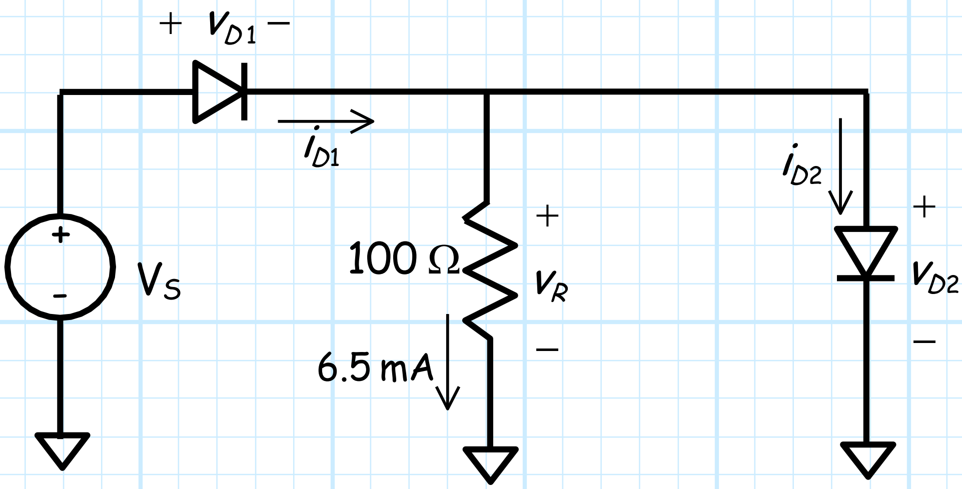
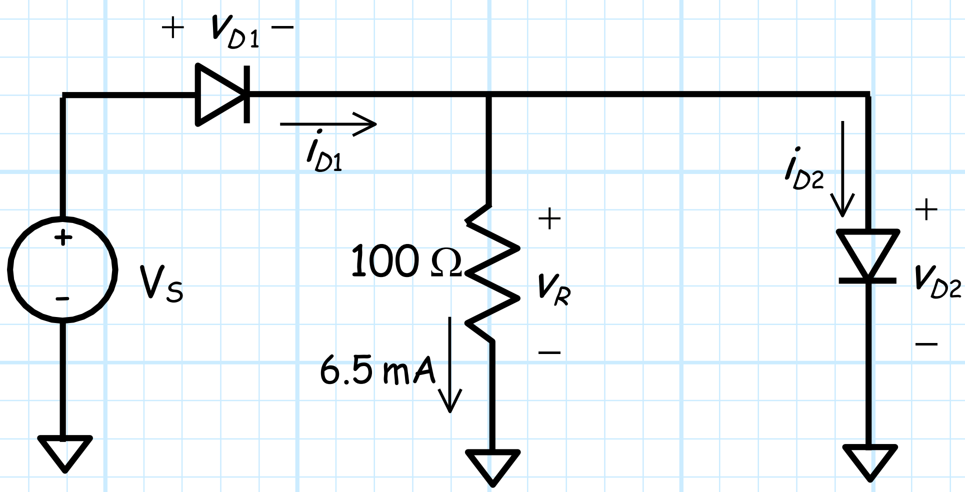
Example: A Junction Diode Circuit

Consider the following circuit with two junction diodes:



The diodes are identical, with n = 1 and $I_S = 10^{-14}$ A.

Q: *If the current through the resistor is 6.5 mA, what is the voltage of source V_S??*



1) If 6.5 mA flows through a 0.1 K resistor, the voltage across that resistor is:

$$v_R = 0.1\,(6.5) = 0.65\ V$$

2) If the voltage across the resistor is 0.65 V, then the voltage across the diode D_2 , which is **parallel** to the resistor, is the **same** value:

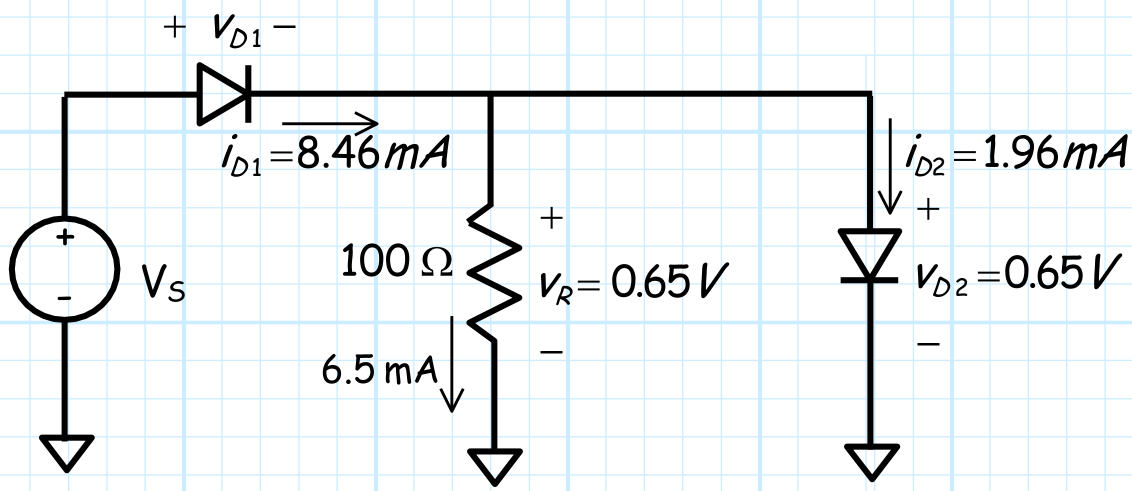
$$v_{D2} = v_R = 0.65\ V$$

3) If we know the **voltage** across a p-n junction diode, then we also know its **current** !

$$i_{D2} = I_S \exp\frac{v_{D2}}{nV_T} = 10^{-14} \exp\frac{0.650}{0.025} = 1.96\ mA$$

4) If we know i_{D2} and the current through the resistor, we know (using KCL) the current through D_1 :

$$\begin{aligned} i_{D1} &= 6.5 + i_{D2} \\ &= 6.5 + 1.96 \\ &= 8.46\ mA \end{aligned}$$

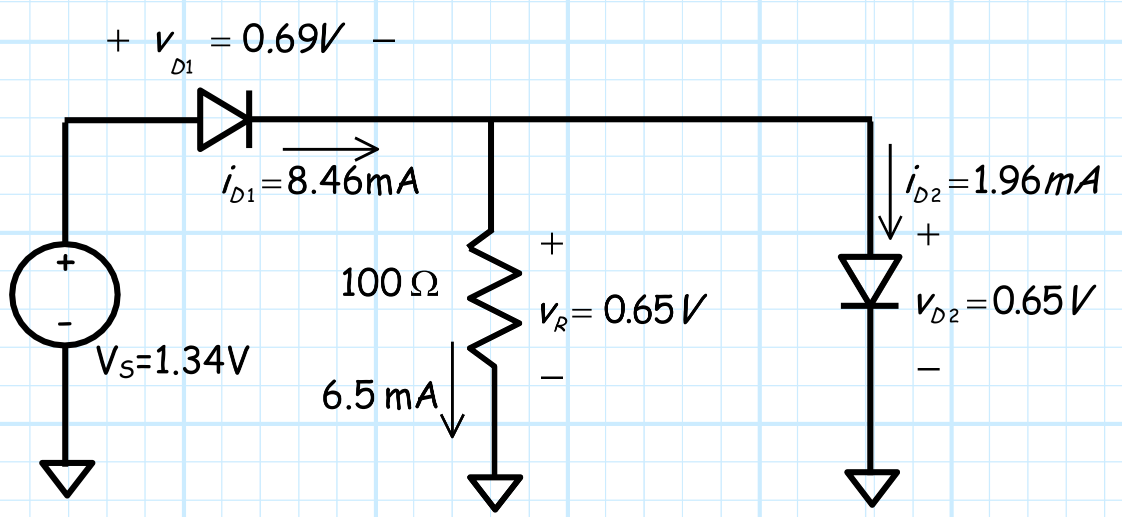


5) If we know the **current** through a junction diode, then we can find the **voltage** across it:

$$v_{D1} = nV_T \ln\frac{i_{D1}}{I_S} = 0.025 \ln\frac{0.00846}{10^{-14}} = 0.69\,V$$

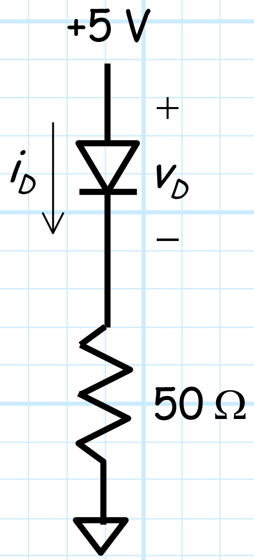
6) Finally, if we know v_{D1} and v_{D2}, we can find V_S using KVL:

$$V_S = v_{D1} + v_{D2} = 0.69 + 0.65 = 1.34\,V$$



Example: Junction Diode Models

Consider the **junction** diode circuit, where the junction diode has device parameters $I_S = 10^{-12}$ A, and n=1:



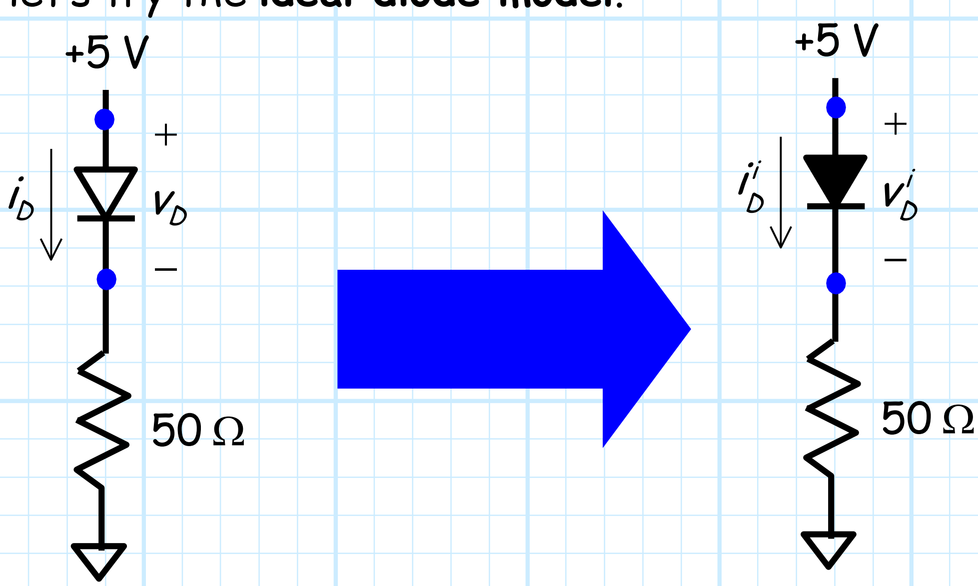
I **numerically** solved the resulting transcendental equation, and determined the **exact** solution:

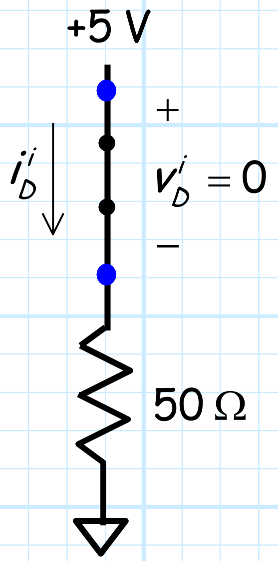
$$i_D = 87.40 \ mA$$

$$v_D = 0.630 \ V$$

Now, let's determine **approximate** values using diode **models**!

First, let's try the **ideal diode model**.





Assume **IDEAL** diode is "on".

Enforce $v_D^i = 0$.

Analyze the **IDEAL** diode circuit.
From KVL:

We therefore can **approximate** the **junction diode** current as the current through the ideal diode **model**:

$$i_D \approx i_D^i = 100\,mA$$

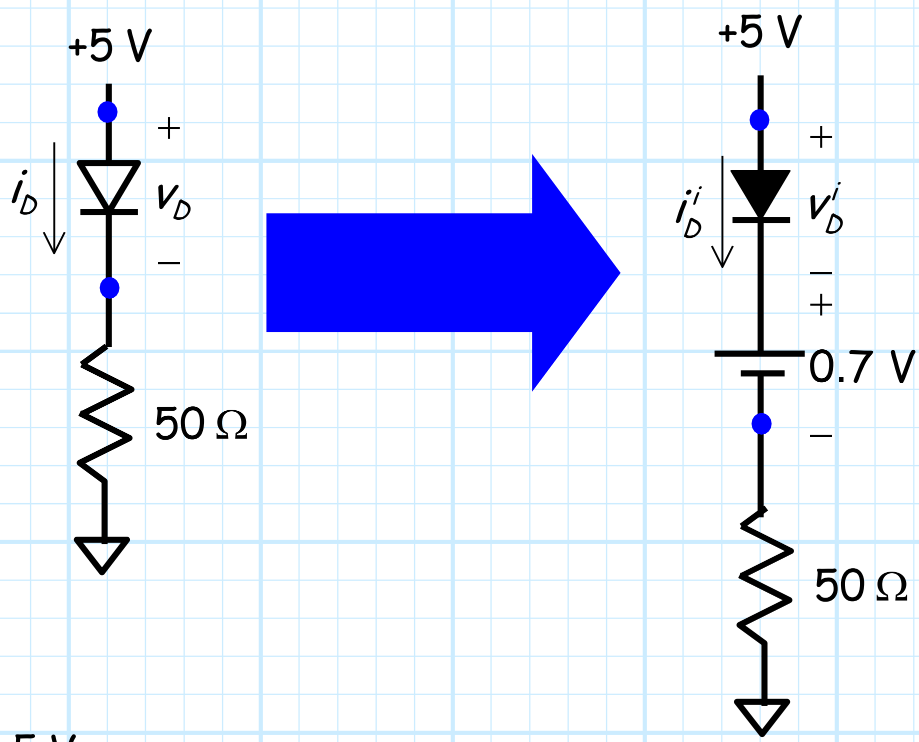
And **approximate** the **junction** diode voltage as the voltage across the ideal diode **model**:

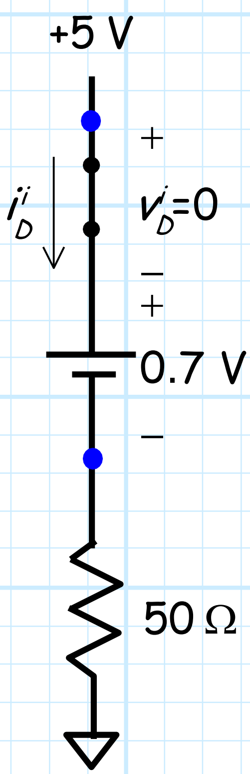
$$v_D \approx v_D^i = 0$$

Compare these approximations to the **exact** solutions:

$i_D = 87.4\ mA$ and $v_D = 0.630\ V$ Close, but we can

do better! Let's use the 'Modified diode model'.





Assume **IDEAL** diode is "on".

Enforce $v_D^i = 0$.

Analyze the **IDEAL** diode circuit. From KVL:

We therefore can **approximate** the **junction** diode current as the current through the 'Modified diode model **model**:

$$i_D \approx i_D^i = 86.0\ mA$$

And **approximate** the **junction** diode voltage as the voltage across the 'Modified diode model **model**:

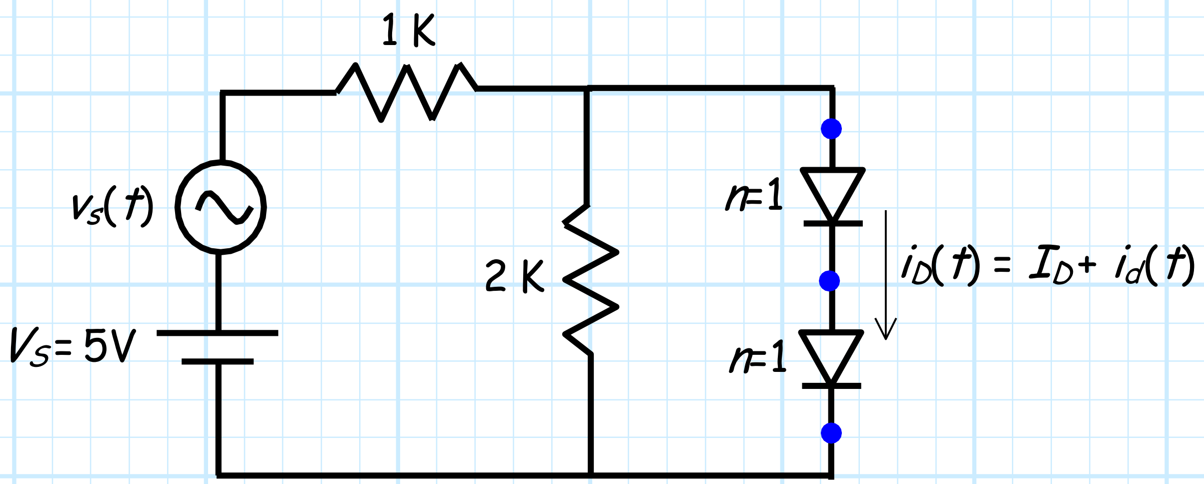
$$\begin{aligned} v_D &\approx v_D^i + 0.7 \\ &= 0.0 + 0.7 \\ &= 0.7\ V \end{aligned}$$

Compare these approximations to the **exact** solutions:

$$i_D = 87.4 \text{ mA} \qquad \text{and} \qquad v_D = 0.630 \text{ V}$$

Example: Diode Small-Signal Analysis

Consider the circuit:

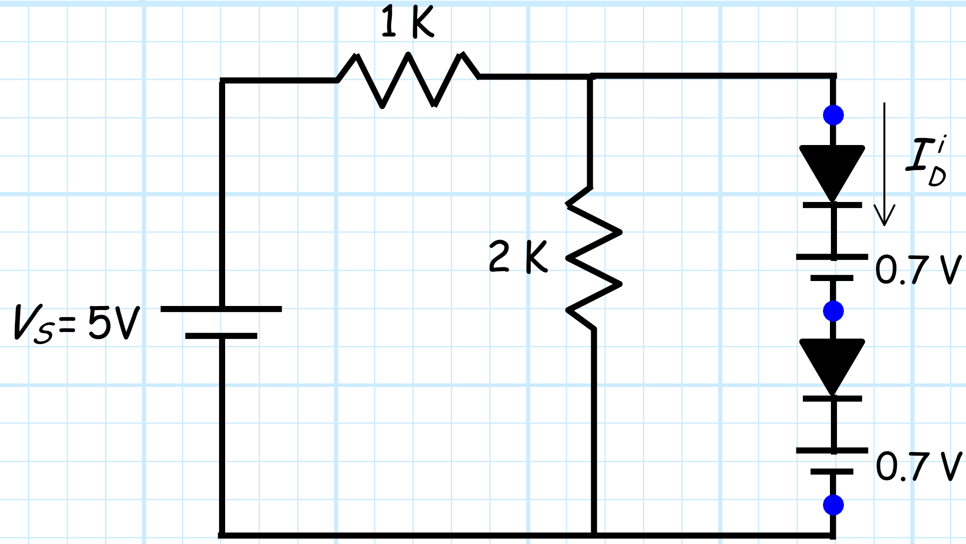


Q: *If $v_s(t)$= 0.01 $\sin\omega t$, what is $i_d(t)$?*

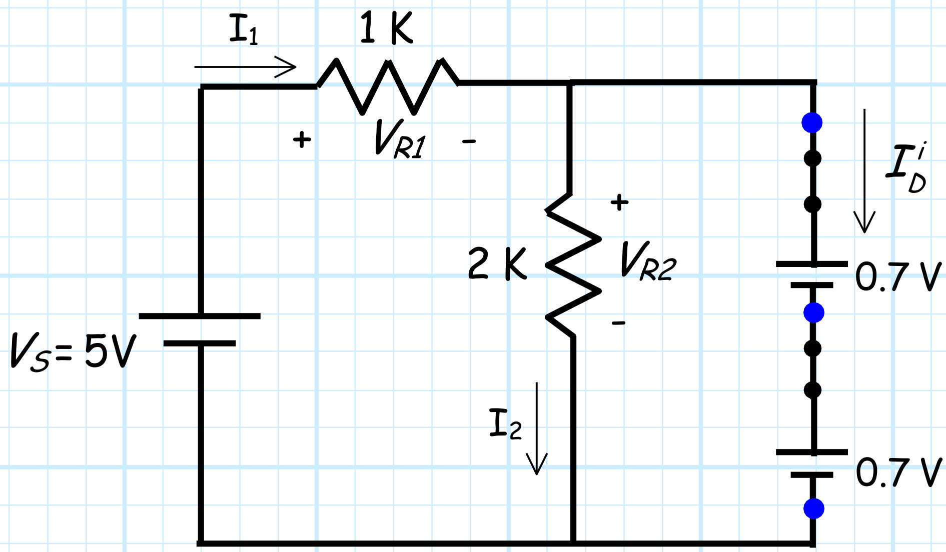
A: Follow the small-signal analysis steps!

Step 1: Complete a **D.C. Analysis**

Turn **off** the small-signal source and replace the junction diodes with the 'modified diode model' model.



Assume the ideal diodes are "on", **enforce** with short circuits.



Now analyze the D.C. circuit:

From KVL $\quad V_{R2} = 0.7 + 0.7 = 1.4\ V$

$$\therefore \quad I_2 = \frac{V_{R2}}{2} = 0.7\,mA$$

From KVL: $\quad V_{R1} = 5.0 - V_{R2} = 5.0 - 1.4 = 3.6\ V$

Thus from Ohm's Law: $$I_1 = \frac{V_{R1}}{1} = 3.6\ mA$$

And finally from KCL:

$$\begin{aligned} I_D^i &= I_1 - I_2 \\ &= 3.6 - 0.7 \\ &= 2.9\ mA \end{aligned}$$

Now **checking** our result:

$$I_D^i = 2.9\ mA \ > 0$$

Therefore our estimate of the D.C. diode current is:

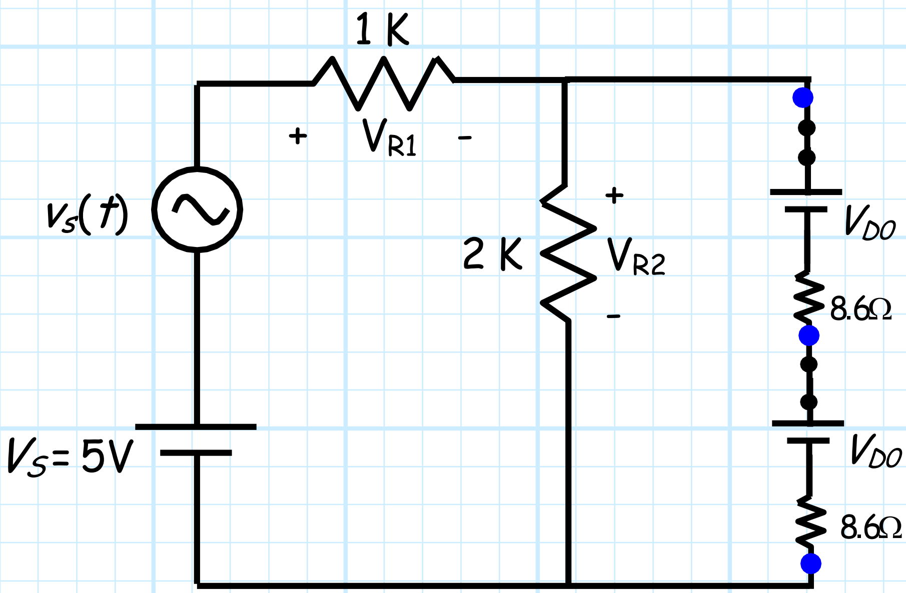
$$I_D = I_D^i = 2.9\ mA$$

Step 2: Calculate the diode small-signal resistance $\mathbf{r_d}$:

$$r_D = \frac{nV_T}{I_D} = \frac{0.025}{0.0029} = 8.6\Omega$$

Note since the junction diodes are **identical**, and since each has the **same** current I_D=2.9 mA flowing through it, the small-signal resistance of each junction diode is the **same** (r_D=8.6Ω).

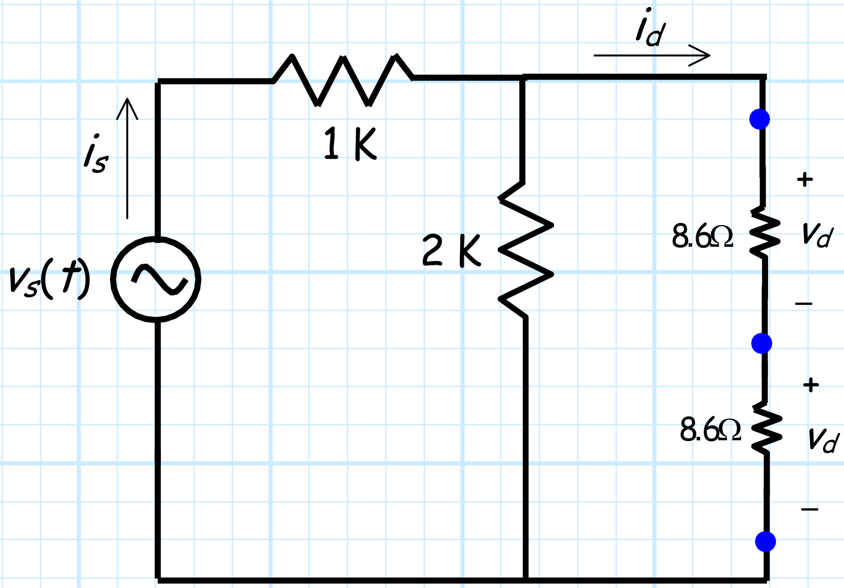
Step 3: Replace junction diodes with **small-signal model**



Step 4: Determine the **small-signal circuit**.

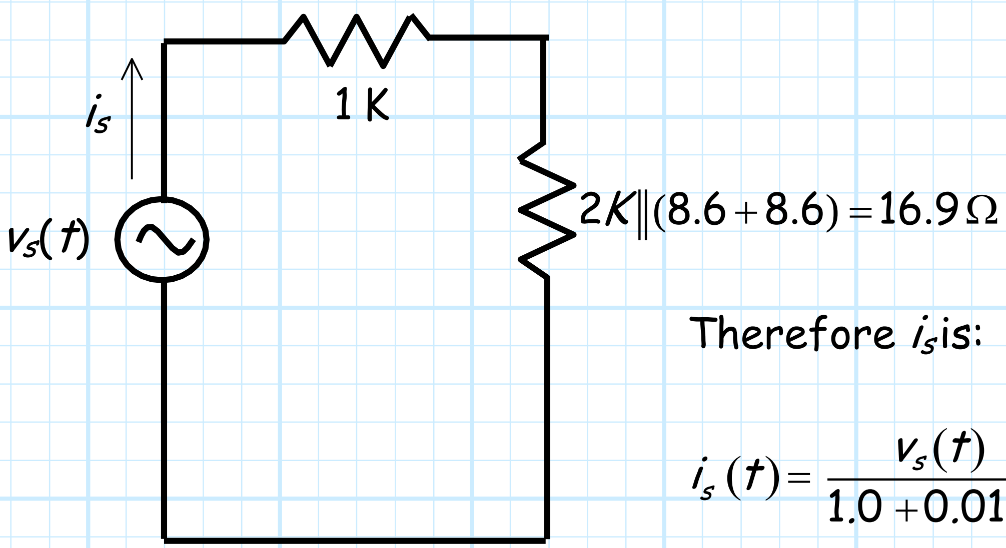
This means turn off the 5V source **and** the V_{DO} sources in the 'modified diode **model'** !

After turning off all DC sources, we are left with our **small-signal circuit**:



Step 5: **Analyze** the small-signal circuit.

Combining the parallel resistors, we get:



Therefore i_s is:

$$i_s(t) = \frac{v_s(t)}{1.0 + 0.0169}$$

$$= \ldots$$

We can now find i_d using **current division**: