OPERATIONAL AMPLIFIERS: REVIEW

- We use differential amplifiers with feedback (output and input connected) to perform mathematical operations.
- We also use amplifiers to provide predictable voltage and additional current to output "loads.
- We can analyze amplifier circuits using the circuit model.
- Or, we can analyze using the simpler "ideal" assumptions.
- We can design an amplifier to perform a certain operation by choosing the right form and then choosing resistor values.

\[ V_0 = A(V_+ - V_-) \]

**Differential Amplifier**

**Circuit Model in linear region**

- Output of logic gate will turn light bulb on or off.
- Light bulb connected directly to logic gate may draw too much current from logic gate!
- Vo is Vin/2 **regardless** of what is attached to output.
- Not true without voltage follower!
INTEGRATING AMPLIFIER

\[ V_0(t) = -\frac{1}{RC} \int_0^t V_{IN}(T)dT + V_C(0) \]

ANALOG VS. DIGITAL

Analog Adder

<table>
<thead>
<tr>
<th>Analog</th>
<th>V1</th>
<th>V2</th>
<th>Vout</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 V</td>
<td></td>
<td></td>
<td>5 V</td>
</tr>
<tr>
<td>2 V</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Digital Adder

<table>
<thead>
<tr>
<th>Digital Adder</th>
<th>A1</th>
<th>A0</th>
<th>S2</th>
<th>S1</th>
<th>S0</th>
</tr>
</thead>
<tbody>
<tr>
<td>&quot;3&quot;</td>
<td>5 V</td>
<td>5 V</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&quot;2&quot;</td>
<td>5 V</td>
<td>0 V</td>
<td></td>
<td></td>
<td>5 V</td>
</tr>
<tr>
<td>&quot;5&quot;</td>
<td></td>
<td>0 V</td>
<td>5 V</td>
<td></td>
<td>5 V</td>
</tr>
</tbody>
</table>
D/A CONVERSION

Example: Digital sound (CD) to analog (speaker)

Let's have each “1” on the CD translate to 0.5 V at the speaker.

Another way is to sum charges instead of current with capacitor networks.

COMPARATORS

Using differential amplifier without feedback:

If \( V_+ > V_- \), the output \( V_o \) will be at the upper rail.
If \( V_+ < V_- \), the output \( V_o \) will be at the lower rail.

UNLESS…

\( V_+ \) is very close to \( V_- \), such that \( A(V_+-V_-) \) is between the rails.
COMPARATORS

Comparator with 2V threshold

差分电压比较器

Comparator transfer curve

Inverter

Symbol

To function as logic gate, set upper rail to logic 1 and lower rail to logic 0.

ONE-BIT A/D CONVERSION
IN DIGITAL SYSTEMS

Set comparator threshold at a suitable value (border between logic 0 and logic 1)

Comparator output goes to +rail (logic 1) if

\[ V_{IN} > V_{THRESHOLD} \]

and to −rail (logic 0) if

\[ V_{IN} < V_{THRESHOLD} \]