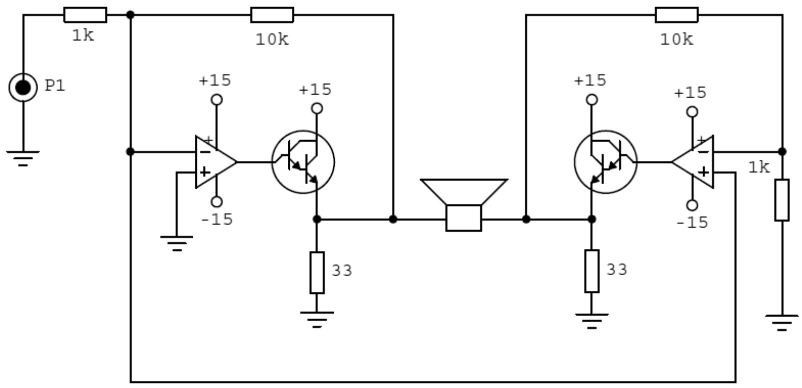
4.10.2 from the Book
"High perfomance audio power amplifiers for music performance and reproduction"

Author: Ben Duncan, URL:
http://images.amazon.com/images/P/0750626291.MZZZZZZZ.jpg and
http://books.google.de/books?id=-5UPyE6dcWgC&pg=PA162&lpg=PA162&dq=High+Performance+audio+power+amplifiers+Sandman+add+on&source=bl&ots=wuHnqoxGj_&sig=Kjx3YB2fUhRrl3FJ2Z4rnfT_GAg&hl=de&ei=MCHTStj2EYjWmQPf25yTAw&sa=X&oi=book_result&ct=result&resnum=1&ved=0CAgQ6AEwAA#v=onepage&q=&f=false

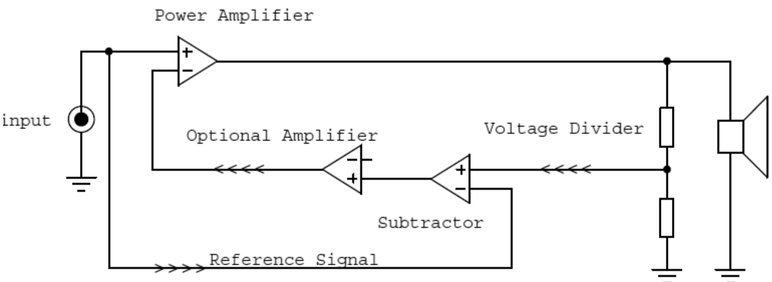
4.10.2 **Other Error Correction Modes - Error takeoff from Sandman**

In the ''Short Circuits' column of the January 1973 issue of Wireless World, A.M. Sandman (UK), having made proposals for class B amplifier improvements in 1971 presented a simple circuit showing how to use a low cost IC op-amp to build a low-quality amplifier, then use a second op-amp to correct the errors



(**Figure 4.65**, Distortion Reduction by error add-on)

This did not involve NFB and was in addition to the global NFB already used by the low quality amplifier, instead, Sandman had noted that the error signal is approximately equal to the residue at the inverting input of the first op-amp. This is true for the series NFB configuration used. The error signal is then simply amplified (with a non-inverting amplifier note), and applied in antiphase by a second power stage, which makes a full-bridge. So here we have a bridge topology, IC op-amp-based, with NFB and one kind of error feedforward. Sandman titled his circuit "Reducing distortion by error add-on".
In the February 1973 issue, Bollen **[78]** followed with 'Distortion reducer'. In this article, a similar, rather more convoluted scheme was proposed

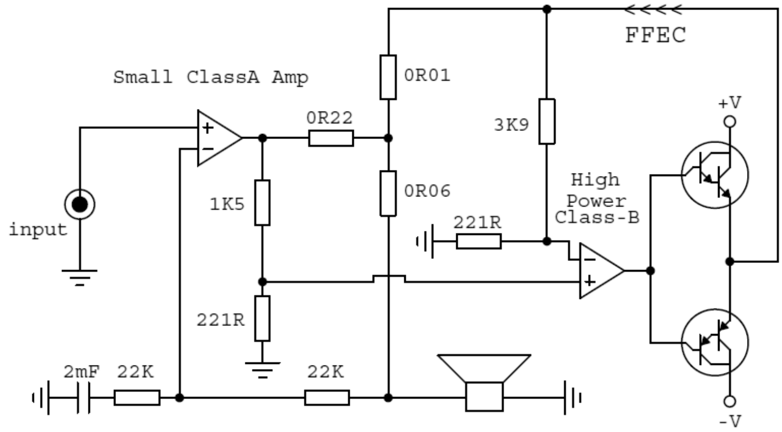


(**Figure 4.66** – Active Error Feedback after McDonald & Bollen)

First, the input signal is subtracted from an attenuated version of the output. This should leave just distortion and noise, Then feed this back into the input stage in anti-phase, to cancel the distortion - and ideally the noise. In practice, the IC op-amps of Ihc day added some substantial noise and also distortion of their own. In turn the circuit was limited to attaining a nonetheless creditable reduction of non-linearity and hum by 15 to 20dB or so. Subsequently J.Ross MacDonald drew attention to his 1955 patent and paper **[79].** where he had described much the same system, but using valves (as you then did) and calling it 'Active error feedback'. Others call this 'multiple feedback'.

In the October 1974 issue of Wireless World, Sandman then presented a more in depth article, showing the 'distortion add-on' circuit providing what he now termed 'error takeoff and also "error feedforward". He also showed an iterative, parallel scheme, where the main signal and error canceling signal are passively summed at the output, n times ad nauseam. He revealed that Howard Black, the inventor of

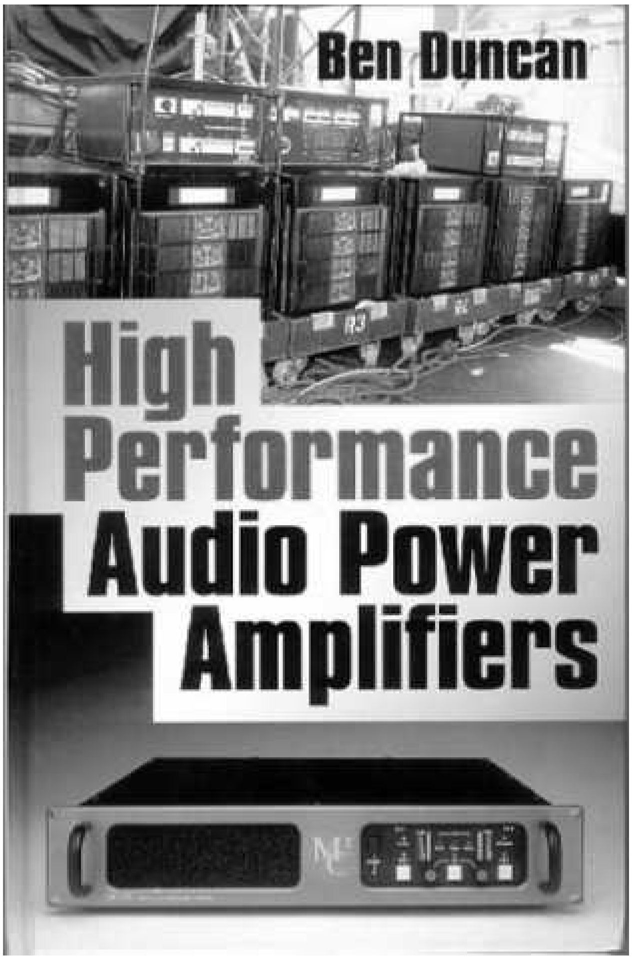
NFB (with 5 patents filed from 1928 to 1932) had patented the latter earlier, in 1925, but it was too far ahead of its time. Sandman now felt that the time for putting feedfoward error correction (FFEC) to work had come. The gist was to measure the error at the output of the amplifier, amplify it. then subtract it from the signal, According to which way you see it, FFEC has a lot in common with current -dumping. Sandman later called this 'class S' **[80].** But it is really a mode of control, and again quite unlike any of the feedback schemes previously discussed. It has seen commercial use in several Japanese domestic amplifiers (e.g. Sansui **[81]** and Technics), but nowhere else high profile. As a measure of what is possible in the realm of improving conventional specifications, in the Technics SE-A100



(**Figure 4.67** Error Feedforward after Sandman),

which employs Sandman's “FFEC", Hood [27] cites 0,0002% THD @ 1 kHz, and a reasonably wide bandwidth, up to 150 KHz, for a nominal 100 watt power at 8 ohms. As in current-dumping, a small, clean amplifier "A", with its own NFB is used to 'fill-in' the relatively small deficiencies of the larger-current-handling high gain amplifier, "B" Each operates in the same class as its respective name. One way to look at the operation of the circuit is that the high gain error amplifier (B) makes the speakers impedance appear to be higher than it really is. But low distortion, including high cancellation of the crossover errors in amp B, requires a precise resistance match, as suggested by some of the ohmic values. And, as soon as the speaker is driven, or even the room temperature varies, nearly exact cancellation is bound to be lost.

75 Mills, P.G.L and M.OJ. Hawksford, *Transconduciance power amplifier systems for current-driven speakers,* **JAES Vol,374 Oct 1989.**
76 Werner, R.E, & R.M. Carrell, of RCA, *Application of negative impedance amplifiers to loudspeakers systems,* **9th AES tonvenlion, Oct 1957.**
77 Grey, Paul.R, & RobeitG. Meyer, *Analog Integrated Circuits,* **Wiley, 2nd ed. 1984. ISBN 0-471-81454-7.**
78 Bollen, D, *Distortion reducer,* **Wireless World, Feb 1973.**
79 Macdonald. J.Ross, *Active error feedback.* **Proc.IRE 43,808, 1955.**
K0 Sandman, A.M, *Class S. a novel approach to amplifier distortion,* **Wireless World, Sept 1982.**
81 Takaashi, Sasumu, & Susumu Tanaka, *Design and construction of a feedforward error-correction amplifier,* **JAES, VoL29, Jan/Feb 1981,**
82 Hawksford, Malcolm G, *Quad input current mode asymmetric cell (CMAC) with error-correction applications,* **Proc.lEE, CDS, vol.143, Feb 1996.**
83 Hawksford, Malcolm O, *Differential current derived feedback in errorcorrecting audio amplifier applications,* **ProcJEE, CDS, vol. 141, No.3, June 1994**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