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Daze of Whine and Noises

—intoxicating information about alternators

One of the puzzling problems that crop up in our VHF FM equipment is the sudden appearance of alternator whine. It is usually the first comment you receive if you have it on your signal. As befits the individualistic aspect of the hobby, there are many myths pertaining to its elimination which I shall attempt to dispel, after which I will suggest some ways of eliminating it. First, however, we should understand the reason for its being, and learn where to look for its source. The charging system in your car is the cause; the reason we have the charging system is to keep the source of all of your car's electrical power at its proper potential; the source being the car battery.

Fig. 1 diagrams the charging system for late-model GM cars. Note that the alternator is a 3-phase full-wave bridge with an output shown in Fig. 2. It is the dc component of the pulsating output voltage of the alternator that charges the battery. Since the output of the alternator will vary with engine speed—anywhere from slow idle of about 600 rpm to several thousand rpm—a regulator is added to ensure an almost constant charging voltage to the battery. This constant voltage is perhaps one to one-and-one-half volts higher than the 12.5-volt battery. Note that the battery is 12.5 volts, not the 12 volts often assumed.

Photos courtesy of Ford Motor Co.

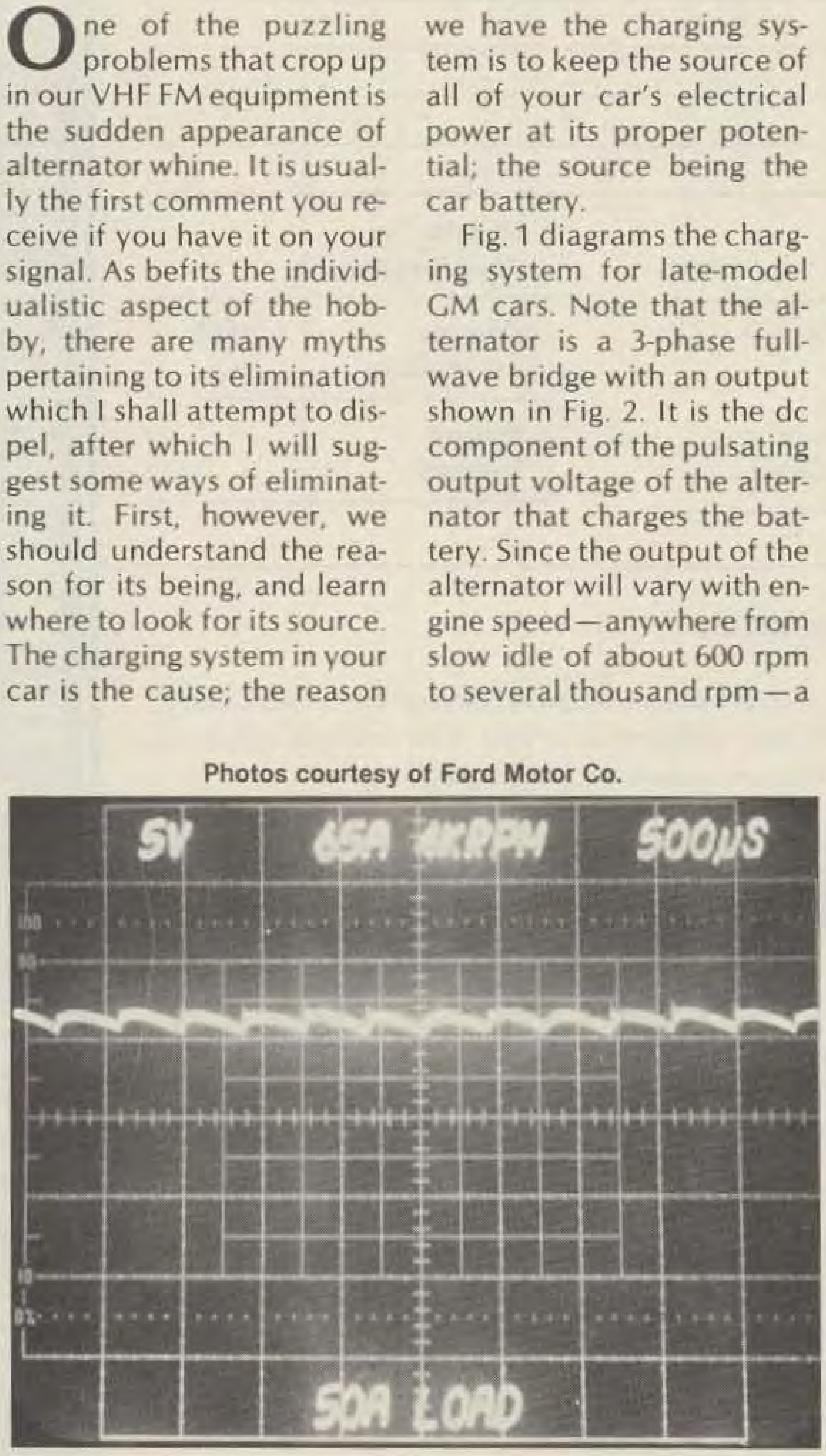

Photo A. Alternator output under actual load condition.

At one time, it was possible to adjust the charging voltage and current. My late-model car is permanently adjusted. The regulator module is mounted inside the alternator. Granted, it is a solid-state assembly, but if the permanent adjustment becomes temporary, the regulator must be replaced in its entirety. A very positive aspect of these new-fangled solid-state regulators is that there are no longer any arcing contacts involved. The older regulators had (at least) one set of contacts (voltage-adjust) opening and closing all the time the engine was running. The spurious radiation from these beauties was stultifying!

Alternator whine is the squeal mixed in with your audio that the receiving stations hear when you transmit. It varies in frequency in proportion to engine speed. The root cause of alternator whine is related to diode switching and the chopping action of the regulator. Rather than the ideal waveform shown in Fig. 2, the output of an alternator is the square wave shown in Photo A—a photo of alternator output under actual load conditions. All the scope-trace photos used a setting of 5 v/cm on the vertical axis and 500-µs timebase for the horizontal sweep.

Square waves contain many harmonics extending well into the VHF range, and since automotive designers may not be aware of the fact that we amateurs are installing VHF equipment in our cars, they don't spend too much time properly routing wiring. Nor do they spend time or additional parts trying to clean up the garbage you will see on a 12-V (sic) bus in the car, should you happen to put a scope on the Vcc line to your radio. They design in only what they have to for general usage. The fact that cars are becoming physically smaller compounds the felony. All wires, by necessity, are closer together.

In most cases, spurious radiation in the audio frequency range gets into your rig via what automotive engineers call backway point of entry. This means through the "A" lead to your rig. The result of this is the modulation of your signal with an unwanted audio signal, represented by the squeal, in addition to the desired modulation from the microphone. I would hazard a guess that the reason that the whine manifests itself more on the transmitted signal, as opposed to receiver audio, is related to total gain in each audio circuit and the number of stages (discrete and/or IC) in the chain. I have experienced whine in a receiver, but not in its transmitter in one instance, and vice versa in another.

The spurious audio is generated by the unique nature of the alternator system. Its frequency is related to alternator rpm times a constant, K, where K equals the number of poles times the number of phases times the diode rectification factor, all divided by 60 (the conversion of rpm to Hz).

For Ford cars, which use a six-pole alternator, K = 0.6; for GM cars, which use a seven-pole alternator, K = 0.7. With an engine speed of 600 rpm, the alternator rotates at approximately 2400 rpm, since there is about a four-times multiplication factor between the engine pulley and the alternator pulley. The spurious is therefore about 1440 Hz (0.6 × 2400) for Fords—right in the middle of the audio range.

All FM gear uses audio wave-shaping in the receiver audio system not only to de-emphasize, but also to limit bandwidth. Audio is usually cut off above three kHz. Any spurious audio is also reduced in amplitude; therefore, when a radio is transmitting alternator whine, you will usually hear it only at low speeds of travel or at idle speeds. The whine may still be there, but your radio's audio system cuts it off or reduces it by a substantial amount. As a point of information, you can, with a little mathematical manipulation, ascertain that when you rev up your Ford engine above 1300 rpm, a ham, listening for your whine, will no longer hear it. All of this presupposes that your charging system is in perfect working order.

Photos B and C show the results of a failure in one of the rectifier diodes in an alternator. Photo B shows a shorted diode; Photo C, an open diode. Note first that the average output voltage drops just a little but, more importantly, that the waveform is more distorted. Without getting into a Fourier analysis, it follows that more spurious harmonics will be generated along with more spurs in the audio range. This will affect the "purity" of the whine you transmit. Get the hint? If your whine suddenly changes its characteristics, check your alternator diodes! Hopefully, you will have removed this annoying signal from the air long before any diodes break down.

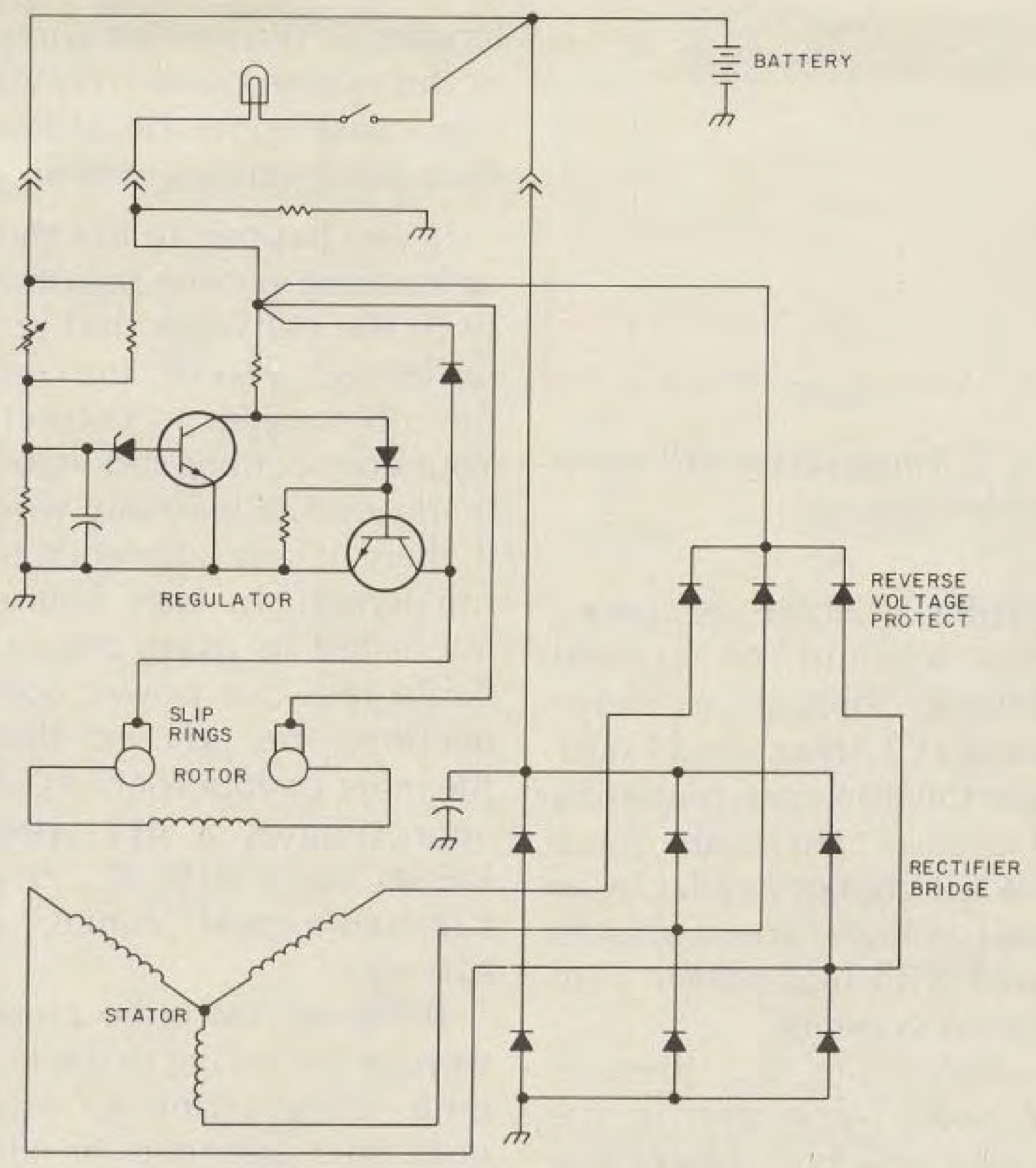

Fig. 1. The charging system for late-model GM cars.

Much has been said, but little written regarding ways to reduce the spurious transmission of whine. The most effective way that I have found, borne out by automotive people I've contacted, is to insert a properly rated choke in series with the "A" line to your radio. A value of about 20 mH worked for me. The most flagrant error made is to attempt to use a standard CB-type choke. These things are rated at only 2 Amperes. Most amateur equipment draws up-

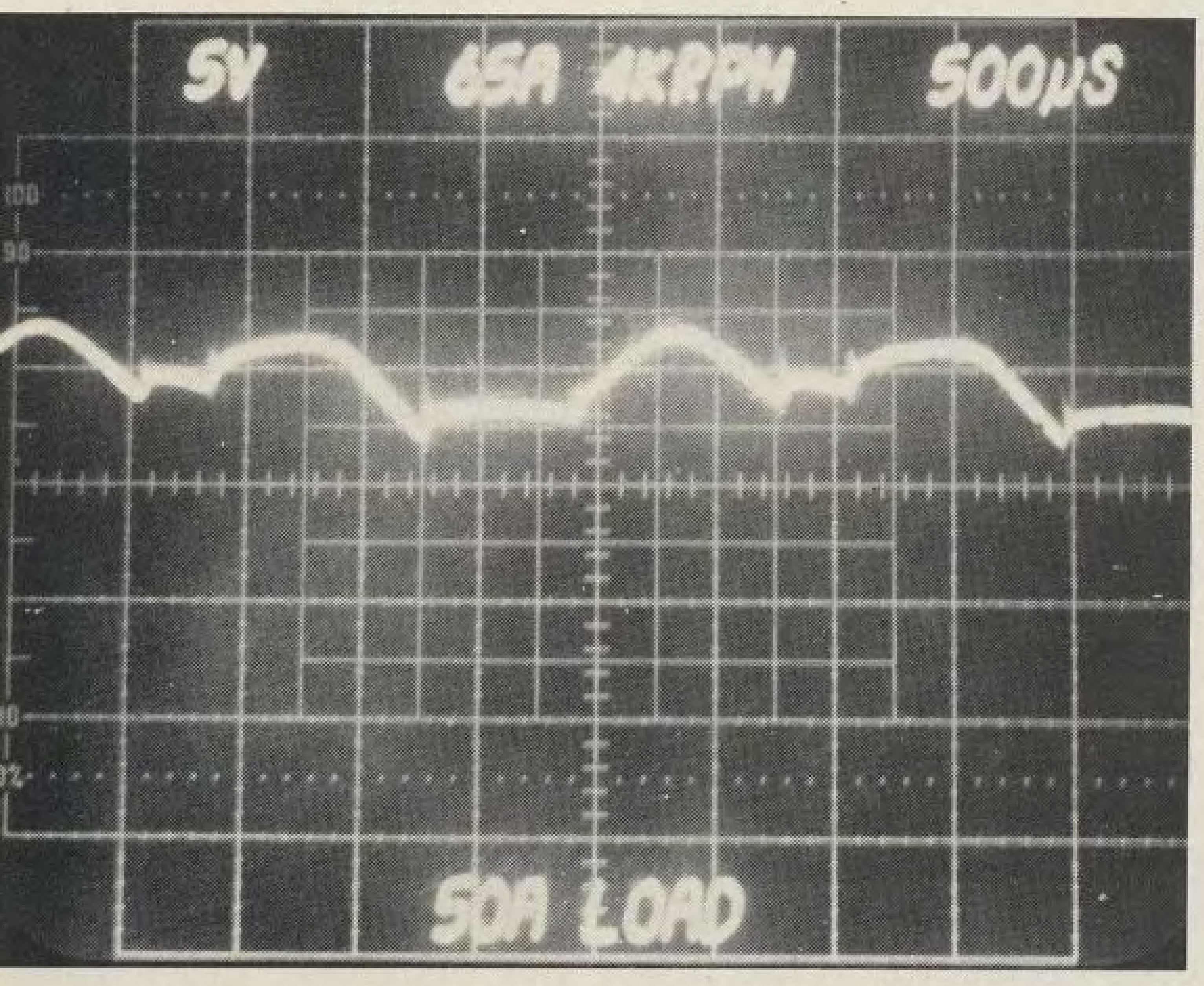

Photo B. Result of shorted diode in an alternator.

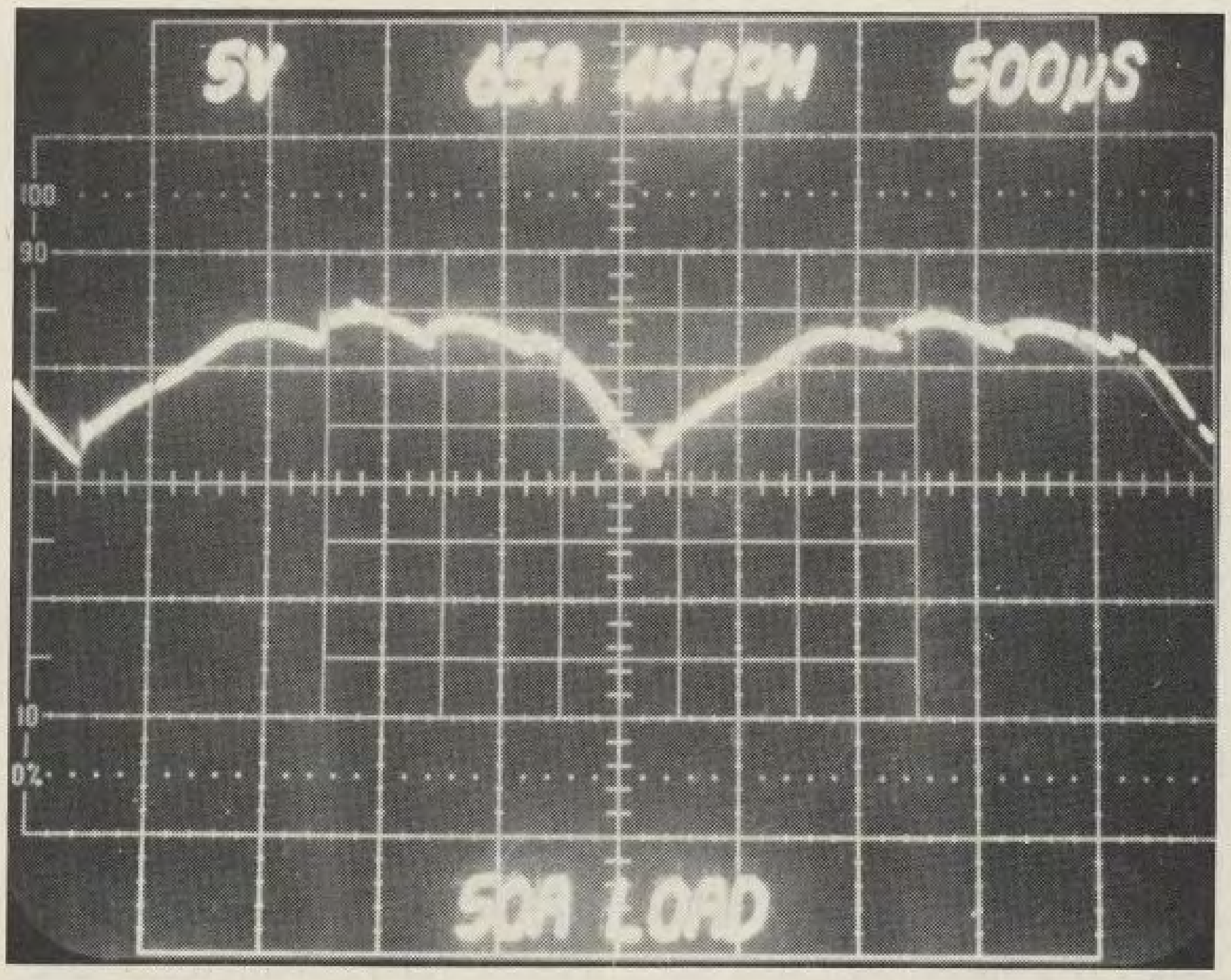

Photo C. Result of open diode in an alternator.

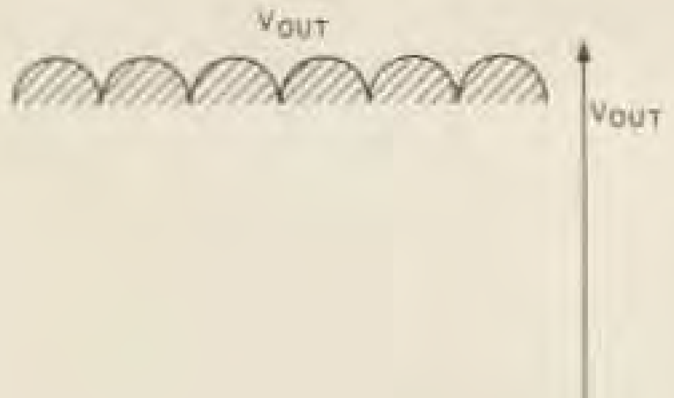

Fig. 2. Three-phase full-wave bridge output.

wards of three Amperes. This amount of current flowing through a choke rated at 2 Amps would saturate the iron core, rendering it useless. There are some 5-A CB chokes available, as well as high-current chokes used with high-power auto stereo systems.

Make sure that there is, in fact, some iron in the choke you buy. I built one on a toroidal core which had strip-iron as its base—not ferrite. Since it involved winding about 100 turns of #16 wire through the toroid, I don't recommend it—unless, of course, your hands are really calloused. I don't find that adding electrolytics across the power line is as effective as a good 0.1-to-0.5-uF capacitor. Among others, Sprague makes an excellent line of feedthrough capacitors (48P series). These should be connected in series with the battery output terminal of the alternator after you check that the capacitor case is truly grounded to the alternator case. Be sure to get a capacitor with an adequate current rating. Remember, the environment under the hood of a car is severe insofar as temperature is concerned.

For years I've been hearing that the only way to eliminate whine is to run the Vcc feed directly to the battery. One problem with this approach is that the batteries in the new cars have terminals that do not lend themselves to adding external connections. The other problem with this approach is that running long lengths of unshielded wires in the engine compartment can cause more problems than using existing wiring.

If you happen to run this new wiring in close proximity to the car wires that are radiating, you're making the job tougher to correct. Your connections should be made with at least #16 wire if there is any appreciable run length. In case you're interested in using coaxial cable for your power connections, be advised that the inner conductor of RG-8 approximates a #12 wire, RG-58 has a #19, RG-59 a #22, and a good "mini 8," a #16 wire.

Bring an AM radio close to your car wiring in the engine compartment, and note the presence or absence of whine. Don't worry too much about the other noises you hear. What you are listening to is the snap, crackle, and pop of the primary and secondary of the ignition system, the myriad solenoids and valves that are now added to the engine for pollution control. The saving grace in all this is that all of the aforementioned snap, crackle, and pop is in the form of amplitude modulation. Our VHF equipment, being frequency modulated, is pretty much immune to these spurious AM radiations. Generally, only whine is the problem.

In view of the number of models of autos on the road, it is obviously impossible to list specific fixes for whine. In general, make sure that you are making good grounds in your installation. If you are connecting your ground to a factory-installed ground, be sure the latter is a *zero resistance* connection to the battery. Arm yourself beforehand with a roll of bonding braid (Belden 8663, 8669, or equal) and literally bond your car together—electrically. You can use the same braid to shield long runs of wire by snaking the wire through the expanded braid and then grounding one or both ends of the braid.

Move some of the wires in the engine compartment away from each other to see if the induced spurs are reduced. Be careful in this operation. The SAE (Society of Automotive Engineers) has had much experience (75 years) in routing wires to prevent them from being wrapped around fans, belts, and other moving parts guaranteed to rip a harness from your car. I cannot stress too strongly the need for good grounding, and one area you should be sure to check is the antenna-to-radio ground connection if you use a magnetic-mount antenna. Remember, the base of this antenna is not grounded—it is insulated from car ground by the paint on the car, rubber gasket, or other nonconducting base material. If you use a gutter-clip mount or a trunk mount, be sure that the mounting screw(s) break through the paint and make zero-resistance contact with the body of the car. These points should be checked regularly to ensure that no oxidation or corrosion sets in to take your antenna off ground.

In my previous car, I used an extra Faston connector in the fuse block as my source of power with a choke in series with my Vcc line. But with the purchase of a new car, I found, much to my chagrin, that GM (at least) changed this connector to a special one, not yet available to the public. Temporarily, I used the cigarette lighter to power my rig with the same choke in the line. According to current myth, this is supposed to be a no-no, but I've had no complaints with that setup. I have since made a direct connection to an unused connector in the fuse block, because the cigarette lighter connection was sloppy and I wanted—or at least my wife wanted—a neater installation. This also provided me with the advantage of ignition-key control of power.

Speaking of cigarette lighters, I have been told that some new cars have reverse polarity. Be sure to check for this, because if you don't have reverse-voltage protection in your rig, you may well cause serious (and expensive) damage to your equipment. When your car is delivered with a factory-installed radio, the manufacturer usually installs a bypass capacitor—probably at the fuse block. After all, they have to have some justification for the prices charged for radios. You might consider tapping the lead that goes to your AM/FM radio for a source of power. This is easily accomplished by three-way pressure taps available in auto supply stores.

In an older car, I once was advised that I had whine where I didn't have it before and that the cause was a "weak" battery; that the internal resistance of the battery was increasing and causing whine. Well, it may have been true that the internal resistance of the battery was increasing with age, but putting in a new battery—which I hastened to do—did nothing to eliminate alternator whine!

Now, after a great deal of time expended in communicating with people at both General Motors and Ford—all of whom have been most cooperative—I have come to the conclusion that eliminating alternator whine must be done at the source—that is, at the alternator. Capacitive bypassing plus a suitable choke in series with the power feed to your radio (at the radio), in addition to good grounding practice should alleviate, if not eliminate, most whine problems. ■