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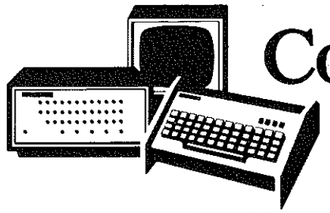

Computer Bits

By Hal Chamberlin

MICROCOMPUTER POWER SUPPLIES

NEXT TO the cabinet enclosure, the dc power supply is probably the most mundane component of a microcomputer system. As a result, it is often overlooked by the prospective purchaser of such a system.

One should know that the power supply has a great deal of influence over the reliability and expandability of the system, as well as size and weight. While a well-designed and constructed power-supply system is usually ignored by the user, a marginal power supply constantly calls attention to itself through unexplained system crashes, overheating or outright failures.

Changing Power Requirements. Before discussing the various power supply philosophies and technologies, we will examine the actual power requirements of today's systems.

Early personal computers such as the Altair-8800 and other S-100 bus machines required three or four different power supply voltages (+12, +5, −5, and −12 volts after regulation) at fairly high current levels. These requirements were a result of the microprocessor and memory IC's used by these machines. In particular, the early 1K static semiconductor memory IC's required as much as 1.5 amperes of +5 volts for each 4K. With full memory (64K) installed, up to 24 amperes of current was needed for the memory. The CPU and other peripherals could easily swell this figure beyond 30 amperes! With that kind of current consumption, power distribution and cooling became major design considerations.

Modern microcomputer circuitry requires far less power than the earlier units. The biggest improvement is in memories, where a full 64K of modern dynamic RAM actually consumes less than 1 ampere and fits entirely on a single printed-circuit board.

The introduction of low-power Schottky TTL logic reduced the consumption of other parts of the system to about a quarter of their former levels. In addition, some systems now require only one voltage level (+5 volts) to operate the microprocessor, memory, and miscellaneous logic. Consequently, power supply design and cooling is much less of a problem for them.

Central vs Local Regulation. All power-supply voltages used by microcomputer circuitry must be carefully regulated for safe and reliable operation, of course. Two distinctly different approaches to doing this have evolved over the history of microcomputers. The first and most obvious method used one high-current central regulator for each voltage in the system. This was the method used exclusively in the past.

However, some problems arose with power distribution. When dealing with low voltages, such as 5 volts, at high-current levels, even short lengths of heavy wire or a slightly oxidized electrical contact could develop a substantial voltage drop. For example, at 30 amperes a resistance of 0.0016 ohms will create a drop of about 50 millivolts, a 1-percent loss at 5 volts. Keep in mind that TTL logic can only tolerate a 5% loss before malfunctioning!

Another problem with central regulation is that the heavy power supply wiring from board to board also transmits digital noise generated on one board to all other boards in the system. Elaborate systems of chokes and bypass capacitors on each board were needed to prevent such noise coupling.

Many microcomputer systems today, notably S-100 systems, use local regulation on each board. The main power supply in such systems provides rectified and filtered (but unregulated) voltages that are about 50% higher than

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the final regulated voltages required by the boards. For example, 8 volts is usually supplied for the 5-volt line and 16 volts for the 12-volt line.

Each board contains an IC regulator for each different voltage required by that board. Although the cost of 30 amperes worth of 1-ampere regulators may be more than a single 30-ampere central regulator, the small regulators can be purchased one at a time, along with the expansion boards.

Local voltage regulation overcomes many of the problems associated with centrally regulated power distribution. Voltage drops in the main power distribution are of little consequence as long as it is not so great as to exceed regulation capability of the local regulators. Ground wiring, though, must remain heavy because voltage drops along ground leads either add to or subtract from the *logic* signal voltages. This might lead to the possibility of a zero being interpreted as a one or vice-versa. Local regulators also prevent noise coupling both forward and backward through them, thus reducing the need for noise-filtering components. Again, this does not help ground noise, which must still be controlled through the use of heavy ground wiring and multiple ground connections to the boards.

Local regulation is not without its problems, however. The most severe of these is that the local regulators dissipate a lot of heat, in many cases as much as the board logic itself. This causes a considerably greater buildup of heat around sensitive logic components than would occur in an equivalent centrally regulated system. Here, all of the regulator heat is in the power supply area. As a result, locally regulated boards should not draw much more than 1 ampere from the unregulated supply unless a fan is present in the system to remove the 10 or more watts of heat that this represents. The 1-ampere restriction, however, is much less of a problem now than it was in the past.

Another problem with local regulation that concerns some people is fail-safe operation. All local and most central regulators are *series* elements which control the output voltage by acting as a variable series resistance. If the regulator element should fail as a short circuit, the twice-as-high unregulated voltage directly enters the logic circuitry, perhaps causing severe damage. A large centrally regulated power supply can absorb the cost of elaborate crowbar overvoltage protection circuitry, but the cost of adding such circuitry to each board in a locally regulated system would be prohibitive. Although integrated-circuit regulators have only modest overvoltage protection circuitry built-in (usually a zener diode across the output), other internal protection makes short-circuit failures very rare.

Perhaps the most insidious problem with local regulators is over-reliance on their regulation capabilities. For proper operation, most IC regulators require an unregulated input at least 2 volts higher than the regulated output voltage. With any less input, the device simply stops regulating and passes ripple and noise directly to the logic circuitry. The problem is insidious because, although a voltmeter may indicate sufficient unregulated voltage (such as +7.5 volts into a 5-volt regulator), the superimposed ripple voltage may momentarily drop below the critical 7-volt level. Use a dc-coupled oscilloscope to check this problem.

Power Conversion Systems. Ignoring the exact method of regulation, most of the bulk and cost of a microcomputer power supply is in the power conversion system, which takes 117-volt ac power and produces rectified and filtered low-voltage dc for the regulators. Three methods of power conversion are used.

The first, which is probably the most common, is the classic iron-core transformer and bridge or center-tapped rectifier system, with a bulk capacitor filter. While conceptually simple and inexpensive, this method has many pitfalls for the inexperienced designer. The most serious of these is the extremely poor voltage regulation which must be overcome by the regulator. It is not unusual for the low-load/high-line output voltage to be double that of the full-load/low-line output voltage. If the regulator is to function under the latter condition, normal conditions will mean a very high unregulated input voltage and, consequently, a lot of heat dissipation in the regulators. Marginally designed power supplies of this type will drop out of regulation during momentary low-line conditions, and possibly cause malfunction of the microcomputer.

The second, although more expensive, approach is to use a *constant voltage transformer* (CVT). This type of transformer has *two* winding "windows" in the core, with the primary in one window and the secondary in the other. A large ac capacitor is connected across one of the secondaries that resonates the winding with the 60-Hz input and thus provides a good deal of regulation. Such transformers are also called *ferroresonant* because of the resonating capacitor. When combined with a conventional rectifier and filter, such a transformer can hold unregulated voltage variations to less than 10%, which reduces regulator dissipation and increases immunity to line-voltage variation. Also, since the transformer puts out an approximately square waveform, a smaller-valued filter capacitor can be used to partially counteract the higher cost and bulk of the CVT. Some of the better S-100 mainframes use CVTs.

There is yet a third power-conversion method that is finding increased acceptance as costs decline. This is the direct off-the-line switching power supply. Such a unit first rectifies and filters line voltage directly without a transformer to provide about 150 volts dc. This high voltage then operates a power oscillator in the 15-to-30-kHz range. The resulting high-voltage, high-frequency ac is stepped down to lower output voltages with a lightweight ferrite-core transformer. The lower-voltage, frequency ac is then rectified and filtered again to provide the final output voltages. Usually the oscillator is constructed so that feedback from one of the output voltages, typically +5 volts, controls its frequency or waveform. It therefore provides sufficient regulation for direct operation of logic. The primary advantages of switching power supplies are small size and light weight for their output capability and a high regulation efficiency, lower heat dissipation, and inherent central regulation.

Safety Approval. Safety testing of a microcomputer's power supply can be a long and expensive process for its manufacturer. When 117 volts is present in the cabinet of a computer, the whole unit must be subjected to a number of stringent tests, some of which are destructive. One solution to this problem is to provide the step-down transformer as a separate unit, much like a calculator battery eliminator, and only have low voltages in the microcomputer. If this is done, only the transformer must be tested, which is a much simpler process. Although limited to smaller machines with low-power consumption, modern low-power ICs make viable.

In sum, one should be aware of the importance of power supplies in microcomputers and add this consideration when making buying judgments. ◇