The S-R Phase Detector

Consider now the Set/Reset Flip-Flop:

Recall the truth table for this device is:

<table>
<thead>
<tr>
<th>R</th>
<th>S</th>
<th>Q_{n+1}</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>\text{Not used}</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>\text{Not used}</td>
</tr>
</tbody>
</table>

It turns out that this device makes a great phase detector for digital signals of the form:

\[ v(t) = \text{pulse}[\Theta(t)] \]
I.E.:

A plot of these signals could be:

\[ v_{VCO}(t) \]
\[ v_{\text{ref}}(t) \]
\[ v_{\varepsilon}(t) \]
Q: Hey wait a minute! I thought you said that the error voltage was supposed to be proportional to the phase difference. This does not appear to be at all true.

A: It is true! It’s just that the error voltage proportional to the phase difference is again a little bit hidden.

Say we find the time-averaged value of error voltage $v_e(t)$ by integrating the error signal shown above over one period:

$$\frac{1}{T} \int_0^T v_e(t) \, dt = V_{dd} \left( \frac{T}{T} \right)$$

This is of course the DC component of the error voltage ($V_e$).

And look what it tells us!

The DC component of the error voltage provides us with the delay value $\tau/T$—this is what we need to determine the phase difference!

Combining with the results above, we get:

$$V_e = V_{dd} \left( \frac{T}{T} \right) = \left( \frac{V_{dd}}{2\pi} \right) \Delta \theta$$

Thus, the proportionality constant for the Set-Reset phase detector is:
\[ K_\theta = \left( \frac{V_{DD}}{2\pi} \right) \]

So that:

\[ V_\epsilon = K_\theta \Delta \theta \]

Note that the gain value \( K_\theta \) of the Set-Reset phase detector is **half** that of the Ex-OR phase detector.

However, the Set-Reset phase detector is a \( 2\pi \)-phase detector—**twice** that of the Ex-OR. Its transfer function is:

![Graph showing the transfer function of a Set-Reset phase detector](image)

**One last point** about the S-R phase detector: if the flip-flop is **“edge triggered”**, then it can likewise be used for digital signals of the form:

\[ v(t) = \text{rect} \left( \Theta(t) \right) \]

In fact, for edge-triggered S-R phase detectors, the duty **cycle** of the input signals matters **not at all**—only the **period** (frequency) of the digital signal matters in the detector output.