A FEEDFORWARD GAIN BLOCK

G. Luettgenau
J. Powell

TRW Semiconductors, Inc.

ABSTRACT

This paper describes the characteristics and in-system performance of a compact feed-forward gain block which is applied in much the same way as conventional hybrids.

The feed-forward approach toward increased linearity and output capability yields a high return on an investment in cost and power consumption.

Detailed analyses are performed with respect to trunking, distribution and general system upgrading. Operation with various degrees of tilt and output level is evaluated.

The feasibility of combining feed-forward blocks with normal hybrids is discussed. The data presented allow the system designer to make performance and cost comparisons with alternate approaches.

In conclusion, mechanical and thermal aspects are discussed. A prognosis for future developments in the area of integrated feed-forward amplifiers is given.

INTRODUCTION

The feed-forward type amplifier established itself as the deluxe model of CATV amplifiers. As such it found a niche for special applications.

Recently, however, feedforward has become an appealing solution for a wide range of applications. Bandwidth extensions, coupled with increased channel loading, have pushed the requirements for normal hybrid performance to the limits. In more and more cases the feed-forward approach offers a technical solution on a broad front.

In general, a trunk or line-extender amplifier can be realized from a combination standard hybrid and feed-forward circuit. Using volume price projections, the cost ratio between a conventional amplifier (two hybrids) and a feed-forward system (one hybrid plus a feed-forward block) is 1:3.5. The ratio of power consumption is 1:2.5. To put these numbers into perspective, one must realize that the feed-forward gain block has the same output capability as at least eight normal hybrids in parallel.

In the following the performance and construction details of an integrated feed-forward gain block are discussed.

A FEEDFORWARD GAIN BLOCK

Trunk Performance

The excellent distortion characteristics of the feed-forward amplifier may be used to extend the trunk length, to increase station spacing or to minimize distortion. Depending on the design objective, the feed-forward block is combined with a second block, or with a standard hybrid, to form a station amplifier. A computer analysis of the maximum trunk reach was performed, since this is a useful figure of merit.

Figure 1 shows the characteristics of the various gain blocks used in the analysis. FF1 is the currently available feed-forward block. FF2 is an anticipated second generation device. G22, G18 and G12 are standard hybrids.

	FF1	FF2	G22	G18	G12
Gain (450)	24	28	23	19.5	12.5
Gain-Slope	1	1	1	1	1
NF (450)	8	7	6	6	6.5
NF-Slope	1	1	1.5	1.5	1.2
CTB*	-75	-75	-58	-59	-57
CTB-Slope	7	7	9	9	7

* CTB = 60 CH @ H22 46dBmV flat
all numbers are dB values

Figure 1. Gain Block Characteristics

The analysis assumed the following station amplifier characteristics:

- o Flat input loss = 2dB
- o Flat interstage loss = 10dB
- o Pre-amp operated with flat output
- o Post-amp output tilted with equalization before and after pre-amp, as required.

The trunk specifications are CTB = -59dB, CNR = 43dB, minimum performance at any channel. The analysis was performed for output tilts in steps of 1dB. It was stopped, when a further increase in tilt did not yield a reach increase.

The results of the various computer runs are tabulated below. In order to preserve space, only the values of zero, maximum, and 6dB tilt (if applicable) are quoted. The reader is invited to study the performance and draw conclusions.

G18 + G18 (27dB Spacing)

Tilt (dB)	V_{out}(dBmV)	Cascade	Reach (dB)
0	32.5	20	540
6	33.4	24	648
9	33.9	27	729

FF1 + FF1 (36dB Spacing)

Tilt (dB)	V_{out}(dBmV)	Cascade	Reach (dB)
0	42.0	15	540
6	43.0	19	684
12	44.0	23	828

FF2 + FF2 (44dB Spacing)

Tilt (dB)	V_{out}(dBmV)	Cascade	Reach (dB)
0	45.5	6	264
6	46.5	8	352
13	47.7	11	484

G12 + FF1 (24.5dB Spacing)

Tilt (dB)	V_{out}(dBmV)	Cascade	Reach (dB)
0	34.6	66	1617
2	34.8	70	1715

G18 + FF1 (31.5dB Spacing)

Tilt (dB)	V_{out}(dBmV)	Cascade	Reach (dB)
0	36.9	41	1291
4	37.4	46	1449

G22 + FF1 (35dB Spacing)

Tilt (dB)	V_{out}(dBmV)	Cascade	Reach (dB)
0	39.7	21	735
6	40.4	25	875
9	40.8	27	945

G12 + FF2 (28.5dB Spacing)

Tilt (dB)	V_{out}(dBmV)	Cascade	Reach (dB)
0	36.3	51	1453
2	36.6	55	1567

Line Extenders

In line-extender and bridger applications, the feed-forward circuit allows operation at very high output levels. Because of this, more taps with high tap loss and low insertion loss can be used, thereby extending the amplifier spacing and substantially increasing the number of subscribers served per amplifier.

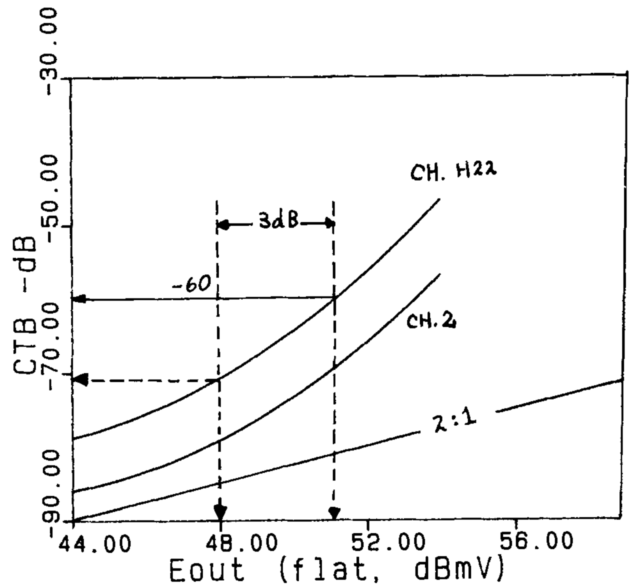

Figure 2. CTB Versus Flat Output

Figure 2 shows CTB as a function of output level for the amplifier type FF1. The curve would also pertain, approximately, to a combination of FF1 with any standard gain block type, since the pre-amp CTB contribution is less than 1dB.

A CTB requirement of -66dB for line-extenders is common. There should be a "headroom" of 3dB in output capability, corresponding to (theoretically) -60dB CTB. Because of deviations from the "two-for-one" law at high output levels, the maximum output voltage must therefore be limited to a value 3dB below the point at which CTB is -60dB. For a flat spectrum this level is 48dBmV. As shown in Figure 3, a 9dB tilt raises the maximum output to 51dB and improves the low level performance by 10dB. This welcome phenomenon can be understood readily by recognizing that tilted operation results in reduced total power to be handled by the amplifier, thus providing more headroom.

Since, further, a modulated TV signal has less power than the carrier (peak-sync) power used for CTB testing, it is to be expected that under real life conditions the overload point is moved to even higher output levels. To investigate this possibility, a test set-up was assembled which allowed the measurement of CTB caused by fully modulated signals. Refer to Figure 4. The analyzer was used as a receiver (Zero-Span, Linear Mode) with its video output fed to a wave-analyzer, which measured RMS signals in a wideband or 20Hz narrow band mode.

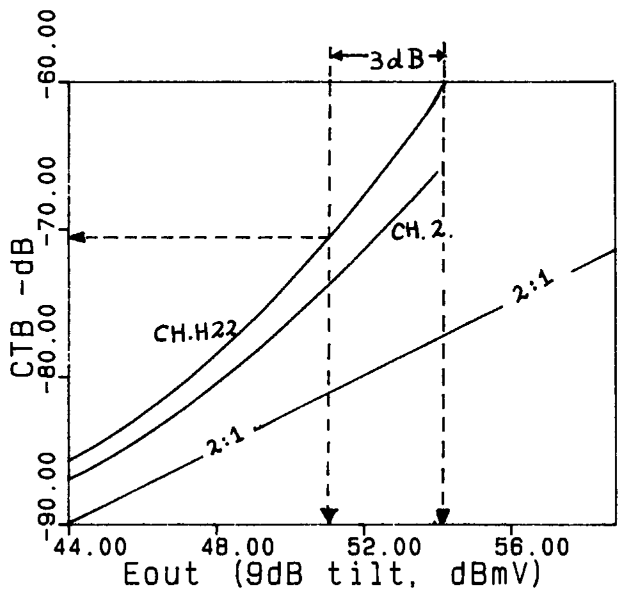

Figure 3. Operation with 9dB Tilt

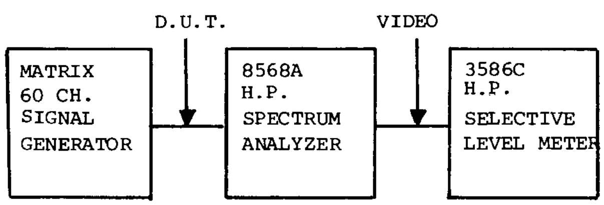

Figure 4. Special CTB Test Set-Up

Figure 5 shows the composition of the video signal analyzed. By subtracting noise and crossmodulation sidebands from the composite signal, the CTB component was derived. The results are shown in Figure 6. In hindsight the outcome is quite plausible. Since all 59 interfering carriers were synchronously modulated by a symmetrical squarewave, CTB components were generated only during half of the time. Thus the CTB power is halved, regardless of output level. Therefore, one may conclude that synchronous modulation reduces the value of CTB noise, but does not change the overload point. The situation of synchronous modulation has a low probability in real life. All synchronization pulses would have to occur at the same time. It is more likely that the amplitudes of all video signals involved are different from each other. Making the simplifying assumption that each signal has a random value between 0 and 1 (= unmodulated carrier), the RMS triple beat noise is 7.2dB below the value measured with all signals at full carrier amplitude. For this case both a CTB improvement and an increase in overload threshold is expected. The validity of this prediction could only be established by a viewer test. It appears to be not unreasonable to expect an improvement in headroom of at least 3dB.

Operating a line-extender at very high output levels requires consideration of certain interrelations:

The spacing between line-extenders is given by

$$\text{Spacing} = E_{out} - E_{min}$$

where

E_{out} = Output capability

and

E_{min} = Minimum level on the distribution cable, typically 16dBmV

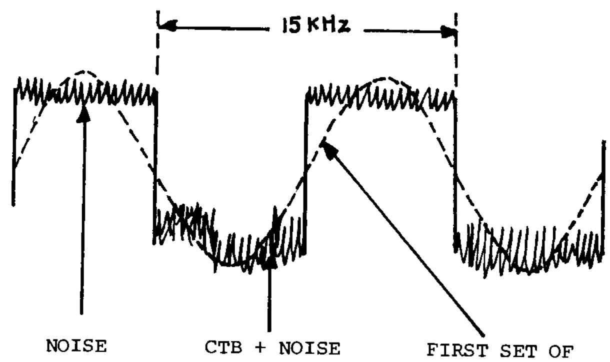

Figure 5. Video Signal

A line extender with an output capability of 51dBmV will therefore need a gain (spacing) of 35dB. The losses between amplifiers can be divided into flat loss (from taps) and cable loss. Using typical lot-size, tap-loss and cable-loss numbers, one may calculate that for a spacing of 35dB, 12 taps with a total flat loss of 12dB and 23dB of cable (450MHz) may be used.

For 50-450MHz operation, cable losses (dB) can be assumed to vary at a ratio of 1:3. Under this condition the following relations exist:

Cable-loss (450)= 3 * tilt -2 * drop-cable loss(450)
Tolerance = cable-loss /3

Tolerance is the range of voltages available to the subscriber. For instance, for a tolerance of 6dB, the average signal voltage would be +3dBmV. Channel 2 would be at 0dBmV at the beginning of the cable and at +6dBmV at the end. The opposite would hold for Channel H22. The best tolerance achieveable for 23dB of cable is 7.7dB. The minimum amount of output tilt for the line-extender depends on the length and quality of the drop-cable used. It would seem that for example given, 10dB or more is appropriate. The conclusion to be drawn is that the feed-forward line extender may have to be operated with more tilt than the usual values.

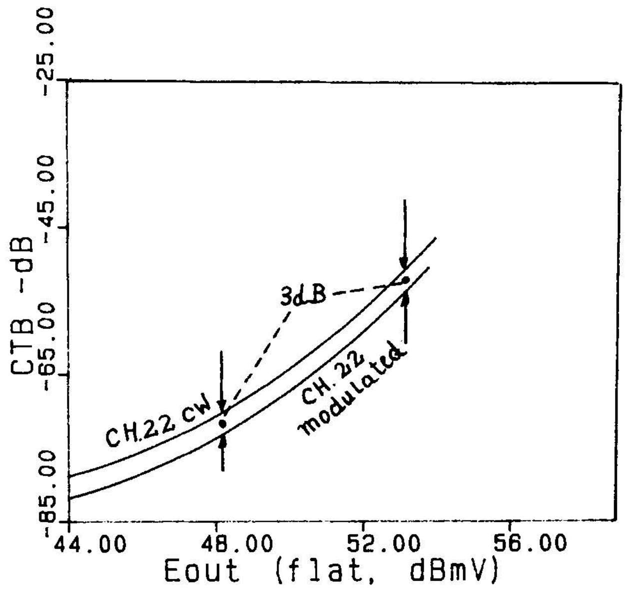

Figure 6. CTB in Modulated System

Package Outline

The feed-forward amplifier is a plug-in module, pre-tuned and fully characterized, that has been designed to replace standard amplifiers in CATV amplifying stations. Due to its small size a minimum of mechanical modifications are usually required.

The photograph (Figure 7) shows the package configuration chosen. It is the best compromise between size, performance and manufacturing costs.

The dimensions are 2 inches x 2.5 inches x 0.8 inches. There are 5 pins on each side (Figure 8) spaced 250 mils apart and 0.5 inch above the mounting surface.

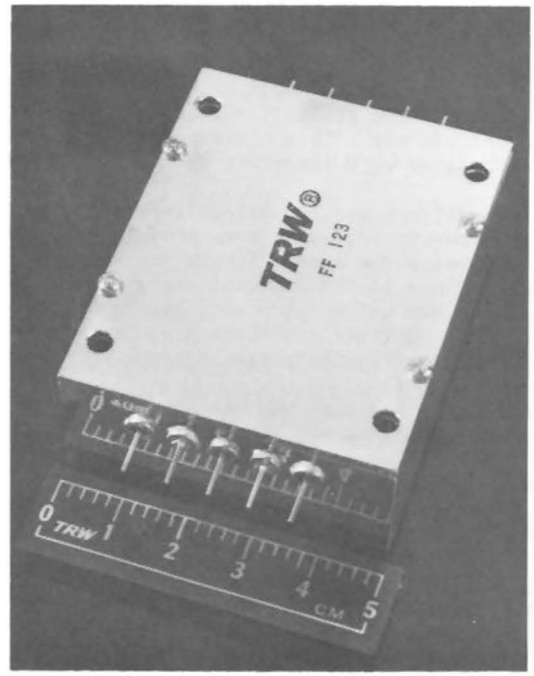

Figure 7. Photograph of Gain Block

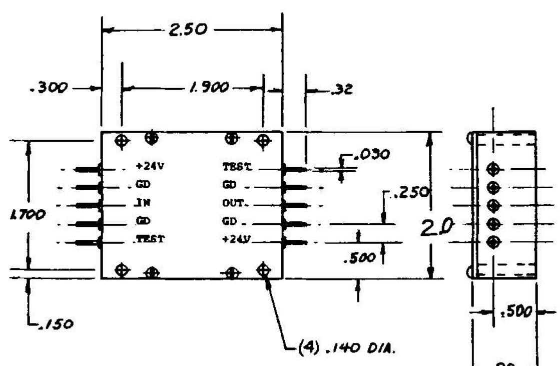

Figure 8. Package Dimensions

Construction

In anticipation of future frequency and gain increases, potential problems such as grounding and isolation have been given special care. The error and main amplifier substrates are mounted directly on the back plane (i.e., ground) of the feed-forward circuit. This minimizes the gain ripple associated with imperfect grounding.

The amplifiers and the delay lines are shielded from each other to achieve a very good isolation between RF paths, where signal levels are very different. Connections to the external circuit are made through input and output pins each surrounded by 2 ground pins. Circuit connections can be very short if a microstrip technique is used.

The package has been designed for a low thermal resistance between the transistors and the case. If the case temperature is kept below 100°C the temperature of the transistors is 135°C in the worst case. The mounting surface of the package is machined for good thermal contact with the amplifying station mainframe.

Circuit Realization

In order to achieve 450MHz bandwidth, the roll-off frequency of the main and error amplifiers used in a feed-forward circuit must be at least 500MHz. This is achieved by the use of transistors that have transit frequencies of typically 6GHz and very low parasitic capacitances.

The delay lines are printed in thin-film technique. The delays are 2.9 ns with losses of .25 and .75dB at 50 and 450MHz, respectively. Lumped delay lines have potentially less loss, but are more costly and are sensitive to temperature variations.

Extensive use of thin and thick film technologies on alumina substrates reduces the number and size of discrete and printed components. This increases the isolation between different parts of the circuit. Compact, microelectronic construction is expected to ensure long-term stability and reliability.

CONCLUSION

This paper describes the first generation realization of a feed-forward amplifier module. The integrated construction yields a compact, easy to use gain block. Performance and power consumption are similar to those found with discrete component realizations.

It is expected that the future will bring improvements in all areas. Specially designed microelectronic amplifiers will reduce the noise figure and increase the gain. At the same time the power consumption will be reduced. Single-ended and monolithic gain stages are expected to find use. In addition to being more efficient such amplifiers have less and more uniform delay than transformer-coupled circuits, as used in conventional hybrids. The bandwidth will follow the trends developing in the CATV Industry. There is no reason why feed-forward blocks could not reach 1GHz.

REFERENCE

G. Luettgenau and J. Powell - The Future of CATV Hybrids - Transactions of SCTE Conference, Boston, 1982.