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Seader et al.

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[54] **UNIT TRANSISTOR AMPLIFIER WITH MATCHED INPUT AND OUTPUT IMPEDANCES**

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[22] Filed: **Mar. 23, 1977**

Related U.S. Patent Documents

Reissue of:

[64]	Patent No.:	**3,493,882**
	Issued:	**Feb. 3, 1970**
	Appl. No.:	**616,918**
	Filed:	**Feb. 17, 1967**

U.S. Applications:

[63] Continuation of Ser. No. 633,961, Nov. 21, 1975, abandoned, which is a continuation of Ser. No. 223,032, Feb. 2, 1972, abandoned.

[51] **Int. Cl.**^{2} **H03F 1/34**

[52] **U.S. Cl.** **330/293**; 330/290

[58] **Field of Search** 330/25, 27, 28, 76, 330/80, 85, 102, 103, 110, 178

[56] **References Cited**

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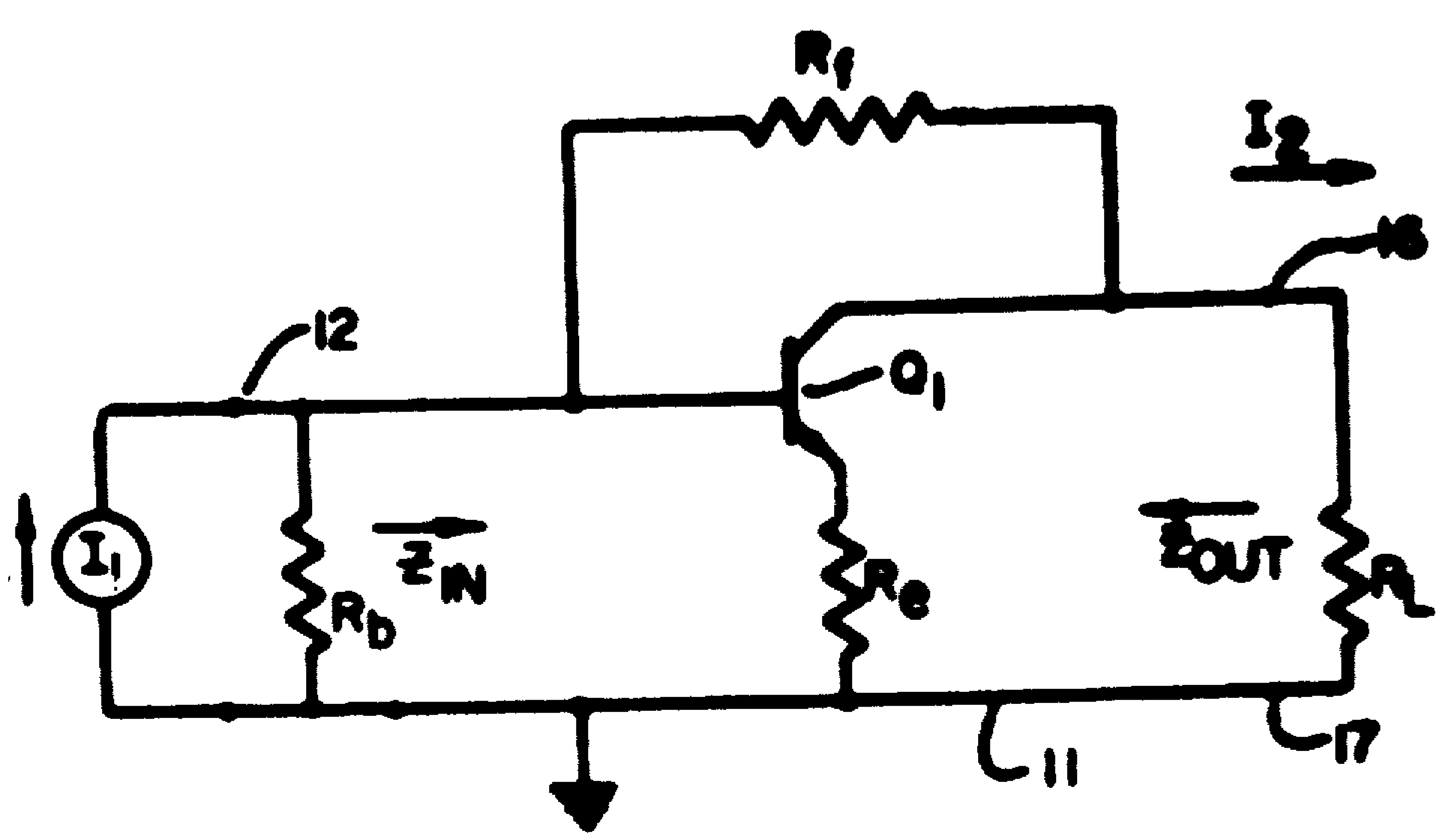
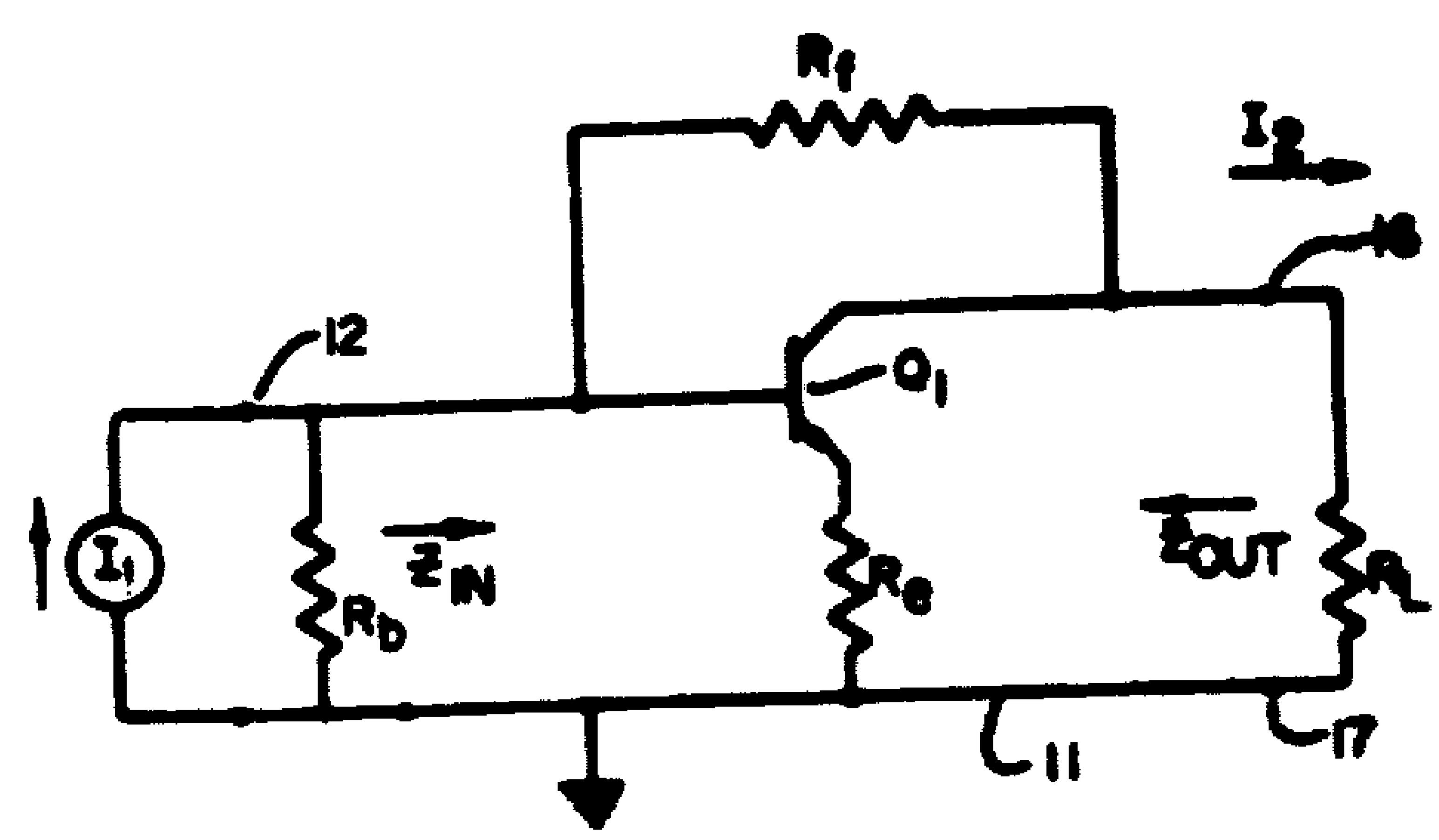
Attorney, Agent, or Firm—Limbach, Limbach & Sutton

[57] **ABSTRACT**

An amplifier having a combination of local series and shunt feedback to provide matched input and output impedances permitting cascading of a number of amplifiers or amplifiers and other devices without signal degradation.

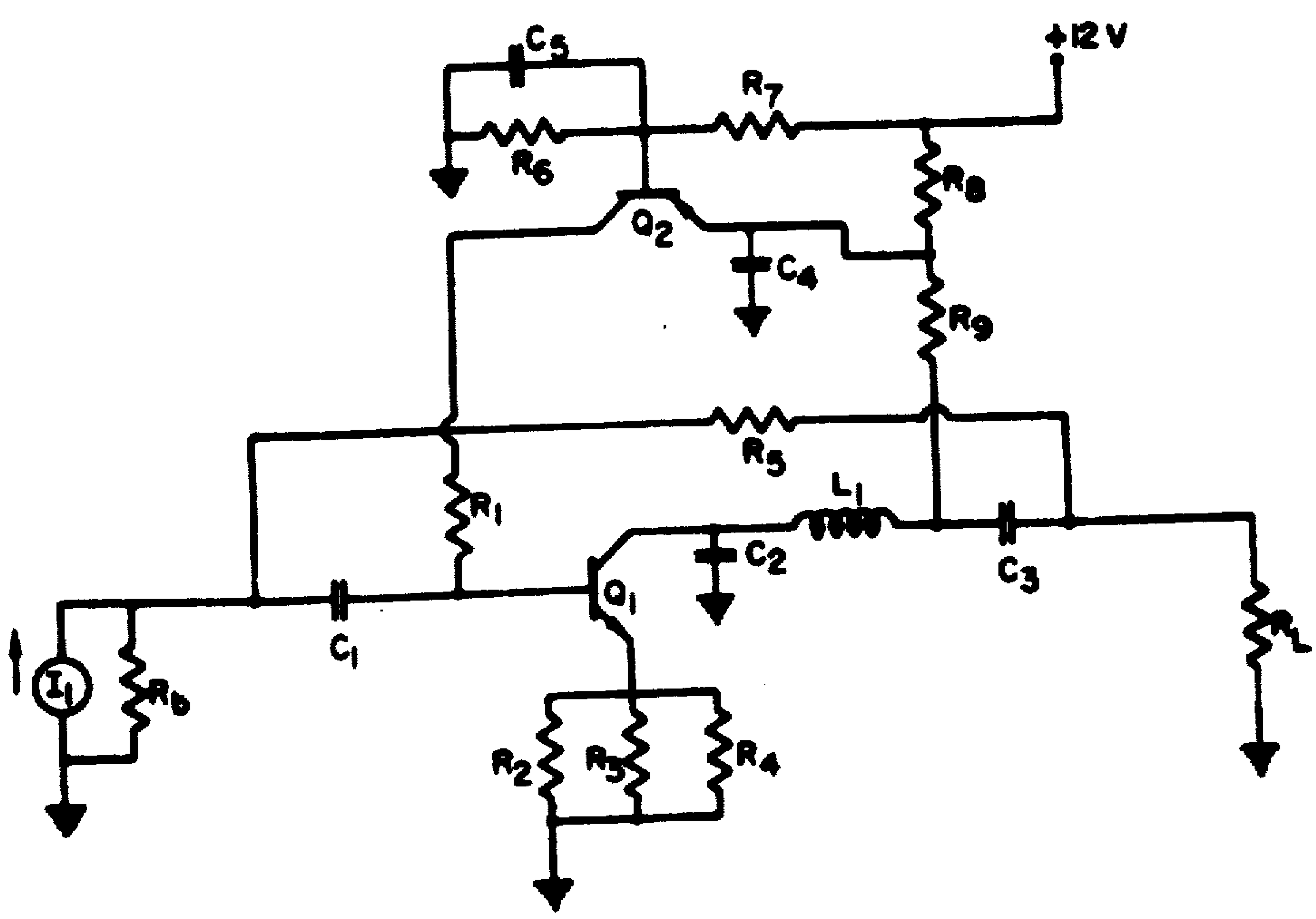
4 Claims, 3 Drawing Figures





Rf
I2
16
12
Q1
I1
Rb
ZIN
Re
ZOUT
RL
11
17

FIG. 1



C5
+12 V
R7
R6
R8
Q2
C4
R9
R5
R1
L1
C2
C3
Q1
C1
RL
I1
Rb
R2
R3
R4

FIG. 2

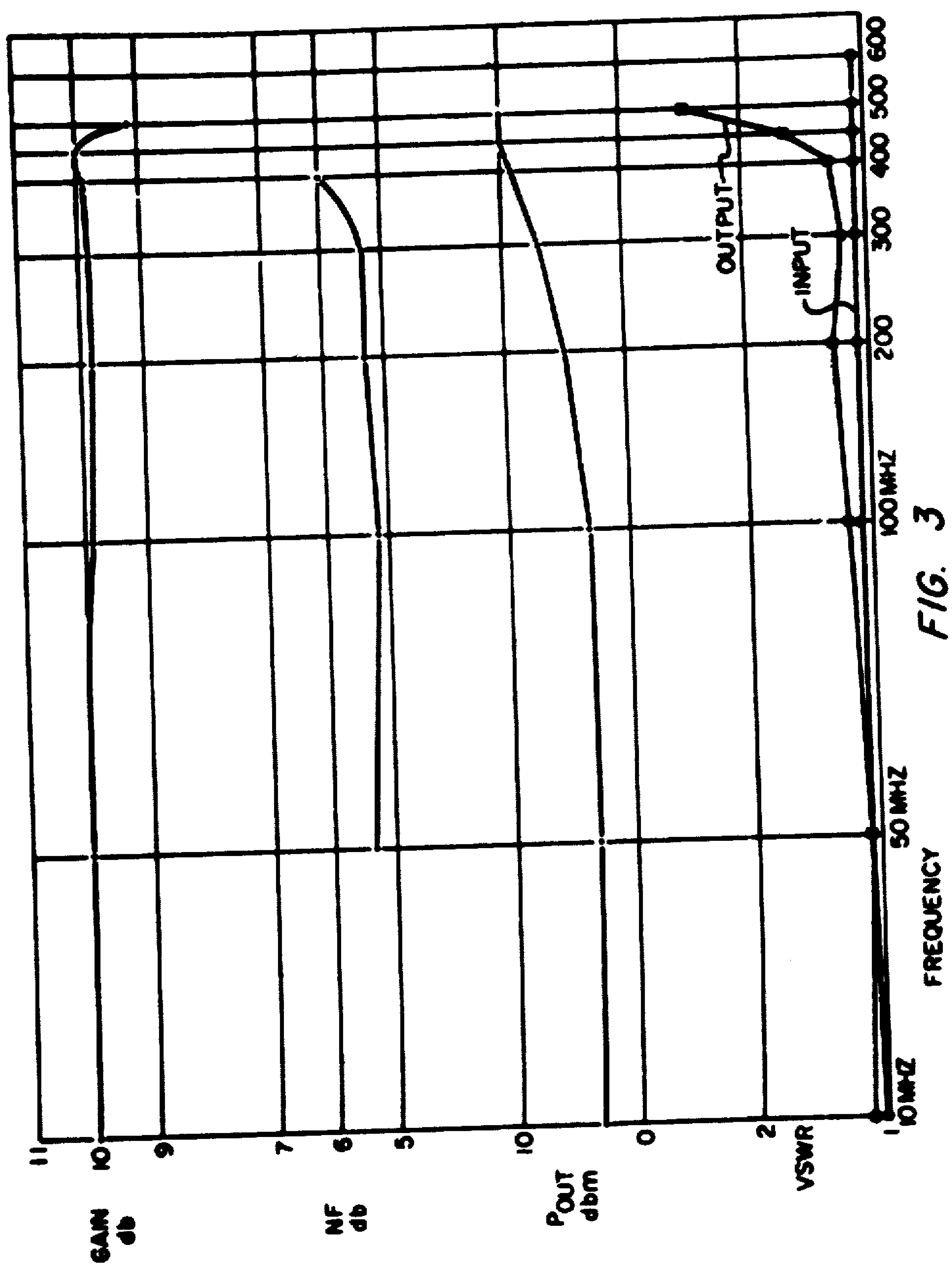

GAIN db
NF db
P_{OUT} dbm
VSWR
11
10
9
7
6
5
10
0
2
1
10 MHZ
50 MHZ
100 MHZ
200
300
400
500
600
FREQUENCY
OUTPUT
INPUT

FIG. 3

UNIT TRANSISTOR AMPLIFIER WITH MATCHED INPUT AND OUTPUT IMPEDANCES

Matter enclosed in heavy brackets [ ] appears in the original patent but forms no part of this reissue specification; matter printed in italics indicates the additions made by reissue.

This is a continuation of application Ser. No. 633,961, now abandoned, filed Nov. 21, 1975, which in turn is a continuation of Ser. No. 223,032, filed Feb. 2, 1972, which is a reissue of Pat. No. 3,493,882.

This invention relates to unit amplifier which can be cascaded without suffering signal deterioration.

The use of local feedback loops in transistor amplifiers to reduce distortion, provide flat frequency response and stabilize operation is well known. The local feedback loops may comprise passive resistance means in series with the emitter terminal of a transistor connected as a common emitter amplifier (series feedback) or passive resistance means connected between the collector and base terminals of a transistor connected in an amplifier circuit (shunt feedback). Some amplifiers have employed a combination of series and shunt local feedback.

When several transistor amplifiers are cascaded and operated at very high frequencies, there is a loss in gain flatness and an increase in distortion due to impedance interaction between stages.

It is a general object of the present invention to provide a unit amplifier having combined series shunt local feedback to provide predetermined matched input-output impedance and gain.

It is another object of the present invention to provide a unit amplifier which may be cascaded with other unit amplifiers or devices such as filters, hybrids, mixers, limiters or the like without suffering degradation or attenuation of signal due to reflections caused by impedance mismatch.

The foregoing and other objects will become more clearly apparent from the following description taken in connection with the accompanying drawings.

Referring to the drawings:

FIG. 1 is a basic circuit diagram of a common emitter unit amplifier;

FIG. 2 is a detailed circuit diagram of a unit amplifier in accordance with the present invention; and

FIG. 3 shows the gain, voltage standing wave ratio (VSWR), output power capability and noise figure as a function of frequency for an amplifier in accordance with FIG. 2.

The basic A-C equivalent circuit of the unit amplifier is shown in FIG. 1. It includes transistor Q_1 connected in a common emitter configuration, the line 11 indicating the common terminal. Input signals are applied to the base of the base of the transistor between the input terminal 12 and the common line 11. Resistor R_b represents the signal source impedance. The emitter terminal is connected to the common line 11 through emitter resistor R_e which forms the local series feedback path. The collector of the transistor is connected to output terminal 16. A local resistor R_L is connected between terminal 16 and the common line 11. A local shunt feedback resistor R_f is connected between the collector and base terminals of the transistor Q_1.

The input impedance is represented by the arrow labelled Z_{in}, while the output impedance is represented by the arrow labelled Z_{out}.

The input and output impedances of the amplifier are given by the following expression:

$$Z_{in} = R_f\left[\frac{1/R_f + 1/R_L}{1/R_e + 1/R_L}\right] \quad (1)$$

$$Z_{out} = R_e\left[\frac{R_f + R_b}{R_e + R_b}\right] \quad (2)$$

The current gain if the amplifier is given by

$$I_2/I_1 = \frac{1 - R_f/R_e}{1 + R_f/R_b + R_L[1/R_b + 1/R_e]} \quad (3)$$

We have discovered that when the input and output impedances are equal

$$Z_{in} = Z_{out} = R_o \text{ and } R_L = R_b = R_o \quad (4)$$

the product:

$$R_f R_e = R_o^2 \quad (5)$$

and

$$I_2/I_1 = \frac{1 - \sqrt{R_f/R_e}}{2} \quad (6)$$

Therefore, the product $R_f R_e$ determines the characteristic input and output impedance of the circuit while the ratio R_f to R_e determines the gain of the circuit. Therefore, the gain and characteristic impedance of the amplifier may be any specified arbitrary value.

With the output and input impedances matched, a number of amplifiers having the same impedance can be connected in cascade to provide high gain amplifiers without suffering appreciable degradation of signal due to mismatch. This is especially important anf RF frequencies where mismatch is typically reactive and results in variations in amplitude response. Thus, the amplifier may be considered a building block or module whose gain with frequency is constant for an arbitrary low frequency to an upper frequency determined solely by the capability of the active device used as the amplifier and at the high frequencies the physical configuration of the circuit. The modules may be manufactured in large quantity at economical prices using printed circuit techniques, hybrid techniques, monolithic fabrication techniques or flip-chip techniques. The amplifiers may also be combined with other modules such as attenuators, filters, hybrids, mixers or limiters having the same characteristic impedance to perform system functions.

FIG. 2 shows a wide band unit amplifier incorporating the present invention. Like reference numerals have been applied to parts which correspond to those in FIG. 1. The resistor R_e comprises the parallel resistors R_2, R_3 and R_4. A blocking capacitor C_1 is connected between the input terminal 11 and the base of the transistor. The shunt capacitor C_2 and the series inductance L_1 provide compensation for the decrease in current gain of the transistor at high frequencies to provide a flat gain versus frequency response over a relatively broad band of frequencies. The capacitor C_3 is a blocking capacitor and serves to block DC signals applied between the collector and base of the transistor from the output load R_L. In the circuit shown, the transistor Q_2 and associated circuit components serve to stabilize the operating point of transistor Q_1. This allows the emitter of Q_1 to be grounded directly through the emitter resistors which minimizes emitter lead inductance at the higher frequencies. The voltage drop in the resistor R_8, due to the collector current in transistor Q_1, is compared with the voltage drop in resistor R_7, due to current flow in resistor R_6, to vary the bias on the base of transistor Q_2 and, therefore, the emitter collector current. This, in turn, controls the base current in transistor Q_1. The resistor R_1 isolates the base of Q_1 from the collector capacitance of Q_2. The resistor R_9 provides a DC path for the collector current of Q_1. An amplifier was constructed in accordance with the circuit of FIG. 2 in which the circuit components and voltages were as follows:

Voltage		volts	+ 12
	Transistors		
Q_1			A485
Q_2			2N3905
	Resistors		
			Ohms
R_b			50
R_1			2.2K
R_2			16
R_3			16
R_4			100
R_L			50
R_5			270
R_6			6.8K
R_7			3.3K
R_8			220
R_9			220
	Capacitors		
C_1		picofarads	1000
C_2		"	2
C_3		"	1000
C_4		microfarad	.01
C_5		picofarads	470

Inductor

L_1: 3 turn #26 wire wound at .090 D.

The curve of FIG. 3 shows the gain, voltage standing wave ratio (VSWR), output power capability (P_{out}), and noise frequency (NF) as a function of frequency for the amplifier. The amplifier provides a very flat gain characteristic with only 0.2 db gain variation with 10 db of gain over the frequency range of 10 mHz. to 480 mHz. Also of particular interest is the very low input and output VSWR-less than 1.1 at the input and less than 1.3 at the output up to 400 mHz.

Thus, it is seen that by using the principles of the present invention, by minimizing emitter lead inductance and by providing high frequency compensation consisting of C_2 and L_1, an amplifier module has been constructed which exhibits a very flat gain characteristic and whose input and output impedance are accurately matched to a desired characteristic impedance.

When the transistor runs at low current, the emitter resistor R_e can consist entirely of the transistor emitter resistance, $R_e=26/I_e$. This would provide advantages in low noise applications since the transistor would be running at low current and no external emitter resistor would be present to generate noise.

Thus, it is seen that there is provided an improved unit amplifier which can be cascaded to form high gain amplifiers or connected with other circuit components in systems applications. The amplifier is simple in construction. Since the amplifier includes passive components having values which are achievable in present day integrated microcircuit technology, it can be so formed. The amplifier may also be incorporated in hybrid circuits combining semiconductor technology and strip-line or microwave technology.

We claim:

[1. An amplifier including a transistor having base, emitter and collector terminals, means for applying an input signal between the base and emitter terminals, and means for deriving an output signal between the collector and emitter terminals in which there is provided shunt feedback resistance means between the output and input means and resistance means in series with the emitter current path providing series feedback, said shunt feedback resistance means and series feedback resistance means being selected to provide predetermined and equal input and output impedances and a predetermined gain whereby said amplifier has a predetermined characteristic impedance determined solely by the square root of the product of said shunt and series feedback resistance means.]

2. An amplifier as in claim [1] *6* including means connected between the base and collector terminals of said transistor for stabilizing the operating point of said transistor.

3. An amplifier as in claim 2 wherein said means comprises a transistor having its emitter and collector terminals connected between the base and collector of said transistor to control the [base and collector of said transistor to control and] base current of said transistor.

4. An amplifier as in claim 2 including blocking capacitor means connected in series with the base and collector terminals of said transistor and a compensating circuit including an inductance series connected to said collector terminal and a capacitance shunt connected to said collector terminal.

[5. An amplifier as in claim 1 wherein:

$$Z_{in} = R_f\left[\frac{1/R_f + 1/R_L}{1/R_e + 1/R_L}\right]$$

$$Z_{out} = R_e\left[\frac{R_f + R_b}{R_e + R_b}\right]$$

and

$$I_2/I_1 = \frac{1 - R_f/R_e}{1 + R_f/R_b + R_L[1/R_b + 1/R_e]}$$

where

R_f=feedback resistance between collector and base of said transistor

R_e=resistance in series with emitter lead of said transistor

R_b=signal source impedance

R_L=load impedance

Z_{in}=input impedance

Z_{out}=output impedance

I_1=input current

I_2=output current

I_2/I_1=gain in which R_f, R_e, R_b and R_L are selected to provide:

$Z_{in}=Z_{out}=R_o$ and $R_L=R_b=R_o$

whereby

$R_fR_e = R^2_o$, the characteristic impedance and

$$I_2/I_1 = \frac{1 - \sqrt{R_f/R_e}}{2}$$

the gain.]

6. An amplifier having a characteristic impedance R_o wherein the signal source impedance R_b and the load impedance R_L are substantially equal to each other and to R_o, said amplifier comprising a transistor having base, emitter and collector terminals, means for applying an input signal between the base and emitter terminals and means for deriving an output signal between the collector and emitter terminals in which there is provided shunt feedback resistance means between the output and input means and resistance means in series with the emitter current path providing series feedback, said shunt feedback resistance means and series feedback resistance means being selected to provide predetermined and equal input and output impedances and a predetermined gain independent of said equal input and output impedances wherein

$$Z_{in} = R_f\left[\frac{1/R_f + 1/R_L}{1/R_e + 1/R_L}\right]$$

$$Z_{out} = R_e\left[\frac{R_f + R_b}{R_r + R_b}\right]$$

and

$$I_2/I_1 = \frac{1 - R_f/R_e}{1 + R_f/R_b + R_L(1/R_b + 1/R_e)}$$

where

R_f = feedback resistance between collector and base of said transistor

R_e = resistance in series with emitter lead of said transistor

R_b = signal source impedance

R_L = load impedance

Z_{in} = input impedance

Z_{out} = output impedance

I_1 = input current

I_2 = output current

I_2/I_1 = gain

in which R_f and R_e are selected to provide the characteristic impedances:

$$Z_{in} = Z_{out} = R_o = \sqrt{R_fR_e}$$

and the gain:

$$I_2/I_1 = \frac{1 - \sqrt{R_f/R_e}}{2},$$

whereby the characteristic impedance of the circuit is determined by the product of R_f and R_e and the gain of the circuit is independently determined by the ratio of R_f and R_e.

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