SINGLE ENDED LINE EXTENDERS

The Transistor

One of the first problems a CATV design engineer must cope with when designing a single ended CATV line extender is the inherent gain v.s. frequency response of the transistor. See figure one.

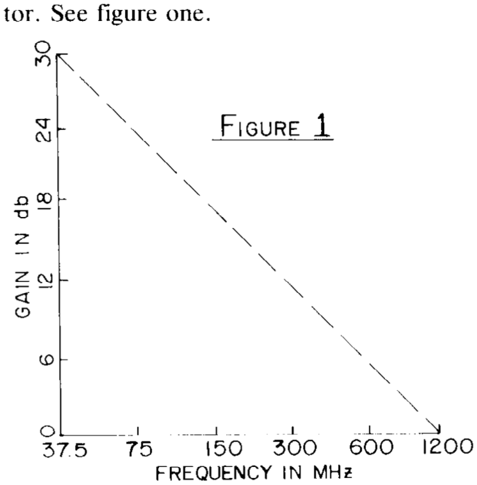

FIGURE 1

Most transistors used in CATV amplifiers have what is known as a 6 db-per-octave gain decrease; that is, if the gain of the transistor is zero (0) db at 1200 MHz, the gain of the transistor one octave lower (600 MHz) is 6 db, at two octaves lower (300 MHz) 12 db, and so on

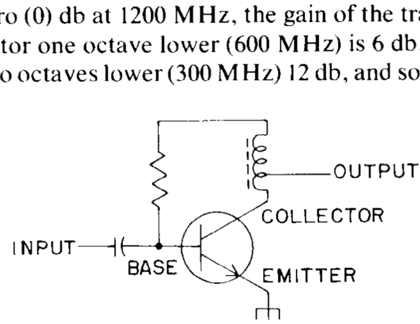

FIGURE 1-A

down to zero frequency. This is far from being a *flat-amplifier* device! So before the engineer can start any serious design work, he must *flatten* out the gain of the transistor.

The most common way to do this is with feedback (see figure two).

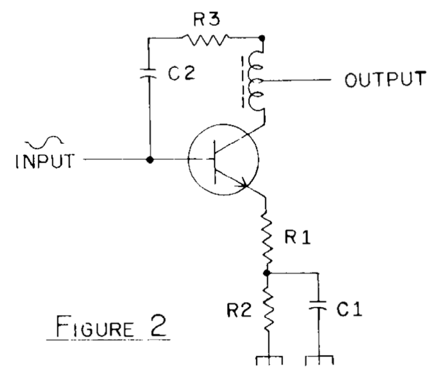

FIGURE 2

The transistor in figure 2 is using two separate types of feedback; current feedback (or emitter degeneration) and voltage (or collector-base) feedback. Notice in figure 1A that to achieve the gain-curve plot of figure 1 that the emitter is at both AC and DC ground potential. By raising the emitter off of DC ground with R2 (in figure 3) but maintaining it at AC ground with C1 (figure 3), we will not change the gain of the stage from figure 1A.

However, if we add a resistor between R2/C1 and the emitter, (R1 in figure 2) we will *lower* the amplifier gain. And because the gain of the amplifier is greater at the lower frequencies the gain reduction caused by inserting R1 into the circuit will be greater at the lower frequencies than at the higher frequencies; this is called *emitter feedback*.

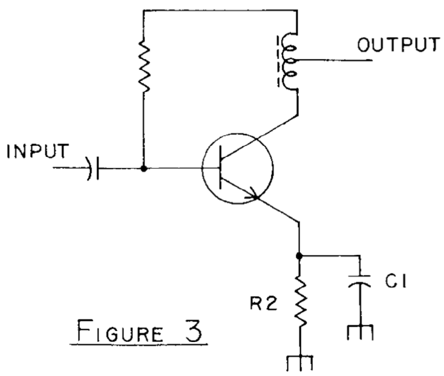

FIGURE 3

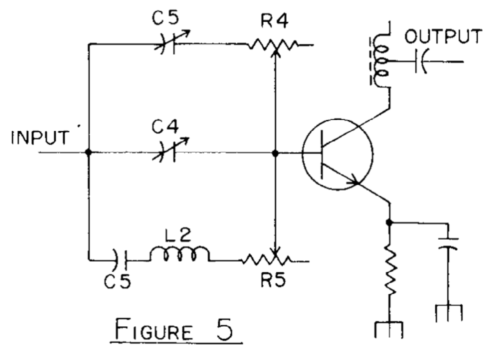

FIGURE 5

The second form of feedback employed here takes advantage of the fact that in a *common emitter amplifier design* the output is *180 degrees out of phase* with the input (see figure 2). And by feeding a portion of the output signal back into the input (through R3 and C2) the signals cancel. And once again because of the higher gain at the lower frequencies, cancellation is greater at the low end. The size of resistor R3 governs the amount of feedback. Use of the two types of feedback (one or both) can be used in designing *flat stage* gain, or a low end tilted response.

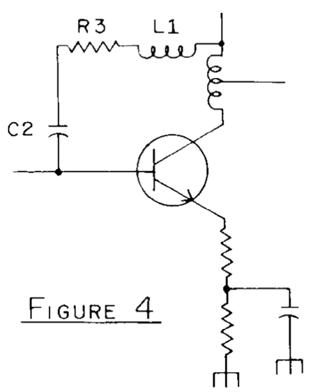

FIGURE 4

If an inductor (L1 in figure 4) is added, the amount of feedback at higher frequencies is decreased. This is caused by the reactance (AC resistance) of the inductor at the higher frequencies; and this gives the maximum amount of gain for the stage at the higher frequencies.

Other Compensation Methods

Figure 5 shows another compensating method for inherent transistor non-linearity in the gain mode. This circuit *pre-distorts* the input bandpass response so that a signal (range) that arrives at the amplifier input essentially *flat* from 50-300 MHz is *tilted* in the pre-compensation network. Then the non-linear gain of the transistor stage takes over, resulting in the output being flat after amplification.

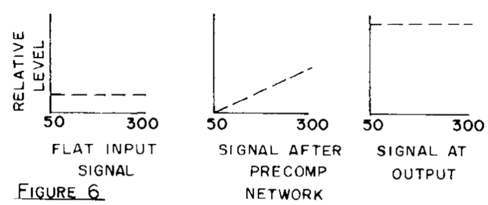

FIGURE 6

Yet another method found in CATV line extenders is shown in figure 7. The input signal is coupled through C1 to the network of L1/R1, where some of the low end signal response is shunted to ground. This is a form of *pre-compensation*. L1/R1 also assist in matching the input of the transistor device to 75 ohms. The signal is then coupled through transformer T1 and capacitor C2 to the base of the transistor for amplification.

C5 and R4 control the mid-band response; C4 controls the high frequency end and C3, L2 and R5 control the low end. Notice the absence of any feedback network.

In the emitter circuit, R3 is there strictly for biasing; a subject to be discussed shortly. R4 is usually about 30 ohms and C3 is .001 or larger; thus forming some emitter feedback. C4 and R5 are for adjusting the mid-band gain while C5 is for high end peaking. Capacitor C6 is a form of positive feedback used on occasions; usually a 5-10 pF disc that also peaks up the high end response.

the base of the transistor. This places forward bias on the base/emitter junction. It should be noted that the resistors used here are usually quite small in value (especially R2); this is done to create a bias condition which is independent of the base current. This promotes stable DC operation.

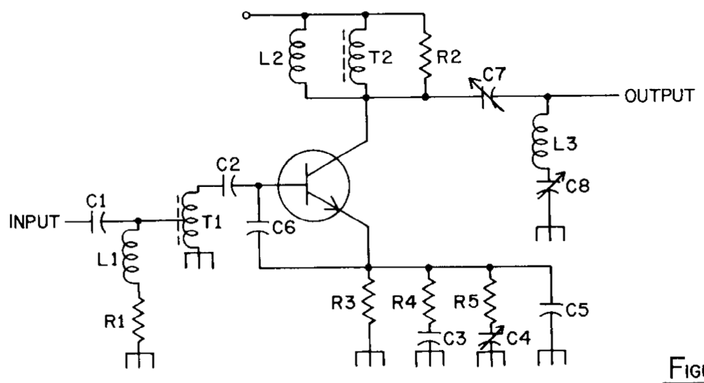

FIGURE 7

In the collector the signal is coupled out through transformer T2 which has a small value low-Q inductor (L2) across it. This inductor swamps the low frequency end down; and resistor R2 does the same thing, to retard the low frequency gain.

C7 couples the output signal to the next stage; its value is chosen typically to have high reactance at the low frequency end which forms a type of post-compensation loss for the low frequency end once again. Finally C8 and L3 form a very broad low Q trap which is again in place to control the low end gain.

Biasing

CATV transistors are biased in a fairly conventional manner; in figure 8 R1 and R2 form a voltage divider network applying voltage to

The voltage appearing at the base can be approximated by the following formula:

$$\frac{R2}{R1 + R2} (Vcc) = \text{base voltage}$$

So if:
R1 = 3.3 k
R2 = 680 ohms
Vcc = 20 volts,
we get:

$$\frac{680}{3300+680} (20) =$$

$$\frac{680}{3980} (20) =$$

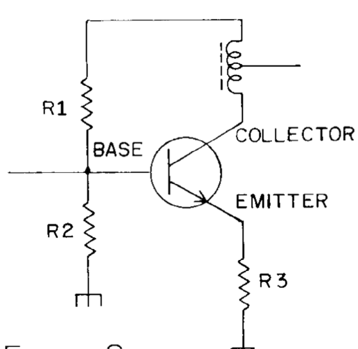

FIGURE 8

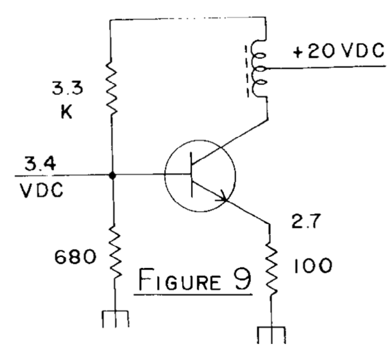

FIGURE 9

.17 x (20) = 3.4 volts on the base, of the transistor. An NPN transistor has a voltage drop of 0.7 volts across the base-emitter junction. So we can then deduce that the correct voltage at the emitter would be approximately 2.7 volts (3.4-0.7). So if the emitter resistor is 100 ohms, we can use ohms law ($I = \frac{E}{R}$) and substituting in the known values, $I = \frac{2.7}{100}$ we find our collector current is 27 mA. Following this same procedure for trouble shooting NPN line extender circuits should allow you to pin down faulty stages that have voltage problems.

Gain Controls

The most common type of line extender gain control is a simple pot on the input circuit (see figure 10). This circuit provides a fairly constant impedance match to the input but its disadvantage is that it varies the output match somewhat.

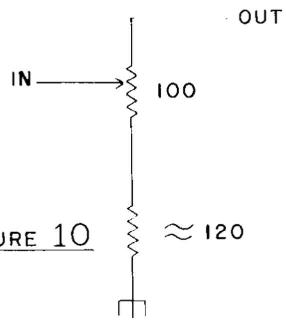

FIGURE 10

Other types of gain controls used are trimmer capacitors located inter-stage (between gain stages), as shown in figure 11. This capacitor varies the coupling between stages and is used extensively in older solid state line extenders. In a few models a voltage variable capacitor (varicap) is found in place of the interstage capacitor. The varicap is "tuned" by a voltage derived elsewhere in the circuit by a pot.

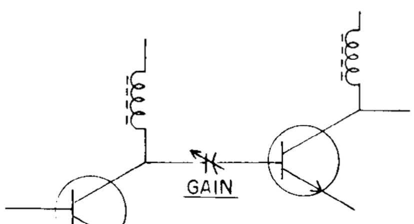

FIGURE 11

Tilt Controls

Tilt controls are added in all line extenders so the operator in the field can adjust the tilt of each amplifier to suit the particular cable loss and flat loss conditions existing where the amplifier is installed. There are five basic ways to vary the tilt. They are discussed here in the order that they are most commonly found in the field.

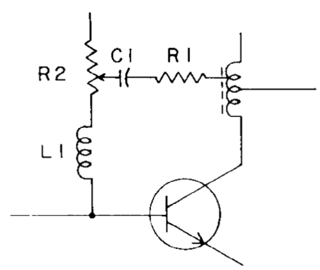

FIGURE 12

The most common utilizes an adjustable collect-base feedback to vary the low end gain of a stage. Pot R2 in figure 12 is the tilt control while resistor R1 sets the range of tile control and L1 governs the response curve of the control. C1 isolates the base voltage from the collector.

Yet another common method is to vary the emitter degeneration or current feedback as shown in figure 13. In this circuit C1 isolates the tilt network from the DC voltage on the emitter while pot R1 is the tilt control and L1 sets the response and R2 sets the range.

A very similar approach utilizes a trimmer capacitor (typically 8-50 pF) in the emitter circuit to vary the amount of emitter degeneration at the lower frequency range. As this capacitor is increased in capacity (or size), its reactance at lower frequencies is reduced, thereby creating more and more degeneration

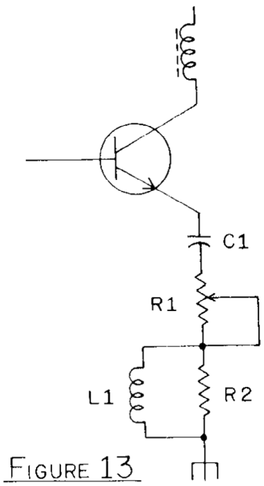

FIGURE 13

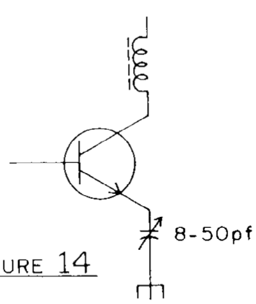

FIGURE 14

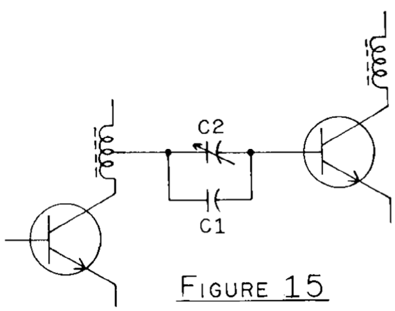

FIGURE 15

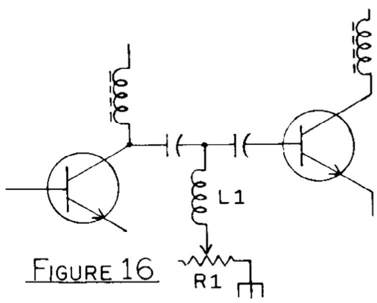

FIGURE 16

at the lower frequency end. See figure 14.

Yet another approach is to use a trimmer (adjustable capacitor) to couple two stages together. As the trimmer (C2 in figure 15) increases in value its resistance at lower frequencies *decreases* and the low end tilts up.

Finally there is the shunt method of tilt, found in figure 16. Inductor L1 retards the passage of high frequencies while the lower frequencies are shunted to ground through R1.

Briefly-Cross Modulation

In addition to flat gain, and tilt control, cross modulation is an important design consideration for a line extender. Cross modulation occurs when two or more signals are passed through *any non-linear device*. A transistor is a non-linear device. It can be controlled (but not eliminated) by proper circuit design; and the line extender design engineer wants to *control* it to the point where it does not degrade TV picture (carriers) passed through the amplifier.

Of all of the various circuits discussed here so far, a circuit with both voltage and current feedback has the best cross modulation characteristics.

The main criteria affecting cross-mod is the biasing condition of the transistor. Normally you want a fairly high Vce (collector — emitter voltage). And, to a degree, as the collector current rises, or the emitter resistors are reduced in size, the cross-mod is decreased.

Equalization

Because of the wide spectrum frequency response range of the typical solid state amplifier, and the inherent loss profile of coaxial cables, the CATV equipment designer has to compensate for a great deal of tilt in his amplifier. Keep in mind that the basic transistor has 6 db *less gain* every time the operational frequency is doubled; and, that coaxial cable losses tend to have about the same problems; i.e. *cable losses* approximately *double* every time the frequency is doubled.

To compensate for the transistor, various circuit designs already discussed are employed.

To compensate for the cable characteristics, two basic schools of engineering have developed.

The first one says that you should build a basically *flat amplifier*. And then you should insert a passive frequency selective pad at the input of the amplifier to insure that the *amplifier input sees a flat signal.*

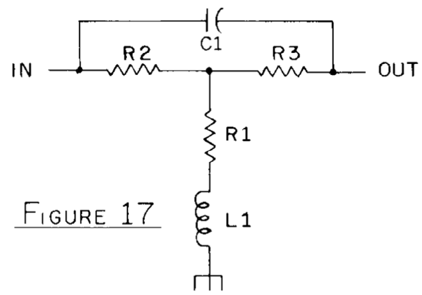

FIGURE 17

A simplified description of this form of equalization is shown in figure 17. This is a bridged-T equalizer where R2 and R3 set the impedance while C1 passes the high frequencies on to the output of the pad and R1/L1 shunt the lower frequencies to ground. The advantage to this type of equalization is greater system flexibility (plug in pad) and ease of amplifier alignment. The disadvantage is a much higher low band noise figure, associated with the shunting of the low band energy to ground.

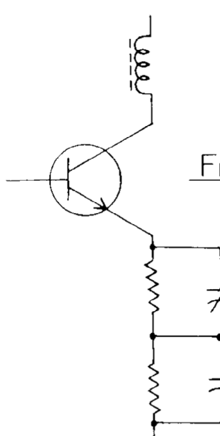

FIGURE 18

The second school of thought distributes the equalization process throughout the various stages of the amplifier. This is done by using greater amounts of feedback and raising the high end response with peaking capacitors (see figure 18). This method has the advantage of maintaining a better low end noise figure and fewer overall amplifier stages (because of high end peaking each stage).

It has the disadvantage of taking this optional alignment or adjustment procedure out of the hands of the field installer on the pole, and it is considerably harder to align for the bench tech.

Power Supplies

The most common power supply circuit used in line extenders is the simple series regulator. The theory behind this is that the transistor will show on its emitter a voltage that is 0.7 volts lower than the voltage on the base, while current is being drawn through the collector. The base voltage is kept constant by zener diode D1 (in figure 19) while the network made up of R1 and R2 act as voltage dropping resistors. In the AC mode, the transistor is an emitter-follower, and the AC (or ripple) output will be reflective mainly of the amount of ripple on the transistor base. This is cured by adding additional filtering in the form of R1, R2 and C1.

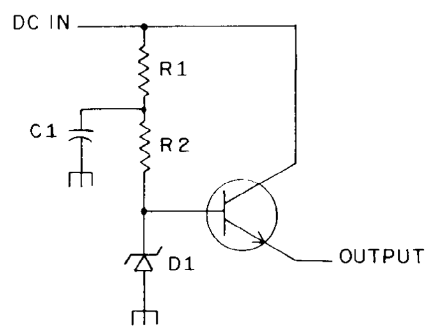

FIGURE 19

Trouble Shooting

Trouble shooting a line extender involves isolating the area of the problem, and then further isolating the component which is causing difficulty. Full trouble shooting procedures for line extenders in general and specific models in particular will be the subject of later articles here in CATJ.

Refer first to your unit schematic and the voltages shown for the various transistors. If voltages are off more than 10% from the published specs, and you are sure of your voltage measuring test equipment, the transistor should be changed out.

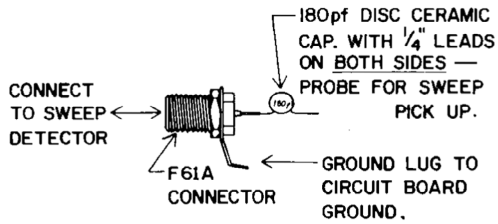

FIGURE 20

At the same time, you can and should construct a simple probe (see figure 20) and trace the signal through the unit starting at the input. Refer to this article for an explanation of what you should find at various RF points in the system.

By providing a sweep input to the defective amplifier, at the proper sweep voltage level recommended by the line extender manufacturer, you can use the probe shown in conjunction with a detector and scope display to trace the RF circuit out and check response stage by stage.

Always make sure to ground the probe (ground lug to circuit board ground) before probing. Keep in mind the function of the various feedback and equalizing networks; *don't expect flat responses throughout the amplifier!*

Taking a properly functioning line extender and the probe can be quite an educational experience and a hedge on future problems. Simply go through the unit stage by stage from the input to the output and make sketches of the response curves you see. This will be useful reference information later on should a defective unit require trouble shooting.

Once the problem area is found, check the voltages against the schematic and what is discussed here. A visual check of the suspected area will usually show up a defective resistor, scorched place on the circuit board, or a blown capacitor.