AUDIO BREAKTHROUGH !

Magnetic Field

An entirely new concept in power amplifier design makes possible an audio amplifier that has high power, low weight and eliminates the power transformer, large capacitors and many other common components.

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A FEW WEEKS AGO I HAD THE PLEASURE OF entertaining Robert W. Carver at my laboratory. If his name is unfamiliar to you, it was Bob Carver who started the Phase Linear Corporation and who developed the first high-powered stereo amplifier for home use that sold for (as he puts it) "less than a dollar per watt."

Recently, Mr. Carver decided to form a new company. And no sooner had the Carver Corporation been formed than we began to hear rumours about a "new" kind of audio amplifier known as a Magnetic Field Amplifier. At the time of his visit to my lab, he was still busy making sure that the new amplifier circuitry was properly protected at the U.S. Patent Office. All he would tell me then was that the amplifier would *not* require a power transformer or extensive heat-sinking. There would be no need for large-filter electrolytic capacitors. The amplifier would weigh around 12 pounds, would be highly efficient and would deliver 200 watts-per-channel at very low distortion. The projected retail price—around $300!

Had anyone else come along with this tale I would have labeled him an incurable dreamer. However, knowing Mr. Carver's earlier achievements in amplifier design, I made him promise that as soon as he was able to disclose more circuit details, he would allow me to describe the circuitry in **Radio-Electronics**. True to his word, Mr. Carver sent me a fairly complete description of how his Magnetic Field Amplifier works, and what follows is pretty much the inventor's own description of his new audio amplification technique.

Magnetic field amplifier

The concept behind the magnetic amplifier can best be understood by referring to Fig. 1. A pair of SCR's identified in Fig. 1 as the SCAN SCR and the RAMP SCR feed amplitude-modulated current into a specially constructed transformer called a magnetic cavity. The magnetic-cavity transformer is similar to an ordinary AM detector transformer found in AM radio sets. However, there are two important differences: First, the windings are arranged so that an output occurs during the *collapse* of the magnetic field instead of during its buildup. Second, it is designed as a very high-powered AM detector transformer instead of the microwatt detector generally found in radio sets. The output of the magnetic cavity is a full wave rectified by a pair of 3-amp (30-amp peak) diodes to form a conjugate pair of time-varying audio voltages. In its most simplified form, the loudspeaker is connected across the conjugate voltages and bidirectional audio current flows in the voice-coil windings.

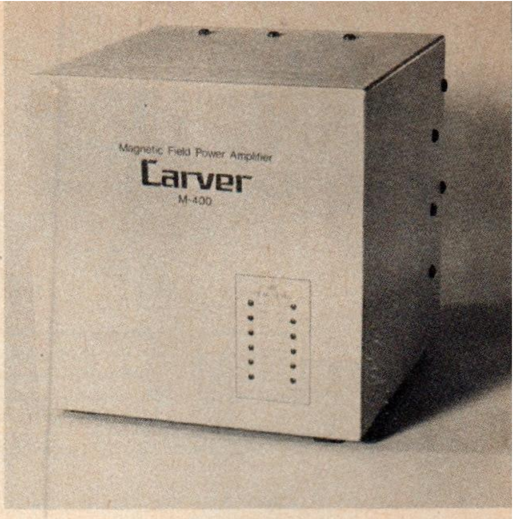
SCR modulator operation

Figure 1 shows the main components of the SCR modulator circuitry. The action of the scan SCR, the ramp SCR, the scan diode and the commutation diode, together with L1, L2 and C1, produces an amplitude-modulated current that corresponds to the incoming audio signal in the primary winding of magnetic-cavity transformer MC1. The peak magnitude of the current depends upon the amplitude of the incoming audio voltage. This current is pumped into the primary of MC1 during a period of time called the ramp interval. Then, the energy contained in the field of MC1 is coupled to the secondary winding and onto the speaker during a period of time called the scan interval. In general, the scan interval is shorter than the ramp interval, but during full-power operation, the ramp and scan intervals are identical.

Figure 2 shows the ramp and scan periods are composed of four timing intervals. At time t_2, the magnetic field has already been established in the cavity and is beginning to collapse. The collapsing field generates a decaying current, i_1, which decays to 0 when the energy in the field associated with the primary winding is depleted at time t_3. During the scan interval prior to t_3, the scan SCR is made ready to conduct by applying a positive voltage step from the control logic. However, the scan SCR does not conduct until a forward bias is also supplied between its anode and cathode.

At time t_3, current is no longer maintained by cavity inductance since the stored energy was transferred to the secondary of MC1 and to the load. The direction of the current is then reversed and the scan diode becomes reverse-biased. At this moment, the scan SCR is forward-biased and current flows as shown in Fig. 3.

The ramp interval operates in a manner similar to that of the scan interval. Ener-



Amplifier

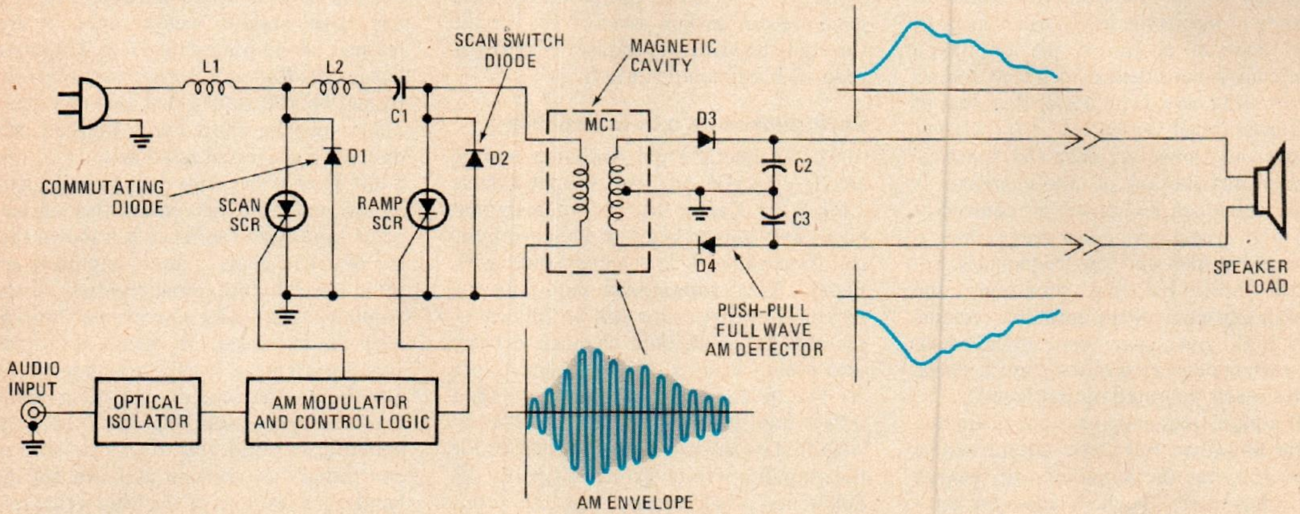


FIG. 1—THE MAGNETIC AMPLIFIER contains a magnetic cavity transformer that is driven with amplitude-modulated current. The output signal is derived from an AM detector.

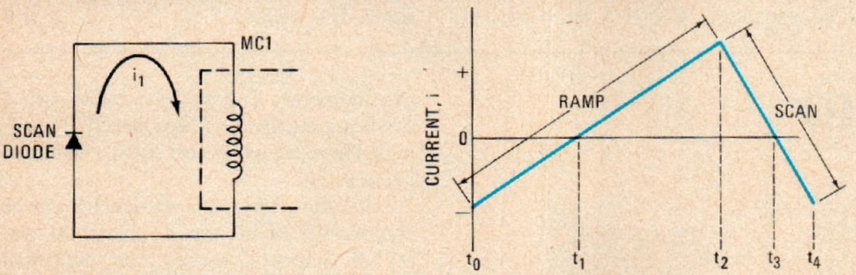


FIG. 2—DURING THE SCAN INTERVAL from t_2 to t_3, current flows through the scan diode and decays to zero.

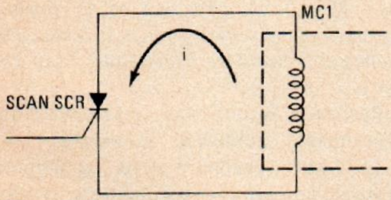


FIG. 3—THE SCAN SCR conducts during the scan interval from t_3 to t_4.

gy that is stored in the magnetic cavity is shuttled about L1, L2, C1 and the load under the control of the logic section.

The combined ramp and scan periods depend upon the amplitude and frequency of the incoming audio signal.

AM detector operation

The speaker load could simply be connected directly across the conjugate voltages at the output of the detector. However, this simple approach would yield very poor performance that would be inadequate for any high-fidelity applications. The frequency response would be poor, with high-frequency power output dropping rapidly above 6 kHz, and virtually no undistorted output power available at 10 kHz or above. In addition, excessive commutation noise at the output would impart a very high noise level to the amplifier, based upon modern high-fidelity performance standards. Finally, harmonic distortion would be about 8% at 400 Hz at all power levels. All these problems are solved by incorporating a more sophisticated AM detector that uses negative feedback to increase bandwith and lessen the noise and distortion.

Operation of the AM detector can be understood by referring to Fig. 4. The audio output is taken at the output (emitter) of Q1 for positive-going signals and at Q2 for negative-going signals. At low frequencies (e.g., 400 Hz), Q1 and Q2 essentially act as switches, except that a small voltage across the devices is developed by the combined action of the incoming audio and feedback signals applied to the input of A1. Because of the high loop gain of A1, this low voltage is just the right amount so that the output follows the input precisely. In this manner, distortion is reduced to less than 0.1%.

At high frequencies (e.g., 15 kHz), the modulator is unable to produce a varying high-frequency output. Nevertheless, it does produce a voltage with a DC component. This output voltage is filtered by C2 and C3 to form a DC voltage with a high-frequency ripple as the detector tries to follow the modulator commands.

Under these conditions, the action of Q1, Q2 and A1 resembles that of a conventional audio-output stage. In other words, the DC voltage developed across

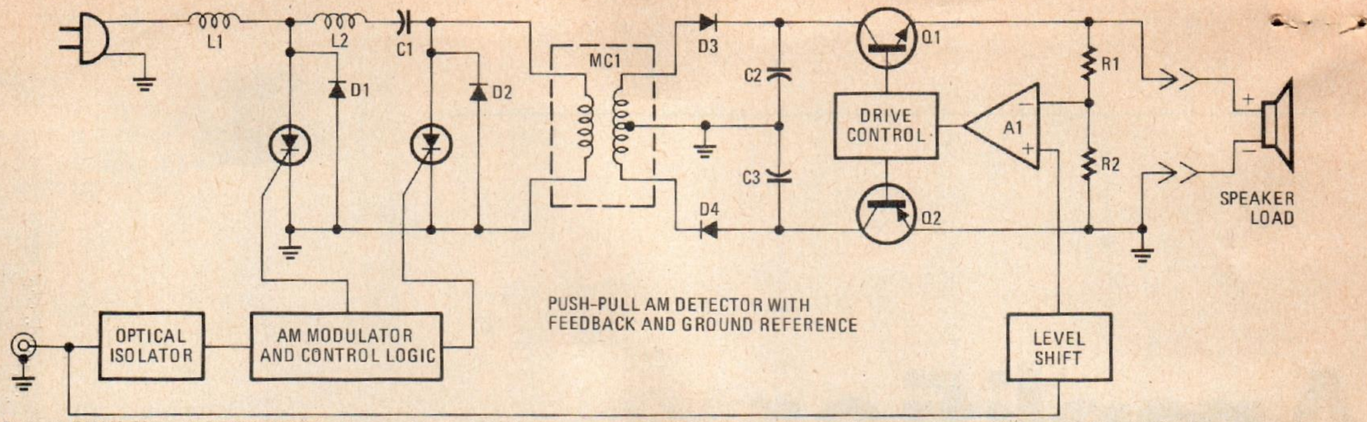


FIG. 4—A PUSH-PULL AM DETECTOR with negative feedback is incorporated into the amplifier to increase bandwidth and reduce distortion.

C2 and C3 is used to power Q1 and Q2 as a standard amplifier. Transistors Q1 and Q2 then deliver low-distortion high-frequency power to the loudspeaker load. In this mode of operation, the amplifier's efficiency is considerably reduced and, in the limiting case, is no better than that of a conventional amplifier. Mr. Carver points out, however, that the spectral-energy distribution of music signals is such that much less power is required at the high-frequency audio range than is required at mid- and low-frequencies. So, under music listening conditions, the overall efficiency of the amplifier remains very high, and it runs cool to the touch even when delivering music signals whose peaks reach the rated output level.

If a high-frequency test tone is applied to the amplifier, full power output will be delivered, but the amplifier will become quite hot to the touch. If excessive temperatures are reached, a built-in thermal-protection circuit causes shutdown to prevent any damage to the amplifier.

Since the circuit has negative feedback that forces the output to follow the input signals, it rejects the commutation noise generated in earlier parts of the circuit through the same mechanism whereby it reduces harmonic distortion.

Performance as a hi-fi amplifier

The Magnetic Field Amplifier will be small, powerful and lightweight (about 12 lb.). Mr. Carver says "it can be carried about by a human being of average physical dimensions." In conformance with Federal Trade Commission requirements, its power output rating will be 200 watts-per-channel (with both channels driven) into 8-ohm loads at any frequency from 20 Hz to 20 kHz with no more than 0.08% total harmonic distortion. The A-weighted signal-to-noise ratio claimed for the amplifier will be greater than 100 dB below its rated output, and the input sensitivity for full rated output will be 1.5 volts RMS.

The amplifier will also be equipped with an LED display having VU ballistics that will display output power-per-channel and cover a 50-dB dynamic range. It has been several weeks since I first learned of the Magnetic Field Amplifier, but in Mr. Carver's latest communication to me, he still insists that this new technology can be offered as a finished product for a suggested retail price of around $300. Even if the price does have to go up as the new amplifier enters the marketplace (and our experience has shown that the best-laid plans of audio engineers are often upset by economic realities), if the amplifier that finally emerges performs as well as promised, it could very well constitute a major breakthrough in amplifier design that could send other audio manufacturers scurrying back to their laboratories. And you can all be sure of one thing: Just as soon as I can get my hands on a test unit of the Magnetic Field Amplifier, I will put it through its paces and report the findings in a future issue of **Radio-Electronics.** **R-E**

PIONEERS IN RADIO

Edouard Branly

FRED SHUNAMAN

PROFESSOR EDOUARD BRANLY IS BEST known as the inventor of the coherer, that "tube of filings" that was for many years the only really useful detector of radio-waves. Yet it appears that, in the course of investigating his coherer, Branly set up the first organized experiment in radio transmission, some years before Popov and Marconi attempted their first transmission.

In his studies of the resistance of powdered metals, Branly noted that his results were erratic and unexplainable at times. Around 1888, he discovered the source of his trouble—nearby electrical discharges reduced the resistance of the powdered-metals. Branly then enclosed the metal powders in tubes with plugs at the ends, and tried different metals plus various degrees of compression and coarseness of grain structure. Using the combination that was the most efficient detector of electrical discharges, he arranged a semipublic demonstration on November 15, 1890.

At the time, Professor Branly was teaching in a Catholic scientific institute in Paris. The building, located at junction of the rue Vaugirard and the rue de Rennes, was L-shaped; and he arranged his experiment in two rooms of the building whose windows were in sight of each other across a courtyard. One room held his transmitter, a Leyden jar (in other experiments he used a spark coil). Branly, with his tube of filings, *(tube des limailles)* was in the other. As Branly signaled through the window, his assistant, Gendron, activated the transmitter, producing a spark. Branly immediately detected it, using a receiver containing his coherer in series with a battery and a galvanometer. Tapping the table with a small mallet, Branly "decohered" the filings. He received several signals on cue to his assistant.

Nine days after this demonstration he communicated his results to the Academy of Sciences, which then published them. They were also described in an article in two French publications, *Les Cosmos,* March 14, 1891 (in which Branly writes of using metals rods to increase the range) and *Lumiere Electrique,* May 16, 1891.

Professor Branly was certain that his experiments published in several *"revues",* were probably read by Popov, Marconi and other experimenters. It may well be, then, that Marconi's message: "Mr. Marconi sends M. Branly his respectful compliments by wireless telegraph across the Channel, this excellent result being due in part to the remarkable works of M. Branly," then considered by Americans to refer to the only accomplishment of Branly's that they knew of, the coherer, actually referred primarily to his experiments in transmitting and receiving electrical waves. **R-E**