Simple DAC architectures
Basic DAC with External Reference

- Most DACs require that their reference voltage be within quite a narrow range whose maximum value is less than or equal to the DAC's VDD,
- Multiplying DACs (or "MDACs"), will work over a wide range of reference voltages that may go well outside their power supply
1-Bit DAC

- If $d0 = 1$
  - Output = $V_{\text{ref}}$
- If $d0 = 0$
  - Output = gnd
The Kelvin Divider (String DAC)

- N-bit version consists of $2^N$ equal resistors in series and $2^N$ switches
- Need N-bit binary to “1 out of $2^N$” decoder
- If input code = k, analog output = V_k

HW: synthesize a 6 bit decode
$V_{\text{ref}}$

$2^N$ resistors

$B_{\text{in}} = b_12^{-1} + b_22^{-2} + b_32^{-3}$

Chapter 16 Figure 01
Chapter 16 Figure 04
Trimming the INL

- Trim the four main resistors after fabrication so that 3 major nodes are at correct potential
- Four point trimming can reduce the INL by a factor of four.
Digital Potentiometer

\[ V_{\text{TAP}} = V_B + D^*(V_A - V_B) \]

- Widely used in appliances, entertainment electronics, …
Chapter 16 Figure 05

Coarse string, needs $2^N$ bit accuracy $N_{\text{int}}$

Fine string, needs 3 $N_{\text{new}}$ bit accuracy
Unbuffered String DACs

- Fine string // R ⇒ 7R/8
- Total resistance = 8R, current = Vref/8R
- Voltage across fine string = Vref/8R * 7R/8 = 7Vref/64
- Each resistor in fine string has voltage = Vref/64
4-Bit R-2R Ladder Network

- One of the most common DAC building-block structures
- uses resistors of only two different values with ratio 2:1
- An N-bit DAC requires 2N resistors, easily trimmable
- two ways in which the R-2R ladder network may be used as a DAC
Voltage-Mode R-2R Ladder

- "rungs" or arms of the ladder are switched between VREF and ground
- Output node has output impedance = R, may need to buffer

Segmented Voltage-Output DACs

- Coarse string has $2^M$ equal resistors, must be accurate to $M+K$ bit level
- Fine stage $K$-bit DAC must have $K$-bit accuracy
- Fine stage could be string DAC or R-2R DAC
- Use buffers to isolate the two stages, buffers need to be accurate to the $M+K$ bit level
Current-Mode R-2R Ladder

- Series R can be used to adjust gain of DAC
- R_out is code dependent, leading to DAC nonlinearity