Digital to Analog Converter

8-Bit DAC

Digital input

Analog Voltage
Pulse Width Modulation (PWM)

Duty cycle = $\frac{t_2}{t_1}$
Pulse Width Modulation (PWM)

Duty cycle = \( \frac{t_2}{t_1} \)

![Diagram of PWM with circuit components and waveform graph showing smooth DC output.](image-url)
Pulse Width Modulation (PWM)
Pulse Width Modulation (PWM)
Figure 2: Simplest Voltage-Output Thermometer DAC: The Kelvin Divider ("String DAC")
Resistor String DAC

Figure 4: The Simplest Current-Output Thermometer (Fully-Decoded) DAC
Resistor String DAC

Figure 4: The Simplest Current-Output Thermometer (Fully-Decimal) DAC

Figure 5: Current Sources Improve the Basic Current-Output Thermometer DAC
Resistor String DAC

Figure 4: The Simplest Current-Output Thermometer (Fully-Decoded) DAC

Figure 5: Current Sources Improve the Basic Current-Output Thermometer DAC

Figure 6: High Speed Thermometer DAC with Complementary Current Outputs
Resistor String DAC

![Resistor String DAC Diagram](image)

**Figure 29.2** (a) A simple resistor-string DAC
Figure 29.2  (a) A simple resistor-string DAC and (b) the use of a binary switch array to lower the output capacitance.
Inverting Op Amp
Inverting summer circuit

\[ V_{\text{out}} = \]
Inverting summer circuit

\[ V_{\text{out}} = - (V_1 + V_2 + V_3) \]
DAC with Weighted Sum

\[ V_{out} = - \left( V_1 + \frac{V_2}{2} + \frac{V_3}{4} \right) \]
Binary Weighted DAC
Binary Weighted DAC

R/2R "ladder" DAC
Digital to Analog Converter

R/2R RESISTOR NETWORK
www.ikalologic.com
DAC Implementation

Table 30.1 Summary of experimental results.

<table>
<thead>
<tr>
<th></th>
<th>8-bit</th>
<th>10-bit</th>
<th>12-bit</th>
</tr>
</thead>
<tbody>
<tr>
<td>DNL (LSB)</td>
<td>0.150</td>
<td>0.450</td>
<td>2.000</td>
</tr>
<tr>
<td>INL (LSB)</td>
<td>0.200</td>
<td>1.000</td>
<td>3.000</td>
</tr>
<tr>
<td>Settling time</td>
<td></td>
<td>200 ns</td>
<td></td>
</tr>
<tr>
<td>Power</td>
<td></td>
<td>3.88 mW</td>
<td>driving a 1k load</td>
</tr>
<tr>
<td>Area (mm²)</td>
<td></td>
<td>0.045</td>
<td></td>
</tr>
<tr>
<td>$f_{clk,max}$</td>
<td></td>
<td>4 MHz</td>
<td></td>
</tr>
<tr>
<td>Output swing</td>
<td></td>
<td>$0 &lt; V_{out} &lt; VDD$ (= 1.8 V)</td>
<td></td>
</tr>
</tbody>
</table>
DAC Implementation

Figure 30.4 Experimental results for the wide-swing DAC of Fig. 30.3.
Pipeline DAC

Figure 29.19 A pipeline digital-to-analog converter.
Digital to Analog Converter