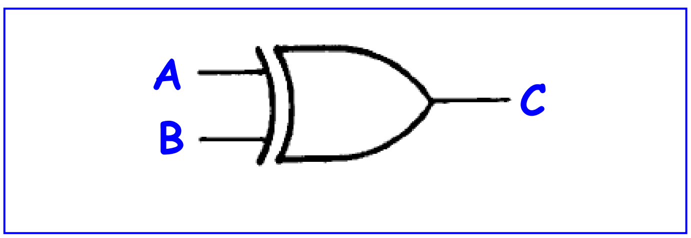
# Ex-OR Phase Detectors

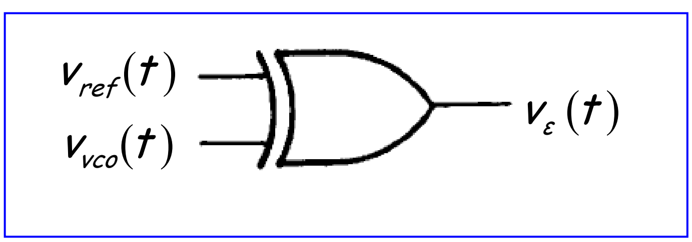
Consider an **exclusive-OR** gate. Recall the **truth table** for this gate is:

| A | B | C |
|---|---|---|
| 0 | 0 | 0 |
| 0 | 1 | 1 |
| 1 | 0 | 1 |
| 1 | 1 | 0 |

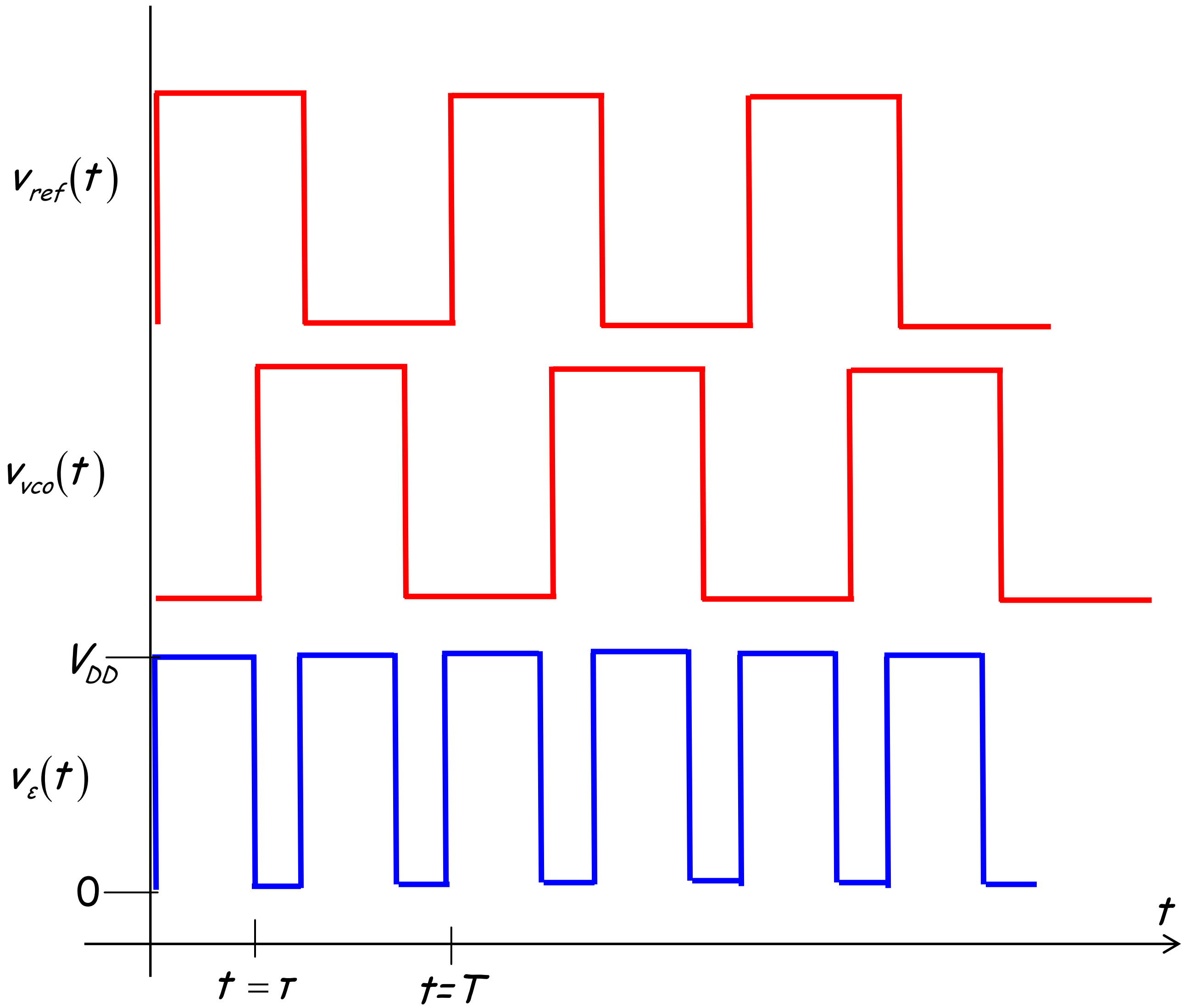



This device makes a great **phase detector** for **digital** signals of the form:

$$v(t) = rect\left[\theta(t)\right] \quad !!$$




A plot of these signals **could** be:




**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 a little bit **hidden**.

Say we find the **time-averaged** value of error voltage $v_{\varepsilon}(t)$ by integrating the error signal shown above over **one period**:

$$\frac{1}{T}\int_0^T v_\varepsilon(t)\,dt = 2V_{DD}\left(\frac{\tau}{T}\right)$$

This is of course the **DC component** of the error voltage ($V_\varepsilon$).

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:

$$V_\varepsilon = 2V_{DD}\left(\frac{\tau}{T}\right) = \left(\frac{V_{DD}}{\pi}\right)\Delta\theta$$

Thus, the **proportionality constant** for this phase detector is:

$$K_\theta = \left(\frac{V_{DD}}{\pi}\right)$$

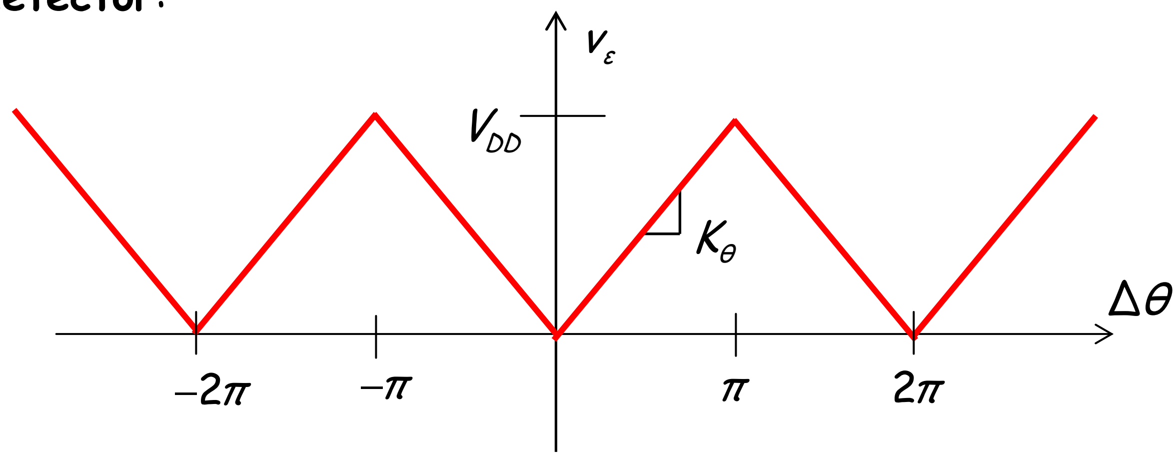
So that:

$$V_\varepsilon = K_\theta\,\Delta\theta$$

**Q:** *But wait! The error voltage likewise has a* ***AC component*** *(i.e., $v_\varepsilon(t) - V_\varepsilon$). Don't we have to* ***remove*** *this AC component?*

**A:** Absolutely! **How** can we remove the AC component from $v_\varepsilon(t)$??

Finally, we note that the Ex-OR phase detector is a $\pi$ **-phase detector**:




Thus, its unambiguous detection range is **limited** to $0 \leq \Delta\theta \leq \pi$ !