Name ______________________
Date ______________________
Instructor ______________________

EXPERIMENT

23

Darlington and Cascode Amplifier Circuits

OBJECTIVE

To calculate and measure DC and AC voltages in Darlington and cascode connection circuits.

EQUIPMENT REQUIRED

Instruments

Oscilloscope
DMM
Function generator
DC supply

Components

Resistors

(1) 100-Ω
(1) 51-Ω, 1-W
(1) 1-kΩ
(1) 1.8-kΩ
(1) 4.7-kΩ
(1) 5.6-kΩ
(1) 6.8-kΩ
(1) 50-kΩ pot
(1) 100-kΩ

Capacitors

(1) 0.001-μF
(4) 10-μF

Transistors

(2) 2N3904, (or equivalent general purpose npn)
(1) TIP120 (npn Darlington)

EQUIPMENT ISSUED

Item	Laboratory serial no.
DC power supply	
Function generator	
Oscilloscope	
DMM	

RÉSUMÉ OF THEORY

Darlington Circuit: A Darlington connection (as shown in Fig. 23.1) provides a pair of BJT transistors in a single IC package with effective beta (β_D) equal to the product of the individual transistor betas.

$$\beta_D = \beta_1\beta_2 \tag{23.1}$$

The Darlington emitter-follower has a higher input impedance than that of an emitter-follower. The Darlington emitter-follower input impedance is

$$Z_i = R_B \| (\beta_D R_E) \tag{23.2}$$

The output impedance of the Darlington emitter-follower is

$$Z_o = r_e \tag{23.3}$$

The voltage gain of a Darlington emitter-follower circuit is

$$A_v = \frac{R_E}{(R_E + r_e)} \tag{23.4}$$

Cascode Circuit: A cascode circuit, as shown in Fig. 23.2, provides a common-emitter amplifier using Q_1 directly connected to a common-base amplifier using Q_2. The voltage gain of stage Q_1 is approximately 1, with the voltage V_{o1} being opposite in polarity to that applied as V_i.

$$A_{v_1} = -1 \tag{23.5}$$

The voltage gain of stage Q_2 is noninverted and of magnitude

$$A_{v_2} = \frac{R_C}{r_{e_2}} \tag{23.6}$$

resulting in an overall gain

$$A_v = A_{v_1}A_{v_2} = -\frac{R_C}{r_{e_2}} \tag{23.7}$$

PROCEDURE

Part 1. Darlington Emitter-Follower Circuit

a. For the circuit of Fig. 23.1 calculate the DC bias voltages and currents.

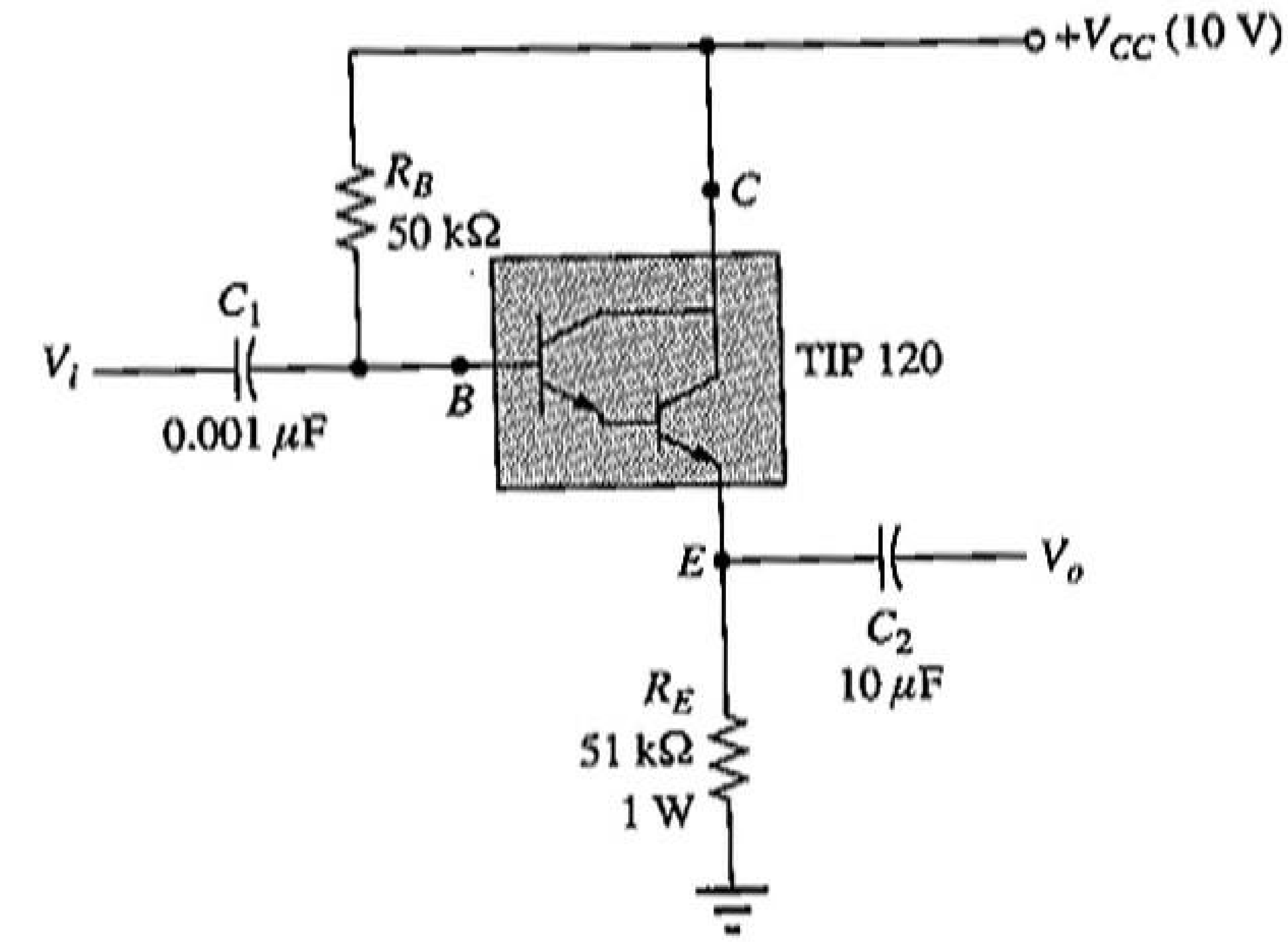

Figure 23-1

V_B (calculated) = ________
V_E (calculated) = ________

Calculate the theoretical values of voltage gain, input and output impedance.

A_V (calculated) = ________
Z_i (calculated) = ________
Z_o (calculated) = ________

b. Construct the Darlington circuit of Fig. 23.1. Adjust the 50-kΩ potentiometer (R_B) to provide an emitter voltage, $V_E = 5$ V. Using a DMM, measure and record the DC bias values:

V_B (measured) = ________
V_E (measured) = ________

Calculate the base and emitter DC currents:

I_B (calculated) = __________

I_E (calculated) = __________

Calculate the value of transistor beta at this Q-point:

β_D (calculated) = __________

c. Apply an input signal V_{sig} = 1 V, peak at f = 10 kHz. Using the oscilloscope observe and record the output voltage to assure that the signal is not clipped or distorted. (Reduce the input signal amplitude if necessary.)

V_i (measured) = __________

V_o (measured) = __________

Calculate and record the AC voltage gain:

$A_v = V_o/V_i$ = __________

Part 2. Darlington Input and Output Impedance

a. Calculate the input impedance:

Z_i (calculated) = __________

Calculate the circuit output impedance:

Z_o (calculated) = __________

b. Connect a measurement resistor, R_x = 100 kΩ, in series with V_{sig}. Measure and record input voltage, V_i.

V_i (measured) = ________

Calculate the circuit input impedance using

$$Z_i = \frac{V_i}{V_{sig} + V_i} R_x$$

Z_i (calculated) = ________

Remove measurement resistor, R_x.

c. Measure the output voltage, V_o with no load connected.

V_o (measured) = ________

Connect load resistor, R_L = 100 Ω. Measure and record resulting output voltage:

V_o (measured) = V_L = ________

Calculate the output impedance using

$$Z_o = \frac{V_o - V_L}{V_L} R_L$$

Z_o (calculated) = ________

Compare the calculated and measured values of Z_i and Z_o.

Part 3. Cascode Amplifier

a. Calculate DC bias voltages and currents in the cascode amplifier of Fig. 23.2 (assuming base currents are much less than the voltage divider current).

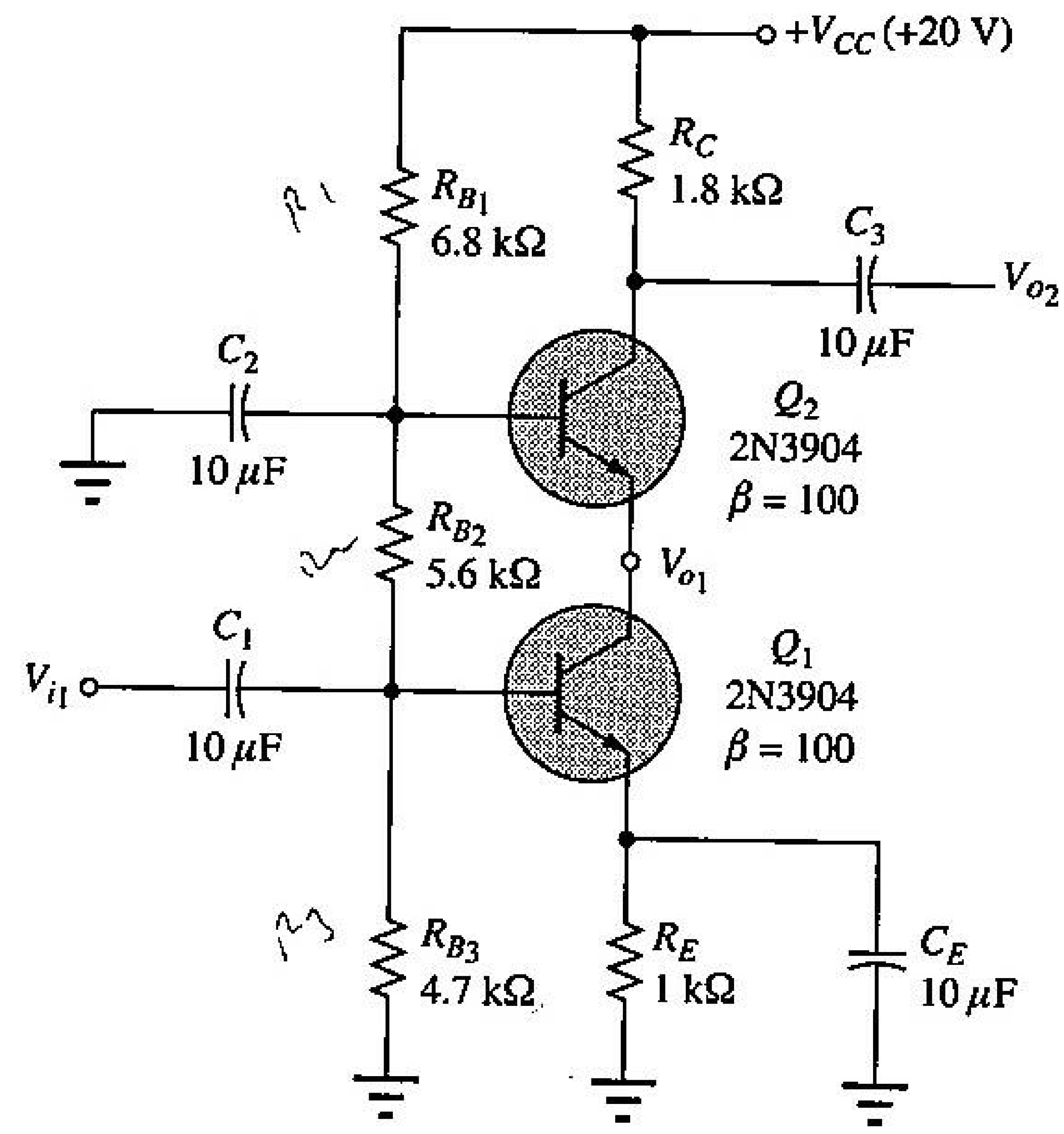

Figure 23-2

V_{B_1} (calculated) = ________

V_{E_1} (calculated) = ________

V_{C_1} (calculated) = ________

V_{B_2} (calculated) = ________

V_{E_2} (calculated) = ________

V_{C_2} (calculated) = ________

Calculate the DC bias emitter currents:

I_{E_1} (calculated) = ________
I_{E_2} (calculated) = ________

Calculate the transistor dynamic resistances:

r_{e_1} (calculated) = ________
r_{e_2} (calculated)= ________

b. Connect the cascode circuit of Fig. 23.2. Measure and record DC bias voltages.

V_{B_1} (measured) = ________
V_{E_1} (measured) = ________
V_{C_1} (measured) = ________
V_{B_2} (measured) = ________
V_{E_2} (measured) = ________
V_{C_2} (measured) = ________

Calculate the values of emitter current:

I_{E_1} = ________
I_{E_2} = ________

and the values of dynamic resistance:

r_{e_1} = ________
r_{e_2} = ________

c. Using Eqs. 23.5 and 23.6 calculate the AC voltage gain of each transistor stage:

A_{v_1} (calculated) = ________

A_{v_2} (calculated) = ________

d. Apply input signal, V_{sig} = 10 mV, peak at f = 10 kHz. Using the oscilloscope observe the output waveform V_o to make sure that no signal distortion occurs. If the output is clipped or distorted reduce the input signal until the clipping or distortion disappears.

Using the DMM measure, record the AC signals.

V_i (measured) = ________

V_{o_1} (measured) = ________

V_{o_2} (measured) = ________

Calculate the measured voltage gains:

$A_{v_1} = V_{o_1}/V_i =$ ________

$A_{v2} = V_{o_2}/V_{o_1} =$ ________

$A_v = V_{o_2}/V_i =$ ________

Compare the measured voltage gains with those calculated in steps 3(**c**) and 3(**d**).

e. Using the oscilloscope, observe and record waveforms for the input signal, V_i, output of stage 1, V_{o_1}, and output of stage 2, V_{o_2}. Show amplitude and phase relations clearly.