BY SAM GOLDWASSER

More About Microwave Ovens

LAST TIME WE TOOK A QUICK LOOK AT REPAIRING MICROWAVE OVENS, AND PROVIDED A HANDY GUIDE WITH COMMON SYMPTOMS AND THEIR LIKELY CAUSES. HOWEVER, BEFORE WE PROCEED FURTHER, WE NEED TO STEP BACK AND look at the basics behind microwave cooking, the magnetron, and microwave-oven electronics.

Microwave Cooking

The typical microwave oven uses between 500 and 1000 watts of microwave energy at 2.45 GHz to heat food. That heating is the result of the microwave energy vibrating the water molecules in the food. That's why plastic, glass, and even paper containers are heated only by the conduction of heat from the food. There is little direct transfer of energy to those materials. This also means that the food does not have to be a conductor of electricity (you can test this by heating a glass of distilled water in your microwave—you'll find that it does get hot even though distilled water is not a conductor).

Since the oven-chamber cavity is a good reflector of microwaves, nearly all of the energy generated by the oven is available to heat the food and heating speed depends only on the available power and how much the food is being cooked. Ignoring losses through convection, the time it takes to heat food is roughly proportional to its weight. Thus two cups of water will take about twice as long to bring to a boil as one cup.

Heating is not (as is popularly assumed) from the inside out. The penetration depth of microwave energy is only a few centimeters, so the outside does indeed cook faster than the inside. However, unlike a conventional oven, the microwave energy does penetrate those few centimeters, rather than being totally applied to the exterior of food. The misconception probably occurs when sampling something like a pie filling just out of the microwave. Since the pie can only cool from the outside, the interior filling seems to be much hotter than the crust and will remain that way for a long time.

One interesting note; since 30 to 50 percent of the power goes out the vents in the back as heat, a microwave oven is really only more efficient than a stovetop or conventional oven for heating small quantities of anything. With a normal oven or stovetop, wasted energy goes into heating the pot, the oven, the air, and so on. However, that waste heat is relatively independent of the quantity of food and may be considered to be a fixed overhead. Therefore, there is a crossover point beyond which it is more efficient to use conventional heat than microwaves.

How Microwave Ovens Work

A microwave oven is really a very simple device. It consists of two main parts;

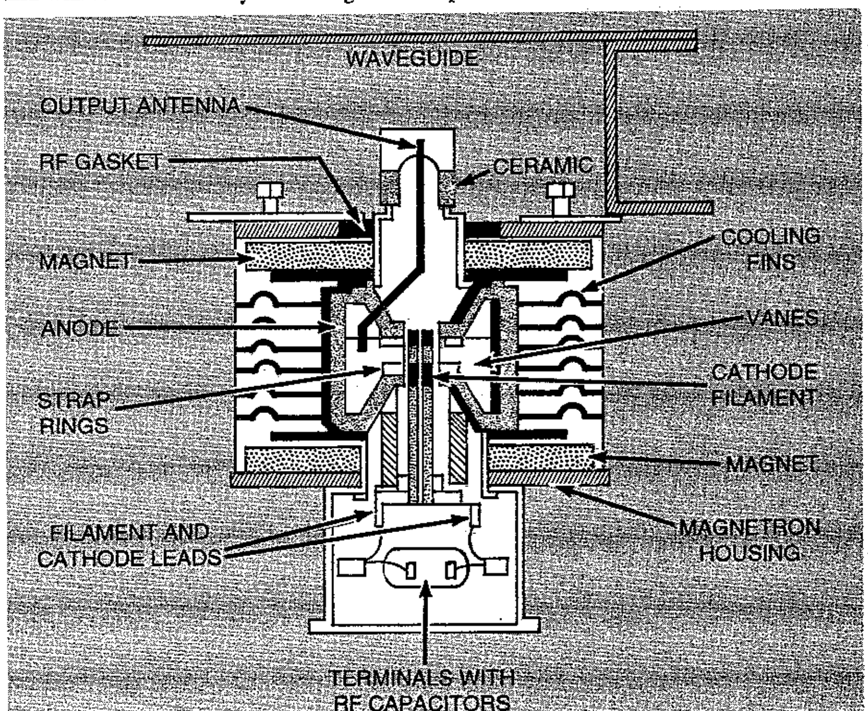

FIG. 1—A CROSS-SECTIONAL VIEW of a typical microwave-oven magnetron. This device is little changed since its invention shortly after WWII.

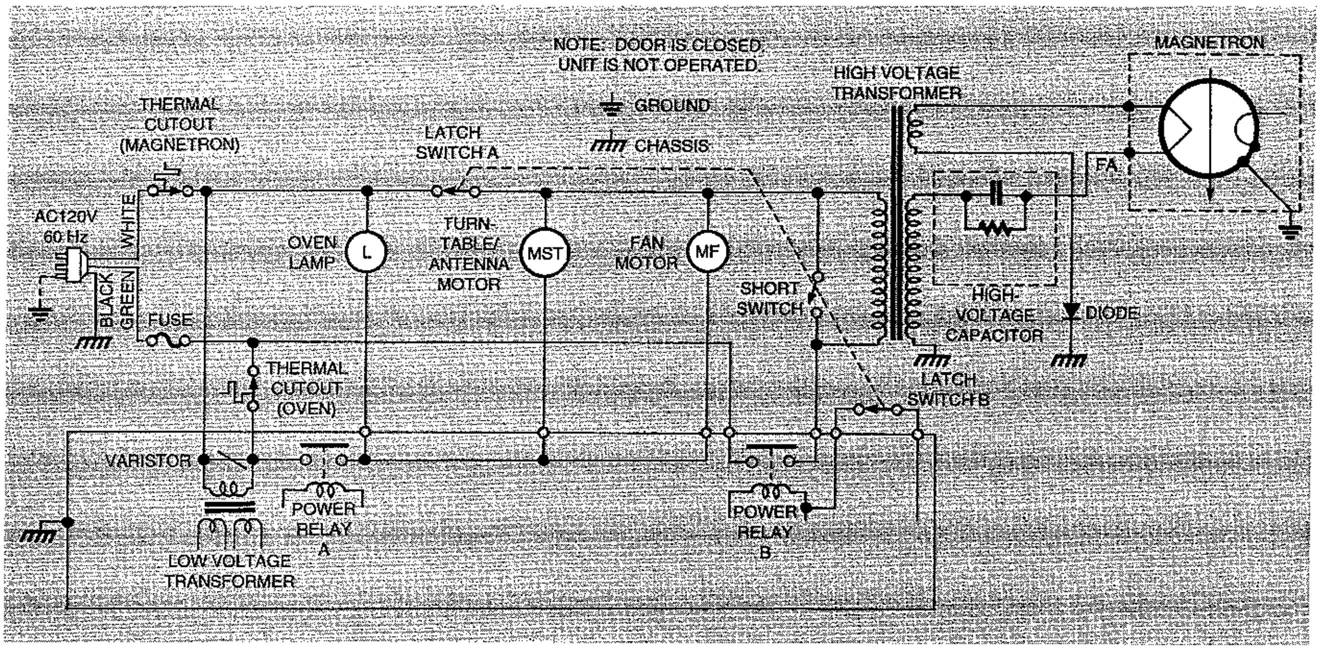

FIG. 2—THIS SIMPLIFIED SCHEMATIC DIAGRAM shows only the oven's power circuits. It is similar to the one you will likely find pasted inside your unit's cabinet.

the controller and the microwave generator. The controller is what times the cooking by turning the microwave energy on and off. Power level is determined by the ratio of on time to off time in a 10- to 30-second cycle. The microwave generator takes AC-line power, steps it up to a high voltage, and applies that to a special type of vacuum tube called a magnetron—a device that is little changed from its invention during World War II (for radar).

The controller section usually includes a microcomputer, though very inexpensive units may simply have a mechanical timer (which ironically, is probably more expensive to manufacture in today's world!). The controller runs the digital clock and cook timer; sets microwave power levels (via pulse-width control of the microwave generator); runs the display; and in high-performance ovens, may even monitor the moisture or temperature sensors.

There are also various door interlock switches that prevent the oven from producing microwaves if the door is not closed completely. At least one of those will be directly in series with the transformer primary so that a short in the relay or Triac cannot accidentally turn on the microwave generator when the door is open. The interlocks must be activated in the correct sequence when the door is closed or opened. There is another interlock across the AC line. It is there to blow the main fuse if the switches are activated out of sequence, as might happen with a damaged door or switch mechanism. Failed door interlocks account for the majority of microwave oven problems—perhaps as high as 75 percent.

The microwave generator is the subsystem that converts AC-line power into microwave energy. It consists of four major parts:

- High-voltage transformer—featuring a secondary of around 2000-volts rms at 0.25 amp and a low-voltage high-current winding for the magnetron's filament.
- High-voltage rectifier—usually rated 12,000 to 15,000 PIV at around 0.5 amp.
- High-voltage capacitor—0.65 to 1.2°F at a working voltage of around 2000-volts AC.
- Magnetron—the microwave producing tube including a heated-filament cathode, multiple resonant cavities with a pair of permanent ceramic ring magnets to force the electron beams into helical orbits, and an output antenna.

Magnetron Construction and Operation

The cavity magnetron was invented by the British before World War II. It is considered by many to be the invention most critical to the Allied victory in Europe. The story goes that shortly after the War, a researcher at the Raytheon Corporation, Dr. Percy Spencer, was standing near one of the high-power radar units and noticed that a candy bar in his shirt pocket had softened. In the typical "I have to know why this happened" mentality of a true scientist, he decided to investigate further. The Amana Radarange and today's microwave oven industry were the result.

Figure 1 shows a cross-sectional diagram of a typical magnetron (this diagram comes from John Gallawa's www.yup.com/microtech/ Web site). The filament and cathode are one and the same, and are made of solid tungsten wire in the form of a helix about $^{5}/_{32}$-inches diameter by $^{3}/_{8}$-inches in length. The cathode is fed a pulsating negative voltage with a peak value of up to 5000 volts. The anode is a cylinder made with an inside diameter of $1^{3}/_{8}$ inches (35 mm) and a length of about 1 inch (25.4 mm).

Rather than cylindrical cavities, as you would find in most descriptions of radar magnetrons, there is a set of ten copper vanes brazed or silver soldered to the inside wall of the cylinder facing inward toward the cathode. Copper shorting rings at both ends, near the center, join alternating vanes. That structure results in multiple resonant cavities that behave like sets of very-high-quality, low-loss L-C tuned circuits with a sharp peak at 2.45 GHz. A connection is made near the middle of a single vane to act as the output-power takeoff.

The entire assembly is placed in a powerful magnetic field—several thou-

TABLE 1-ELPH SPECIFICATIONS

Type: IX 240 fully automatic lens shutter camera with built-in zoom lens and magnetic IX functions.

Lens: 24–48mm f4.5-6.2,6 elements in 6 groups (with 2 aspherical glass lenses).

Viewfinder: Real-image zoom finder covers approx. 82% of actual picture area. 0.31× magnification in wide; 0.62× in telephoto.

Shutter: Combination aperture and program electromagnetic-drive shutter.

Autofocus: Passive and active autofocus using 1/IRED skimming CCD sensor as a distance-measuring element.

AF Mode: Single point measurement only.

Focusing Range: 1.5ft./0.45m to infinity. 150 focusing zones.

AF Control: Program AE; AE lock upon completion; three-segment measurement with SPC light sensing elements.

Metering Range: (at ISO 100) Flash On/Flash Auto: WIDE EV9.5-EV17 (1/35 sec at f/4.5 to 1/500 sec at f/16); TELE-EV 11.5-EV19 (1/70 sec at 6.2 to 1/500 sec at f/32); Flash Off/Slow Sync: WIDE-EV3.5-EV17 (2 sec at f/4.5 to 1/500 sec at f/16); TELE-EV4.5-EV19 (2 sec at f/6.2 to 1/500 sec at f/32).

Film Speed Setting: ISO 20-10,000 automatically set in 1/3 step increments by reading data disk.

Film Loading: Manual drop-in loading. Fully automatic advance and rewind. Mid-roll rewind possible.

IX: Date, Print aspect ratio, Cartridge loading direction, Strobe On/Off, Subject brightness, and Title area recorded on film using a single track, write-on magnetic recording head.

Flash Exposure Controller: Determined by film speed and AF distance.

Red-eye Reduction Mode: Activated via Auto flash button.

Flash Recycling Time: Approximately 5 sec.

Flash Coupling Range: WIDE: 1.5ft–9.8ft/0.45–3m; TELE: 1.5ft–7.2ft/0.45m–2.2m (with ISO 100 color negative film.)

Self-Timer: Electronically controlled with 10-second delay.

Remote Controller: Optional remote controller RC-5, 2 seconds delay shutter release; transmits up to 16.4 ft/5.3m when directly in front; up to 11.5ft/3.5m at periphery.

Data Imprint: Recorded magnetically and can be printed on either the front and back or only the back of print.

Power Source: Battery: One Lithium (3V).

Battery Capacity: Approximately 12–25 exposure rolls with 50% flash use.

Dimensions (inches): 3.6 (W) × 2.4 (H) × 1.1 (D)

Weight: Approximately 6.3 oz. without battery.

analog image on the film. All the digital information could be downloaded to a database application. A database might store a roll number, a print ID, a category, and descriptive text for each print, and likewise for the cartridge as a whole. With thumbnails available, annotating the images ("Johnny's first birthday") would be much simpler and more likely to get done.

Standards

It's ironic when you consider that, like the (PC portion of the) computer industry, the photography industry grew up around standards. Interchangeable film cartridges, flash units, lenses, mounts, and so on all contributed to the overall variety of choices.

Now it's time for a similar set of standards concerning digital photographic technology. We need a standard interface such as Universal Serial Bus (USB). But we need more than just a way of moving bitmaps down a wire.

We also need a standard set of data structures, communications protocols, and APIs. Putting a CCD behind a lens does not make a camera digital. To fully bring photography into the digital age, we need a comprehensive model of what is to occur, independently of how it happens. By analogy, we routinely place computer data on media with widely differing physical characteristics without a second thought. I want the same media independence from film, CCDs, and whatever may develop in the future.

Anyway, Canon's ELPH is a marvel of electro-mechanical miniaturization. It won't replace my Nikon, but it's a harbinger of things to come.

Pilot Redux

Last month I wrote about another high-tech gadget, US Robotics' handheld organizer, the Pilot, one of which I do happen to own—and use every day, I might add. I've been brainstorming several avenues for serious technological evolution of the Pilot, and thought you might be interested in these ideas.

But first, I should report two interesting developments. First, networking giant 3Com has just about completed its purchase of USR, and there are persistent rumors that the Palm division will be sold, as it seemingly—but see below—has little to do with telecommunications. Second, Xerox is suing USR, claiming that its Graffiti handwriting recognition is based on a prior technology called Unistrokes, invented and patented by Xerox, possibly as early as 1979.

Xerox, of course, has achieved fame for inventing but failing to deploy and profit from several of today's more popular computer technologies, including the GUI, Ethernet, and laser printers. Later, after said technology achieves widespread market acceptance, the lawyers get in the act, figuring that even if the marketing folks blew their chance, there's still an opportunity. So Xerox sues Apple, and Apple sues Microsoft, and . . .

Some people suspect that the suit may represent a serious liability, thereby decreasing Palm's perceived market value, should it be sold. Does that say anything about Palm's (and the Pilot's) longevity?

But let's get back to technology. Here's my vision of the ultimate handheld organizer; call it a PDA or whatever you want.

Start with your basic Pilot: small, lightweight, handheld. Eliminate the dedicated app-launching buttons (except power) and the dedicated handwriting recognition area, making the whole screen programmable (like Apple's Newton). Then add the following (the biggie is the first one):

(1) Full telecommunications capability, including voice, data, and fax transmission over EIA232, IR, V.34 modem (or better), some form of cellular, USB or FireWire, possibly Ethernet. Data communications must include a credible e-mail system, net news reader, and Web browser. No, it doesn't have to do Shock-

Wave and RealAudio, just the basics. One DSP should be able to handle all those, though not necessarily simultaneously.

(2) Integrate a robust chargeable power system.

(3) Add an earphone jack and a microphone to handle voice communications and voice memos.

(4) Integrate a clever, robust, low-cost universal I/O connector, kind of like a laptop docking station or port replicator.

(5) Integrate text-to-speech to allow the device to read your e-mail to you while driving, riding the subway, or enduring a boring meeting. Don't bother with voice recognition.

(6) Integrate SmartCard technology to handle everything from ATM/debit cards to music and video playback, in effect turning the device into a miniature stereo/ entertainment/ information center. Choose your own in-flight entertainment. Of course, it will need audio and video I/O jacks.

(7) Integrate a television tuner.

(8) Integrate an AM/FM tuner. Make it digital and totally software controlled so it can receive on any (reasonable) band. Add another connector for an external antenna.

(9) Strategically locate the IR device (and add the appropriate software) so it can function as a remote control.

(10) Integrate a vibrator (like some pagers have), and allow built-in and external (e.g., cellular) alarms to activate it.

(11) Make the screen two-way optical. In other words, allow it to function as a scanner for capturing business cards, passages from books or magazines. May as well throw in OCR. Perhaps even give it a snapshot lens and CCD. Or combine it with an ELPH?

(12) The current plastic case is well-done, but could be beefier. Provide a super lightweight metallic case, with flip-up cover housing the telephone earpiece. Provide foam or other padding for comfort and to protect the screen when closed.

(13) Provide robust GPS implementation.

(14) Provide sensors for temperature, relative humidity, and air quality.

Basically I want something to integrate and replace my wallet (including credit cards, cash, and identification) and my telephone, and to supplement all other data-gathering and enhancement functions. It's not intended to compete with either a laptop or desktop computer, but to function as an adjunct, and to provide a complete personal identification and information system. I don't want it to do anything computationally intensive, so CPU speed and RAM availability are not major issues. I'd rather keep power usage to a minimum to keep the size down.

Is that a crazy idea or what? Until next time, you can stay in touch via e-mail at jkh@acm.org **EN**

Let me get this straight, you were watching Lassie and ..."