You typically connect circuits together to make larger ones. Knowing the input/output impedance of each sub-circuit allows you to understand better the behavior of the larger circuit.

You measure Vout with an oscilloscope. The oscilloscope can be usefully modeled as just a big (R = 1 MΩ) resistor that draws a graph of the voltage drop across the 1 MΩ resistor on the screen.
So, \( V_{IN} \) and \( R_B \) come into play.

Since \( R_E \parallel R_{IM2} \), but typically \( R_E \ll R_{IM2} \), THE PARALLEL \( R_1/S \) of THE EMITTER FOLLOWER \& THE SCOPE REDUCE TO JUST BEING \( R_E \). THE EMITTER FOLLOWER DOESN'T NOTICE THE SCOPE'S PRESENCE. WE SAY THAT THE SCOPE: "DOESN'T LOAD" THE CIRCUIT BEING TESTED.

THE EMITTER FOLLOWER CAN BE MODELED MORE SIMPLY AS:

\[
\begin{align*}
\text{Output} & \quad Z_{out} \\
\text{Input} & \quad V_S \\
\text{Current} & \quad I_C \\
\text{Voltage} & \quad V_E
\end{align*}
\]

WHERE THE CIRCUITRY TO THE LEFT OF THE DASHED LINE HAS BEEN REPLACED WITH A VIRTUAL VOLTAGE SOURCE \( V_S \) & A VIRTUAL RESISTOR ("OUTPUT IMPEDANCE") WE SAY "VIRTUAL" B/C THEY ARE NOT REALLY THERE, THEY JUST SEEM TO BE.

\( Z_{out} \) IS A QUANTITY OF INTEREST.
We want to measure $Z_{out}$.
($V_s$ is less interesting.)

From PHYS 3104 Lecture, the voltage drop across $R_E$ is:

$$V_E = \left(\frac{R_E}{R_E + Z_{out}}\right) V_s$$

Since $Z_{out}$ and $V_E$ are unknown, we need another equation. Add a resistor of known value in parallel with $R_E$ and of about the same magnitude.

\[ \begin{array}{c}
V_s \\
\downarrow \\
R_E \\
\downarrow \\
Z_{out} \\
\downarrow \\
V_E 
\end{array} \]

The drop across $R_E \parallel R_L$ ($= R'$) is

$$V_E = \left(\frac{R'}{R' + Z_{out}}\right) V_s$$

Again drawing.

\[ \begin{array}{c}
V_s \\
\downarrow \\
R' \\
\downarrow \\
Z_{out} \\
\downarrow \\
V_E 
\end{array} \]

Dividing our equations for $V_E$ & $V_E$ by one another allows us to solve for $Z_{out}$. \[ \text{[3]} \]
\[
\frac{V_E}{V_{EL}} = \eta = \left( \frac{R_E}{R'} \right) \frac{R' + Z_0}{R_E + Z_0}
\]

\[
\eta = \left( \frac{R_E}{R'} \right) \frac{R' + Z_0}{R_E + Z_0}
\]

\[
R'(R_E + Z_0)\eta = R_E (R' + Z_0)
\]

\[
R'Z_0\eta + R'E\eta - R_E Z_0 = R_E R'
\]

\[
Z_0 (R'\eta - R_E) = R_E R' + R'E\eta
\]

\[
Z_0 = \frac{R_E R' (1 - \eta)}{R'\eta - R_E}
\]

So, measure \( V_E \) \& \( V_{EL} \) to get \( \eta \).

Compute \( R' = R_E || R_L = \frac{R_E R_L}{R_E + R_L} \).

Pick \( R_L \). I suggest \( R_L = R_E \), but other values OK.

For the emitter follower, you will discover \( Z_0 = \frac{R_B}{\beta} \).

Where \( \beta \) is transistor \( \beta \).
THIS TECHNIQUE OF MAKING 2 MEASUREMENTS OF THE OUTPUT VOLTAGE, W/ 2 DIFFERENT RESISTOR VALUES CONNECTING THE CIRCUIT OUTPUT TO GROUND, IS COMPLETELY GENERAL AND NOT RESTRICTED TO THE EMMITTER FOLLOWER. YOU CAN FIND THE OUTPUT IMPEDANCE OF ANY CIRCUIT THIS WAY... (OR AT LEAST TRY, IT MAY BE TOO SMALL TO MEASURE.)
THE CLOUD HIERES THE REAL CIRCUIT WHICH YOU MODEL AS JUST SOME VOLTAGE SOURCE IN SERIES W/ THE OUTPUT IMPEDANCE.

INPUT IMPEDANCE

REPLACE ACTUAL CIRCUIT W/ CLOUD AND VIRTUAL RESISTOR (AKA, "INPUT IMPEDANCE")

TO MEASURE ZIN, PLACE A RESISTOR OF YOUR CHOOSING (SAY, R = 1kΩ) IN SERIES WITH THE INPUT.
The voltage drop across the \( Z_{in} \) is just

\[
V_v = \left( \frac{Z_{in}}{Z_{in} + 16 \Omega} \right) V_{in}
\]

If \( Z_{in} \ll 16 \Omega \), then \( V_{v} = 0 \).

For those too embarrassed to ask how you measure this voltage drop across \( Z_{in} \), connect your scope probes like this:

![Diagram showing how to connect scope probes](image)

To get a precise number for \( V_{v} \), measure \( V_{v} \) and \( V_{in} \) and then use the above equation to solve for \( Z_{in} \). BTW, there is nothing sacred about the 16 \( \Omega \) resistor. It was selected for convenience. Other values are OK.