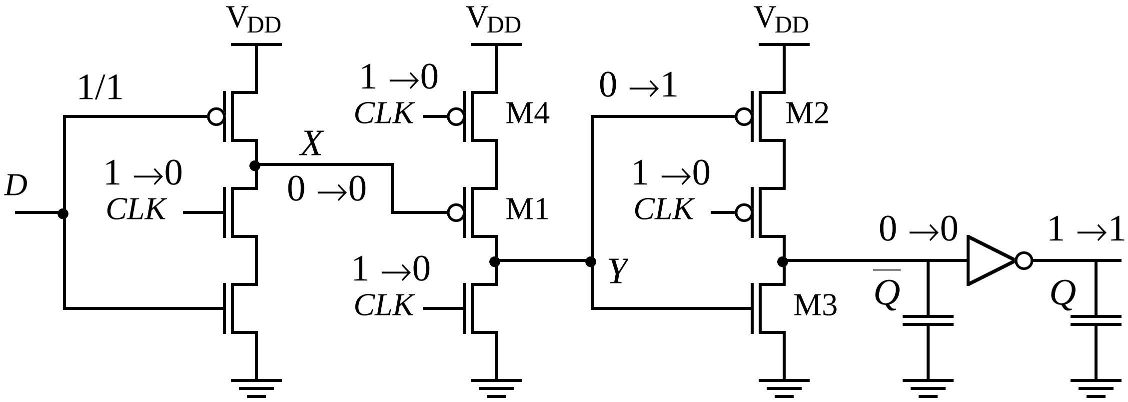
Node *Y* is also precharged low when *CLK* = 1.

When *CLK* 1 → 0, *X* is left floating. Node *Y* will be pulled from 0 → 1.

Because device M1 is on, coupling capacitances C_{gd}, C_{gs} are maximized.

As node *Y* pulled 0 → 1, some charge will coupled from *Y* and *X*. This will reduce device M1's available V_{SG}, consequently slowing the rise time of *Y*. Will this cause problems???

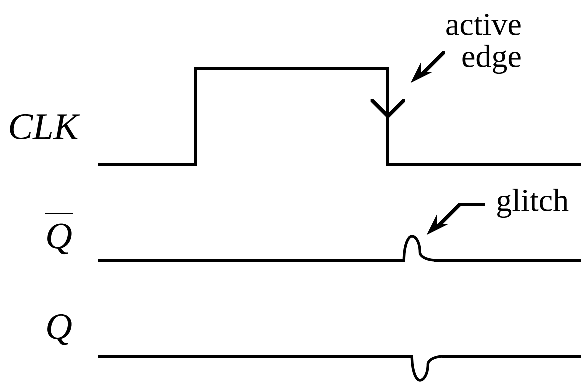
Dynamic D Flip-Flop Falling Edge Triggered



Charge coupling problem – will cause *Y* to rise more slowly than it should.

If it rises slowly, what happens?

M2/M3 get turned on at the same time, we see some charge getting dumped on $\overline{Q}$, causing a glitch on Q!



See SPICE curve . . .

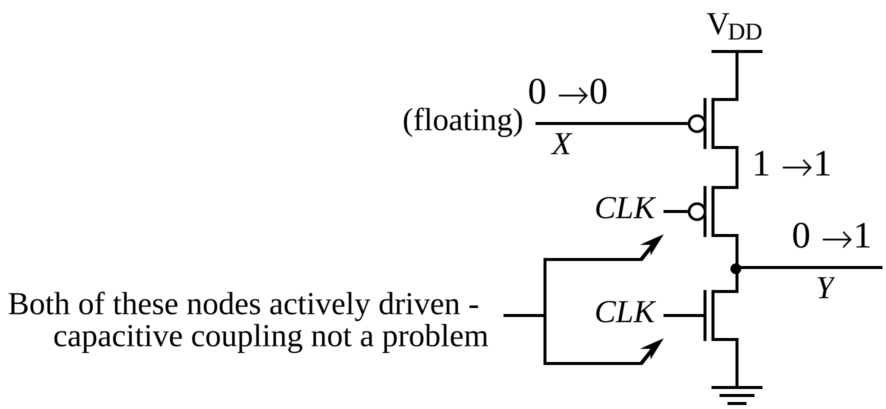
(SPICE curve given in class)

How can we fix this glitch problem???

If we want Y to rise faster despite slow-down effects of capacitive coupling, can make M1, M4 devices wider!!

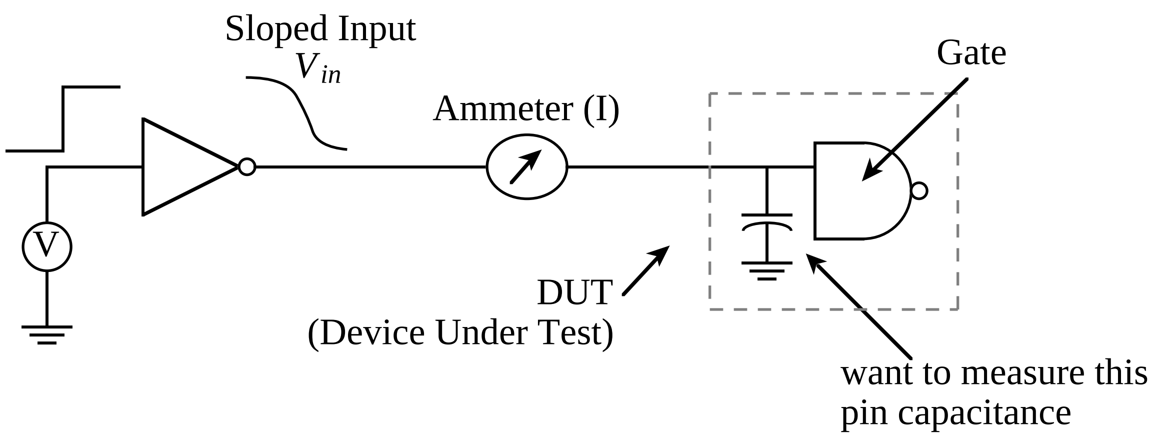
SPICE simulation shows that doubling the transistor widths reduces the glitch by almost 50%.

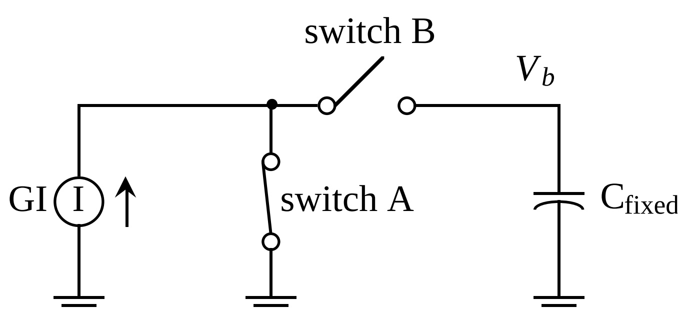
Can also swap positions of M1, M4 (see result in SPICE curve...)



(SPICE curve given in class)

Input Pin Capacitance Measurement





$$V_{70} = 0.7 \times V_{DD},\ V_{30} = 0.3 \times V_{DD}$$

For falling V_{in}, let switch A open and switch B close when $V_{in} = V_{70}$, then let switch B open and switch A close when $V_{in} = V_{30}$. Switch B operates exactly opposite of switch A.

Amount of charge ΔQ stored on C_{fixed} is

$$\Delta Q = I \times \Delta t$$

$$V_b \times C_{fixed} = I \times \Delta t$$

At C_{pin} we know

$$(V_{70} - V_{30}) \times C_{pin} = I \times \Delta t$$

If we set the previous two equations equal and solve for C_{pin} we get

$$V_b \times C_{fixed} = (V_{70} - V_{30}) \times C_{pin}$$

$$C_{pin} = \frac{V_b \times C_{fixed}}{V_{70} - V_{30}}$$

$$C_{pin} = \frac{V_b \times C_{fixed}}{0.4 \times V_{DD}}$$