MOS Sample & Hold

**Ideal Sampling**
- $v_{IN}$ to $v_{OUT}$ via switch $S1$
- $\phi_1$
- $C$
- **Pros:**
  - Grab exact value of $v_{in}$ when switch opens

**Practical Sampling**
- $v_{IN}$ to $v_{OUT}$ via transistor $M1$
- $\phi_1$
- $C$
- **Cons:**
  - $kT/C$ noise
  - Limited bandwidth
  - $R_{sw} = f(V_{in})$ → distortion
  - Switch charge injection
  - Clock jitter

---

EECS240 – Spring 2010

Lecture 23: MOS Sample and Hold

Elad Alon
Dept. of EECS
Switch Resistance

Acquisition Bandwidth

• Finite switch $R \rightarrow$ finite bandwidth

• Assuming constant $V_{in}$ and $C$ starts at 0V:

$$v_{out}(t) = v_{in}(1 - e^{-t/\tau})$$

• Leads to min. switch size for given bandwidth, resolution
  • Linear settling calc. – remember may only get $T/2$

• (Will $C$ always start at 0V?)
Switch $R_{on}$ Non-Linearity

Sampling Distortion

$$v_{out} = v_{in} \left( 1 - e^{-\frac{T}{2\tau} \left( \frac{v_{out}}{v_{in}} - 1 \right)} \right)$$

$T/\tau = 10$

$T/\tau = 20$
Constant $V_{GS}$ Sampling

- Switch overdrive voltage is independent of signal
- Error from finite $R_{ON}$ is linear (to first order)
Complete Circuit


Charge Injection

- “Extra” charge dumped onto holding capacitor
- Channel charge has to go somewhere
- (Also get injection through $C_{ov}$)
- Problems:
  - Offset
  - Distortion (error charge is function of $V_{IN}$)
Worst-Case Error Example

Channel charge:

$$Q_{CH} = WLC_{min}(V_{DD} - V_{in} - V_{TH})$$

Max pedestal error:

$$V_{in} = V_{SS}$$

$$\Delta V = \frac{Q_{CH}}{C_2} = \frac{WLC_{min}}{C_2}(V_{DD} - V_{SS} - V_{TH})$$

Example:

$$\Delta V = \frac{10 \times 0.35 \times 5}{1000} (3 - 0.6) = 42 \text{mV}$$

Dummy Switch

- Dummy switch is half width
- Depends on equal split between source and drain
- Is split equal?

Charge Injection Analysis

- Can perform more detailed, distributed analysis
  - Results depend on how fast switch is turned off

- Note that SPICE doesn’t do this (lumped model) – uses “XPART” parameter instead:
  - XPART = 0: Source 60%, Drain 40%
  - XPART = 0.5: equal split
  - XPART = 1: 100% Drain

Rejecting Injection Error
Bottom-Plate Sampling

- Turn off $\Phi_{1a}$ first
  - Injected charge is constant
  - Removed in differential output
- Switch $\Phi_{1b}$ opens later
  - $C_2$ disconnected
  - “zero” charge injected
- Is this useful?
  - $V_2 = 0V$...

Using Bottom-Plate Sampling
Using Bottom-Plate Sampling