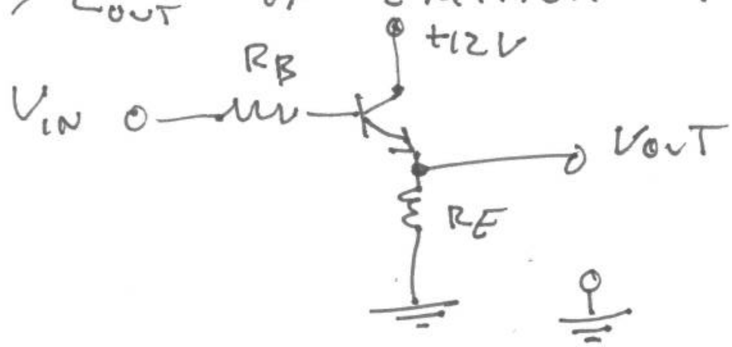
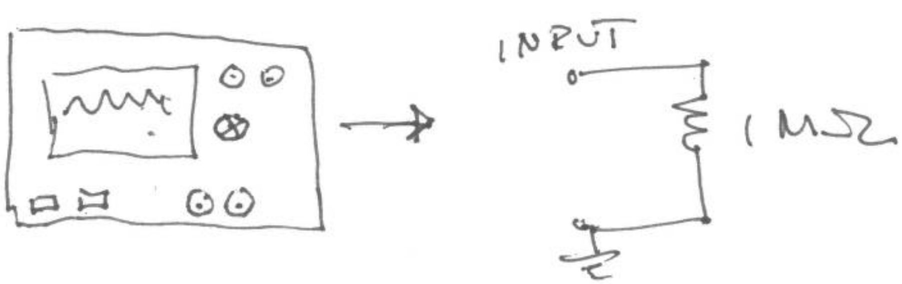
INPUT / OUTPUT IMPEDANCE

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.

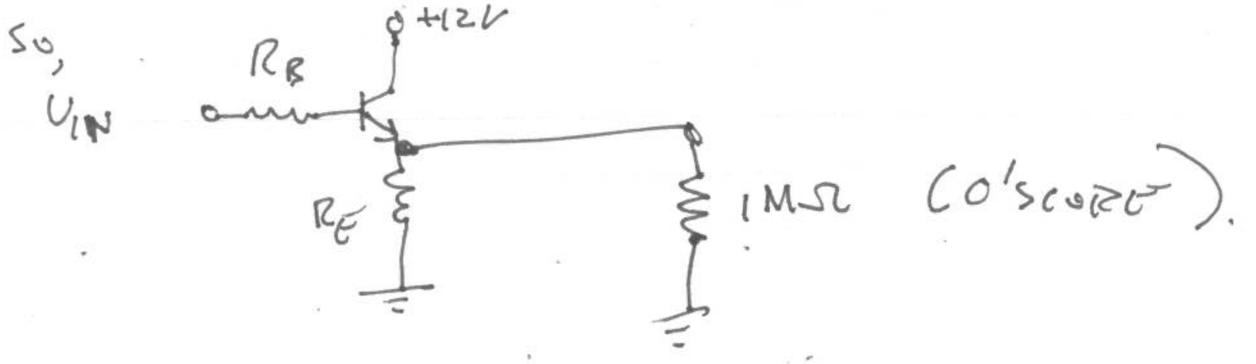
<•> Z_{OUT} OF EMITTER FOLLOWER



~~YOU~~ YOU MEASURE VOUT w/ AN O'SCOPE. THE O'SCOPE 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.

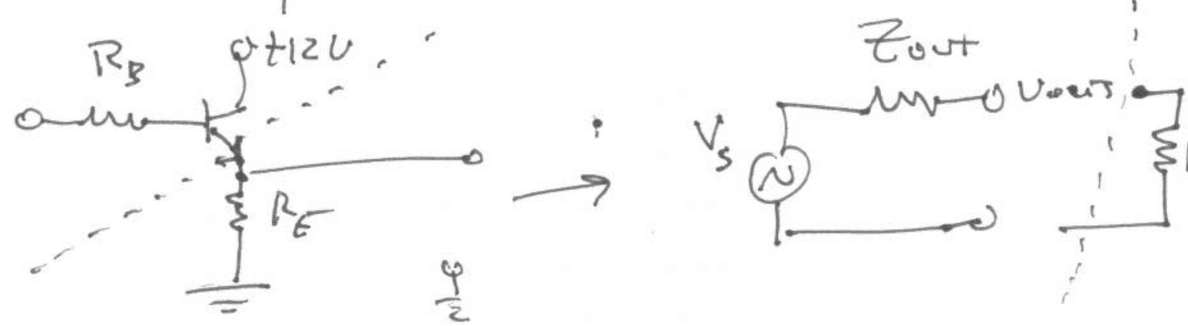


SO,



SINCE $R_E \parallel 1M\Omega$, BUT TYPICALLY $R_E \ll 1M\Omega$, THE PARALLEL R'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:



WHERE THE CIRCUITRY TO THE LEFT OF THE DASHED LINE HAS BEEN REPLACED W/ 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.

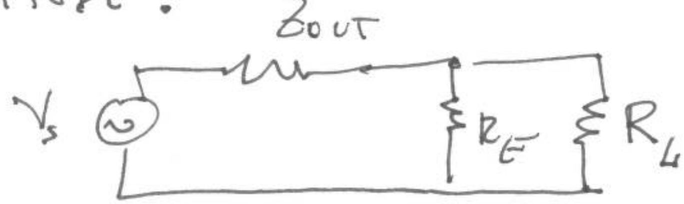
Z_{OUT} IS A QUANTITY OF INTEREST.

WE WANT TO MEASURE Z_{OUT}.
(V_S IS LESS INTERESTING.)

FROM PHYS 1304 LECTURE, THE VOLTAGE DROP ACROSS R_E IS:

$$V_E = \left(\frac{R_E}{R_E + Z_{OUT}}\right) V_S$$

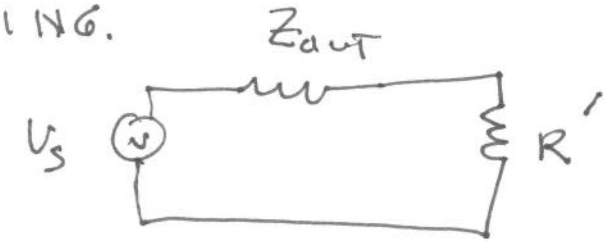
SINCE Z_{OUT} & V_S ARE UNKNOWN, WE NEED ANOTHER EQUATION. ADD A RESISTOR OF KNOWN VALUE IN PARALLEL w/ R_E AND OF ABOUT THE SAME MAGNITUDE:



THE DROP ACROSS $R_E \parallel R_L$ $(= R')$ IS

$$V_{EL} = \left(\frac{R'}{R' + Z_{OUT}}\right) V_S \quad \text{w/ } R' = \frac{R_E R_L}{R_E + R_L}$$

REDRAWING.



DIVIDING OUR EQUATIONS FOR V_E & V_{EL} BY ONE ANOTHER ALLOWS US TO SOLVE FOR Z_{OUT}.

$$\frac{V_E}{V_{EL}} = \eta = \left(\frac{R_E}{R'}\right) \frac{R' + Z_0}{R_E + Z_0}$$

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

$$R'(R_E + Z_0)\eta = R_E (R' + Z_0)$$

$$R' R_E \eta + R' Z_0 \eta - R_E Z_0 = R_E R'$$

$$Z_0 (R'\eta - R_E) = R_E R' - R' R_E \eta$$

$$\boxed{Z_0 = \frac{R_E R' (1 - \eta)}{R'\eta - R_E}}$$

SO, MEASURE V_E & V_{EL} TO GET η.

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

$$Z_0 \simeq R_B / \beta$$

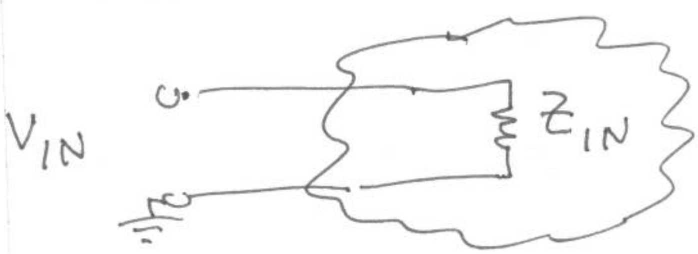
WHERE β = TRANSISTOR β.

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
EMITTER FOLLOWER, YOU CAN FIND THE
OUTPUT IMPEDANCE OF ANY CIRCUIT
THIS WAY. (OR AT LEAST TRY. IT
MAY BE TOO SMALL TO MEASURE.)

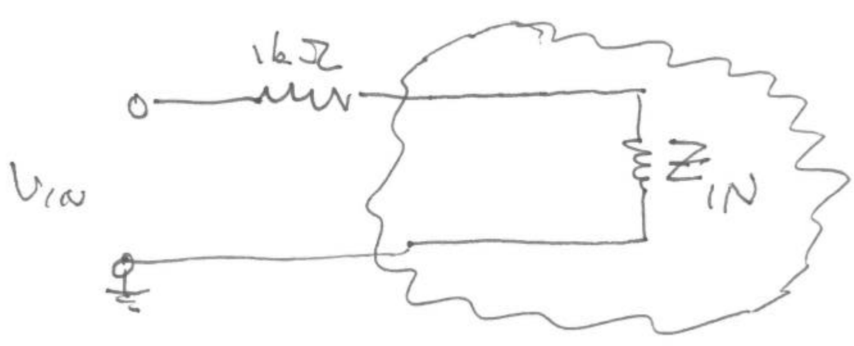
THE CLOUD HIDES THE REAL CIRCUIT WHICH YOU MODEL AS JUST SOME VOLTAGE SOURCE IN SERIES w/ THE OUTPUT IMPEDANCE.

INPUT IMPEDANCE

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



TO MEASURE Z_{IN}, PLACE A RESISTOR OF YOUR CHOOSING (SAY, R= 1kΩ) IN SERIES WITH THE INPUT:

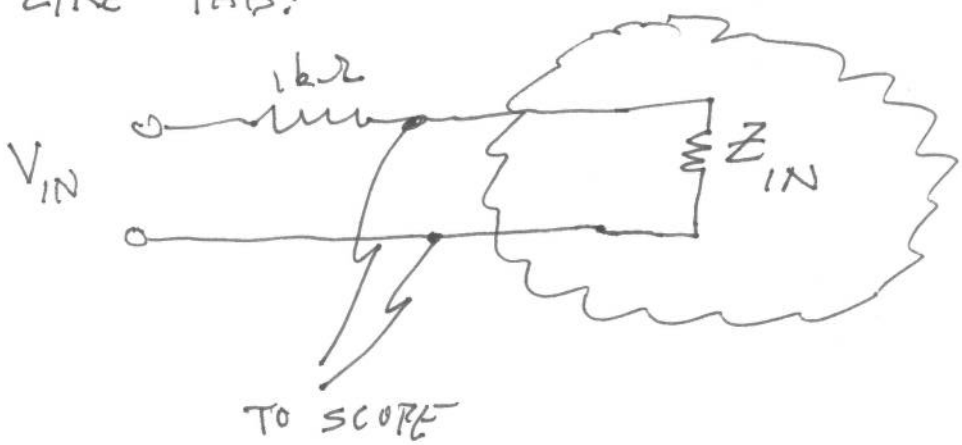


THE VOLTAGE DROP ACROSS THE Z_{IN} IS JUST

$$V_{Z_{IN}} = \left(\frac{Z_{IN}}{Z_{IN} + 1k\Omega}\right) V_{IN}$$

IF $Z_{IN} \ll 1k\Omega$, THEN $V_{Z_{IN}} \simeq 0$.

FOR THOSE TOO EMBARRASSED TO ASK HOW YOU MEASURE THIS VOLTAGE DROP ACROSS Z_{IN}, CONNECT YOUR SCOPE PROBES LIKE THIS:



TO GET A PRECISE NUMBER FOR $V_{Z_{IN}}$, MEASURE $V_{Z_{IN}}$, V_{IN} AND THEN

USE THE ABOVE EQUATION TO SOLVE FOR Z_{IN}. BTW, THERE IS NOTHING SACRED ABOUT THE 1kΩ RESISTOR. IT WAS SELECTED FOR CONVENIENCE. OTHER VALUES ARE OK.