

# **SHARP**

## **Microwave Oven**

### **Technical File**

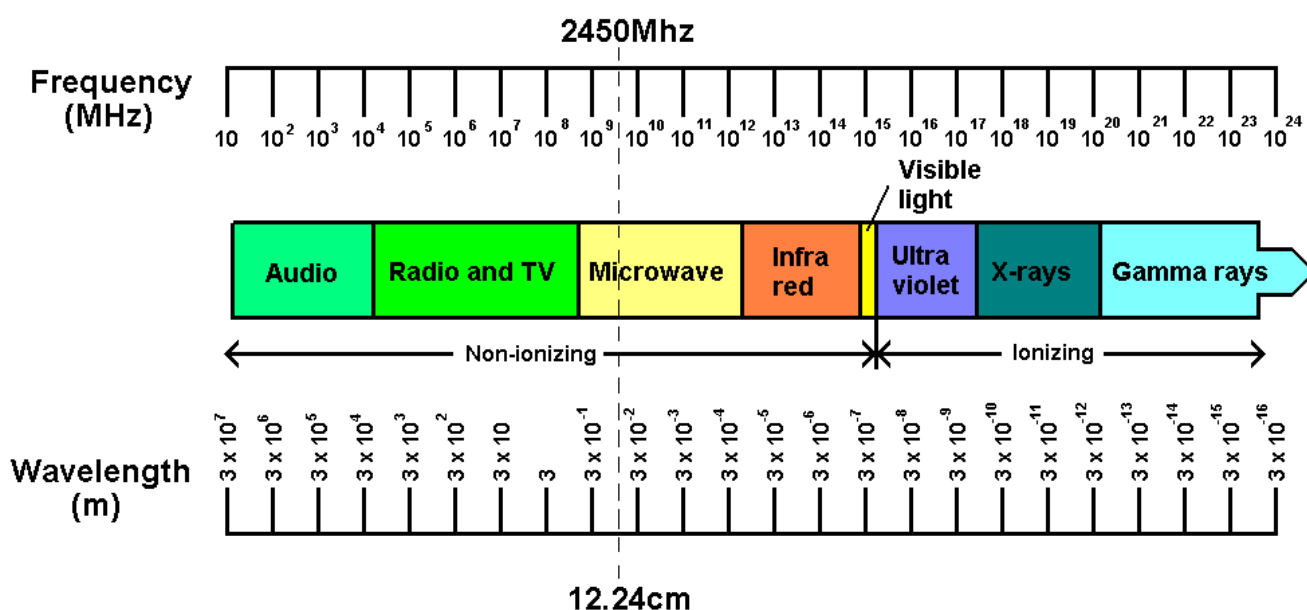
**Volume 1 – Microwave Energy**

## Microwave Energy

Microwaves are electromagnetic energy, the same type of energy that carries Radio and Television signals. A point to be considered is that while you read this information you are surrounded by such energy. If you were to operate a transistor radio you would expect to be able to listen to radio stations, therefore radio frequency energy must be present to enable this to happen.

The major difference between the electromagnetic energy that brings you your favourite radio station and the energy used in a microwave oven is the frequency. Microwave ovens use radio frequency (RF) at 2450MHz. A typical TV broadcast frequency is about 400MHz. The higher the frequency, the shorter the wavelength, hence the term 'microwave'. From the diagram below it can be seen exactly where each frequency lies, and how the rest of the electromagnetic spectrum is allocated.

### Electromagnetic Spectrum



The whole of the energy spectrum can be split into two broad areas: frequencies in the ultraviolet section and above and frequencies that are below ultraviolet. Energy in and above ultraviolet is Ionising, if our bodies are exposed to this type of energy permanent tissue damage will occur. The effect of Ionising radiation is cumulative, each time we are exposed to this type of energy the level within our bodies is increased, which will eventually lead to sickness. Hence the reluctance of the medical profession to over use X-ray photographs.

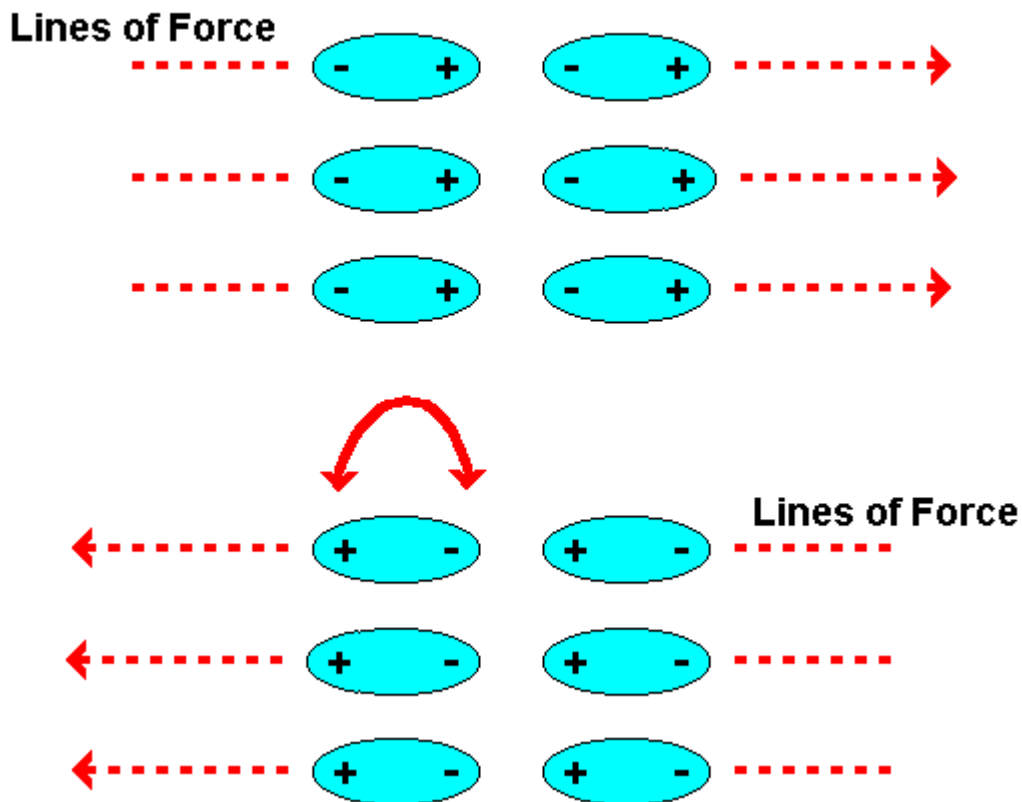
Energy at frequencies below ultraviolet light are non-ionising and the effects are not cumulative, that is to say there would be no long-term problems if exposed to energy in this part of the spectrum. There is no permanent tissue damage or change in molecular structure. For example when we are over exposed to sunlight while sun bathing and get burnt, the skin quickly heals and returns back to normal. However there may be long term problems due to the sun's rays containing ultraviolet energy.

Energies at microwave frequencies and of sufficient power have a heating effect and this principal is exploited in the use of microwave energy for cooking.

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## Molecular Agitation

All matter is made up of atoms and atoms of different elements combine in long strings to form molecules, which are affected by magnetic force. It is the molecules of water, fats and sugars in food that are affected by microwave energy. If these molecular structures were examined under a microscope, under normal conditions, the molecules would be arranged in random form i.e., not aligned in any particular pattern. If the food were then placed in a strong electromagnetic field, it would be seen that the molecules had aligned themselves in the direction of the force of the field. If the field were then reversed, the polarity change would cause the molecules to be reoriented. It is possible to cause the electromagnetic field to alternate continuously, producing a continuous movement of the molecules. This movement produces heat due to the friction caused as the molecules move against each other.



Microwave ovens use RF energy that causes the molecules in substances being cooked to move 4,900,000,000 times a second (2 X 2450MHz).

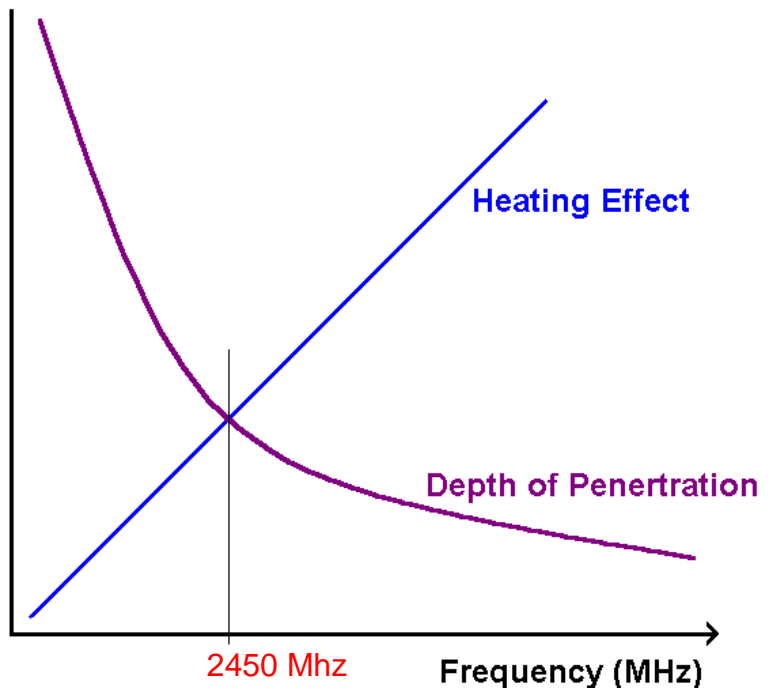
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## Heating Effect and Penetration Depth

The frequency used for microwave cooking is an industry standard currently being used by all manufacturers of microwave ovens. This frequency is a good compromise between the speed of cooking achieved due to the heating effect of the microwave energy and its penetration depth into the food being cooked.

An increase in the microwave frequency would give an increase in the speed of heating, but less penetration depth. Lowering the frequency would allow much deeper penetration, but would have a poorer heating effect.

The frequency of 2450MHz is a compromise giving the best heating effect against penetration depth, as the chart opposite shows. Typically the penetration depth in meat is approximately 2.54cm (one inch) and approximately 6cm (two and a third inches) for most other types of food.



## Characteristics of Microwave Energy

Microwave energy has three main characteristics:

### Reflection

Microwave energy will be reflected by the surfaces of metal objects. This characteristic is useful when designing microwave ovens. The cavity and waveguide are made of metal and this keeps the energy confined within these areas, whilst directing the energy onto the food.

Reflection from metal objects however can be a problem. When cooking, energy would be unable to penetrate a metal vessel leaving the food inside uncooked. Large metal objects can also have a detrimental effect on the wave pattern within the cavity, which affect the cooking.

It should be noted that if a metal object is present in the cavity while cooking, this object will act as a receiving aerial and therefore a potential difference will exist between the object and the oven walls. If the metal object comes close to or in contact with the cavity then arcing will occur. This will result in damage to the surface of the cavity and the metal object.

### Penetration

Certain substances absorb very little or no microwave energy, the energy is able to pass through them without having an effect. This characteristic is helpful for oven design and oven use. Waveguide covers and stirrer covers are made of materials that allow energy to pass through without loss. For cooking purposes china and glass are good examples of non-absorbent materials. They are therefore ideal for holding food whilst still allowing the energy to reach the food from all sides.

### Absorption

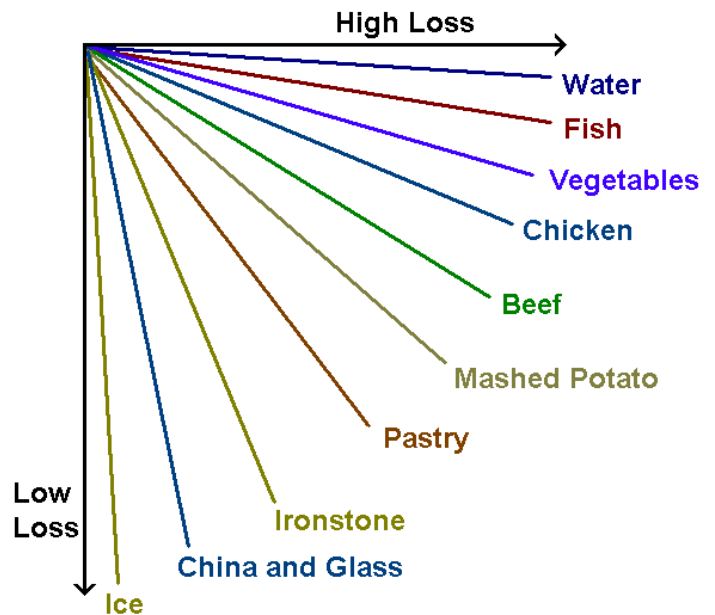
There are many substances that absorb microwave energy and are therefore heated by it. However it should be noted that different substances absorb energy at different rates which in turn will affect their required cooking times. The chart on the next page shows the absorption rates of some different types of food/materials.

## Loss Angle Chart

Substances will absorb microwave energy in differing degrees, which is usually dependent upon the molecular structure of the material. A diagrammatic view of this is shown on the right.

High loss materials will heat up faster than low loss materials because the molecules have more space to move around and thus more heat is generated by friction.

Note that water and ice are at opposite ends of the Loss Angle Chart. This is because the molecular lattice structure of ice is very ridged and therefore they do not move when vibrated by the microwave energy. This may seem confusing as microwave ovens are often used for defrosting. Refer to the section below for an explanation on how defrosting is achieved.



## The Absorption Phenomenon

The loss angle chart shows just a few examples of substances that absorb microwave energy at different rates. It can be seen that water is one of the most absorptive of substances to microwave energy and therefore heats up most rapidly. However when frozen it becomes one of the least absorptive.

If a mixture of food substances is heated together, perhaps a meal being reheated on a plate, then it is possible that certain items will heat more rapidly than others. Fish for instance, would heat up quickly whereas a mashed potato would take longer. This effect is perfectly normal, although some customers new to microwave cooking may find this strange at first.

A slightly different technique is required for microwave cooking when compared with conventional cooking methods. Purchasers of new ovens receive a cook book and instruction leaflet with their oven.

One technique that is used, and will help with our mixed meal example discussed previously, is to allow 'standing time'. Standing time is an additional cooking time after the heating has finished. If the mixed meal were covered after the heating period, the cover would help retain the heat generated within the foods that heat up the most rapidly. This heat is then available to assist the heating of the other food in the area using the heat exchange principle. Therefore if at the end of the microwave heating time the food is allowed to stand, the heat exchange effect will continue the cooking process and the result will be an evenly heated meal.

Standing time is **not** used to allow microwave energy to escape from the food before it is eaten. This is just one of the myths that have circulated over the years regarding microwave energy.

The other effect considered previously was the way in which water absorbs microwave energy much more readily when in its liquid state compared to ice. This could cause problems when using a microwave oven to defrost some food. Since ice is not affected by microwave energy, the defrosting process will not begin until the ice begins to melt naturally. Only when some water has formed, will the microwave energy start having an effect and the defrosting cycle begins. The delay caused is likely to result in the food not being completely defrosted when the defrosting cycle ends. The way to overcome this is to remove the food from the freezer about five minutes before using the oven in defrost mode. This will allow some ice to melt and the microwave energy will have an effect on the food immediately the oven is turned on.

Most ovens will have at least one defrost setting and usually a range of settings is available.

Sharp ovens use a cyclic system of power control. This involves running the magnetron at full power for a pre-set time, the amount of time depending on the mode selected, and then the magnetron is turned off for the remainder of the cycle. Cycle time is usually about 30 seconds. The timing diagrams for the electromechanical ovens can be seen in the Variable power control section of this book.

Changing the on time of the magnetron in this way allows some parts of the food to be warmed while the magnetron is on, then when the magnetron is off, heat is conducted into other parts of the food. This process is repeated until the food is defrosted. Using this method ensures an even defrost while not causing the food to be

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## The 'Inside Out' Story

The loss angle chart shows that pastry absorbs less microwave energy than meat for example, therefore if a quantity of meat and a quantity of pastry were put into the microwave oven together for the same amount of time the meat would end up much hotter than the pastry. This fact could be the reason why another story has circulated over the years regarding the way in which food is heated in a microwave oven. There is a popular misconception that food is heated from the inside and then heat works its way to the outside, the outside being the last region to cook.

If we consider a small item such as a sausage roll, it consists of a quantity of meat surrounded by a layer of pastry. If this was placed in a microwave oven and cooked on full power for a time it would be found on examination that the meat was much hotter than the pastry. This may give the impression that the sausage roll was cooking from the inside out, but if the trouble was taken to make a sausage roll with the meat on the outside it would be found that the meat still got the hottest. The different amount of heat developed is entirely due to the loss factors of the materials and not positioning.

## Microwave Energy and Customer Anxiety

Because of concerted efforts over many years the microwave oven industry has vastly improved customer awareness of what microwave ovens can and cannot do, and at the same time have educated people about microwave energy itself. There are still many misconceptions regarding about microwave energy and some customers remain apprehensive about using this form of cooking.

### Choice of Words

We have already seen in the section entitled Microwave Energy that the frequency used for the microwave cooking is well below the 'nasty' end of the frequency spectrum and the shorter wavelengths with their suspected carcinogenic effects. Nevertheless some customers connect microwave energy with X-rays and even alpha, beta and gamma rays given off by radioactive substances. For this reason engineers need to choose their words carefully when dealing with customers.

An example of the sort of comment that could cause alarm is, "I'm just going to check your oven for radiation leakage". The word radiation is a valid technical term, but if the words microwave energy or RF energy were used instead, the statement does not sound so worrying to the customer. The message is to avoid the use of emotive words such as "radiation".

### Imagined Leakage of Microwave Energy

Microwave energy leakage is another emotive issue and customers will tend to imagined problems in this respect even though they do not exist.

An example of the way this problem may manifest itself is a customer noticing light shining from the small gap around the door, or through one of the air vents. Or warm air can be felt coming from one of these gaps. Once this is noticed, the customer may be concerned that the oven might be leaking.

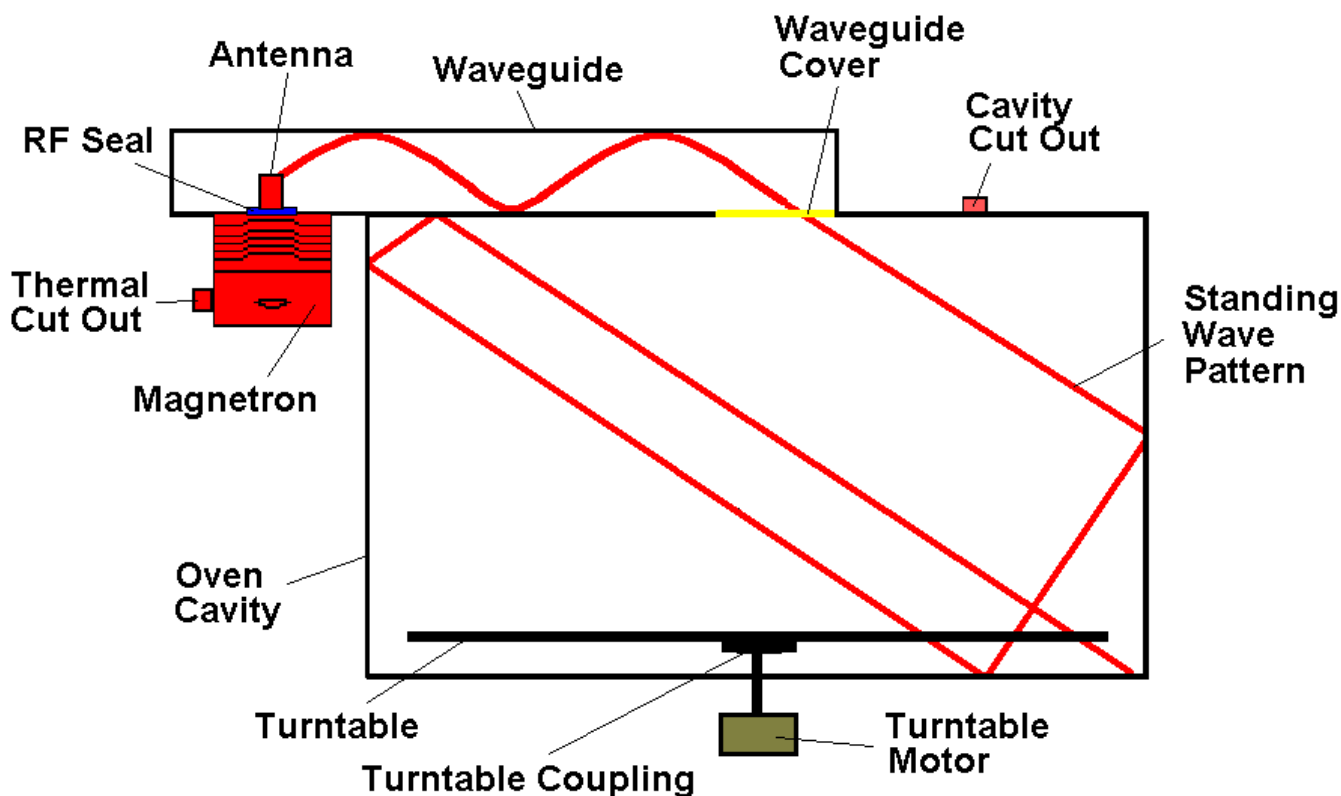
When dealing with a problem such as this, one idea that may help to put the customers mind at rest is to use the 'Box within a Box' concept. Microwave energy is present within the oven cavity when cooking, the cavity is the inner 'box' and the energy is safely confined to this area. Around this inner box is built the rest of the oven, including oven lamps and cooling fan. The case of the oven is then fitted over this and forms the outer 'box'.

When the oven is operated the oven lamp or lamps will be illuminated. As well as shining into the cavity they will light up the area between the cavity and the case. So it is possible light may be seen shining from gaps in the outer case or through the gap around the door. The cooling fan will also run and air will be blown through the space between the cavity and the case and also through the cavity. It is possible that warm air may be felt coming out from the above mentioned gaps. This does not mean that the oven is leaking microwave energy

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## Distribution of Energy within the Oven Cavity

The microwave energy produced by the magnetron is fed to the oven cavity through a waveguide. The waveguide shape and size is designed to enable the energy to be transferred with very little loss. When entering the cavity, the energy will, if left unmodified set up 'Standing Waves'. These standing waves are produced by reflected energy from the wall, floor and ceiling of the cavity. A regular pattern is established, with energy present along the standing waves. Some areas within the cavity will have no microwave energy present.



The difference in energy levels throughout the cavity, caused by the standing waves, would produce uneven heating of the food during the cooking process. However, there are two main ways in which this problem can be alleviated. That is by using either a mode stirrer system, or by the use of a turntable.

### The Turntable

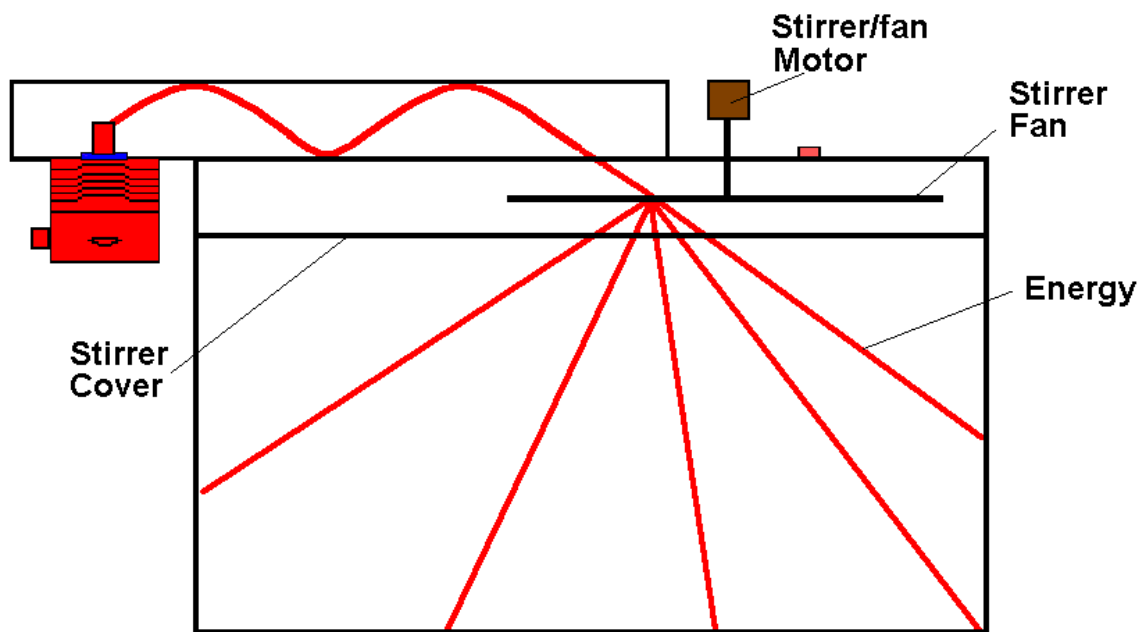
This method leaves the heating pattern produced by the cavity design unaltered. The food is placed on a turntable during cooking, the turntable is rotated so that all parts of the food pass through several standing waves of energy during each rotation of the turntable.

The most effective way of using a turntable system is to place the food close to the outside of the turntable allowing the maximum travel through the standing wave energy field. Note that if food is placed too near to the edge of the turntable, it may become unbalanced and not rotate correctly.

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## Mode Stirrers

Mode stirrers, stirrer fans and devices known as rotating antennae, work in such a way as to constantly change the energy wave pattern within the cavity during the cooking process; These units are made of materials that will reflect microwave energy. Therefore when they are placed in the energy field and made to spin, they will randomly affect the pattern. This sets up a continuously changing energy field in the cavity. These devices are usually motor driven, but can be air driven, usually the food remains static within the cavity.



Sharp microwave ovens for domestic use employ the turntable method to produce even cooking, whereas microwave ovens designed for commercial use generally incorporate mode stirrers. Commercial ovens also use two magnetrons, which gives a double advantage of more power with two heating patterns. A detailed description of differences of a commercial oven compared with the domestic models is included in the **Sharp Commercial Microwave Ovens** section at the end of this book.

The magnetron, waveguide and cavity can be thought of as a 'matched' or 'tuned' circuit. The oven cavity is a multi-mode cavity resonator, designed to resonate at the frequency generated by the magnetron. The whole system requires a load to work into. So when running a microwave oven in the cook condition, there should always be at least a small load in the cavity. The most convenient load is probably a glass of water, this will enable the oven to be run long enough to carry out most tests.

If an oven is run for any length of time without a load, then the magnetron will be stressed. This is caused by a back heating effect, and if left too long, eventual damage causing low output will result. Modern magnetrons are fairly tolerant of the no load condition, so a sudden catastrophic failure is unlikely, however the effective life expectancy could be greatly reduced.

Another way in which a magnetron may be damaged is by the use of an excessive amount of metal foil or large metal utensils within the oven cavity. The effect can be that energy is reflected back to the magnetron where it will be dissipated as heat. Small amounts of foil can be tolerated, as called for in certain recipe books, and devices such as temperature probes, which are part metal in their construction.

It should be remembered though, when using metal in an oven to keep it well away from the cavity walls. If metal objects are placed in the energy field and then come close to an earthed surface, arcing will occur and the surface of the metal could be marked. In the case of the temperature probe, it could be rendered inoperative. Metal racks and turntables, designed for use in the cavity, have good insulation or make good contact each other, e.g. the metal rack and metal turntable tray used in convection ovens. Therefore arcing does not occur.

The life expectancy of a magnetron is approximately 2000 hours. Which equates to about seven years of use by the average customer. Therefore it is expected that most magnetrons will last for the lifetime of the oven.

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## Cavity and Waveguide Practical Problems

A motor usually rotates mode stirrers and turntables and therefore occasional motor failure is possible. It is important that the turntable couplings are kept clean otherwise food debris may find their way down to the motor below and this may cause premature failure because of seizure. It is also possible for turntable couplings to become damaged due to the repeated heating and subsequent carbonising of food debris beneath the turntable. This may cause the plastic coupling and 'spider' to melt and the excessive heat may crack the glass turntable.

It should be noted that the turntable motor is asymmetric, which means that it is possible for the motor to turn in either a clockwise or anticlockwise direction.

Another item that may give problems from time to time, if it is not kept clean, is the waveguide cover, or the stirrer cover. Waveguide and stirrer covers are made of materials that are inert to microwave energy. However, if the cover is not kept clean, food debris will build up and be repeatedly cooked. This will then carbonise, and arcing will occur, finally the waveguide cover will have holes burnt in it. The cure is a new waveguide cover and a tactful reminder to the customer to keep the oven clean. Although this problem is simple to cure, and the customer can replace most waveguide covers, when the fault occurs it can nevertheless be disconcerting.

The oven should not be operated with a damaged waveguide cover or with the cover removed. In these situations food splashes could enter the waveguide, causing arcing and eventually corrosion. The result is that a new cavity is required to remedy the problem.

Very occasionally an engineer may encounter an oven that has a broken glass turntable. Apart from the obvious possibility of its having been dropped, the damage could have been caused by the use of a browning dish. To safeguard against possible damage when using a browning dish, use an upturned oven proof plate on the turntable, so that the turntable is insulated from the heat source generated by the browning dish.

Periodically an engineer may come into contact with an oven that has been damaged because of severe overcooking of food. The amount of damage can vary between smudging that can be cleaned off, to extensive damage requiring the replacement of the cavity and other components. Sharp ovens incorporate temperature fuses, which will operate and stop further magnetron output in the event of severe overheating within the cavity. However, depending on the amount and type of food, some damage to the cavity may still occur.

Although damage of this type is most often due to customer error, the oven should be checked for power output and correct timer operation. These tests will confirm whether the oven is faulty or if it's down to misuse. The warranty does not apply if the oven is working correctly.

If any difficulties are encountered when dealing with the problem of cavity fires then engineers can, if necessary, contact the Sharp Electronics CE Technical Support Hot Line for guidance.

# **SHARP**

## **Microwave Oven**

### **Technical File**

**Volume 2 – Magnetron and High  
Voltage Circuit**

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## Magnetron Theory

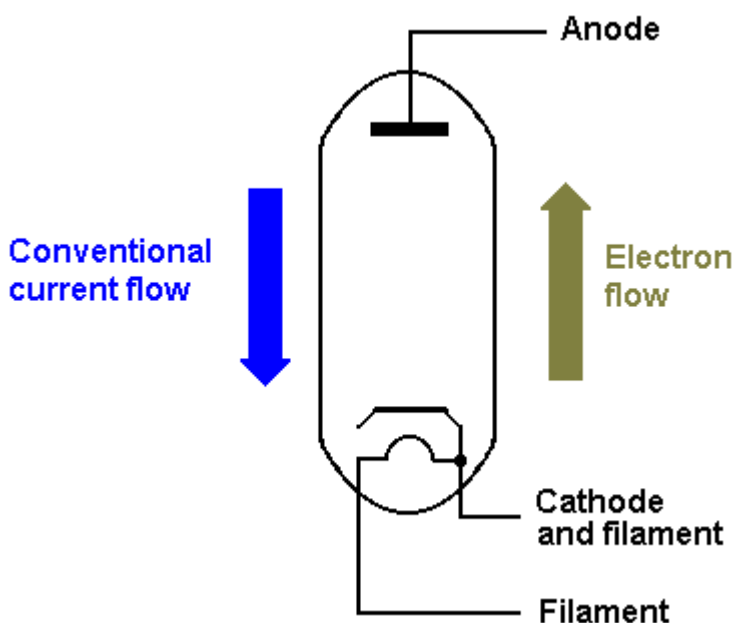
So far we have discussed microwave energy and its characteristics. In this section we will look at how the microwave energy is generated. The component used to generate microwave energy in a microwave oven is called a Magnetron; this is a thermionic device similar in some respects to a thermionic diode. To understand the basic operation of the magnetron, the operation of a thermionic diode valve will be discussed.

### Thermionic Diode Operation

A diode consists of two electrodes, the Anode and the Cathode, which are contained within an evacuated glass or metal envelope.

The cathode is coated with a material that, when heated, will emit electrons (sub-atomic particles). The cathode has to be heated in order to free these electrons. In a magnetron the cathode is directly heated and is usually referred to as the filament.

The anode is used to collect electrons given off by the filament. To do this the anode has to be positive with respect to filament. Electrons are negatively charged particles, therefore they are attracted towards the positive anode. Electrons will flow constantly as long as the potential difference is maintained, providing current flow through the device.



### Overview of Magnetron Operation

The magnetron is a specially designed type of thermionic diode, which is made to self oscillate. The major differences being the shape and structure of the anode and the addition of two strong external magnets, one above and one below the anode chamber. The resultant magnetic field is critical, as together with the anode voltage, it determines the path the electrons will take.

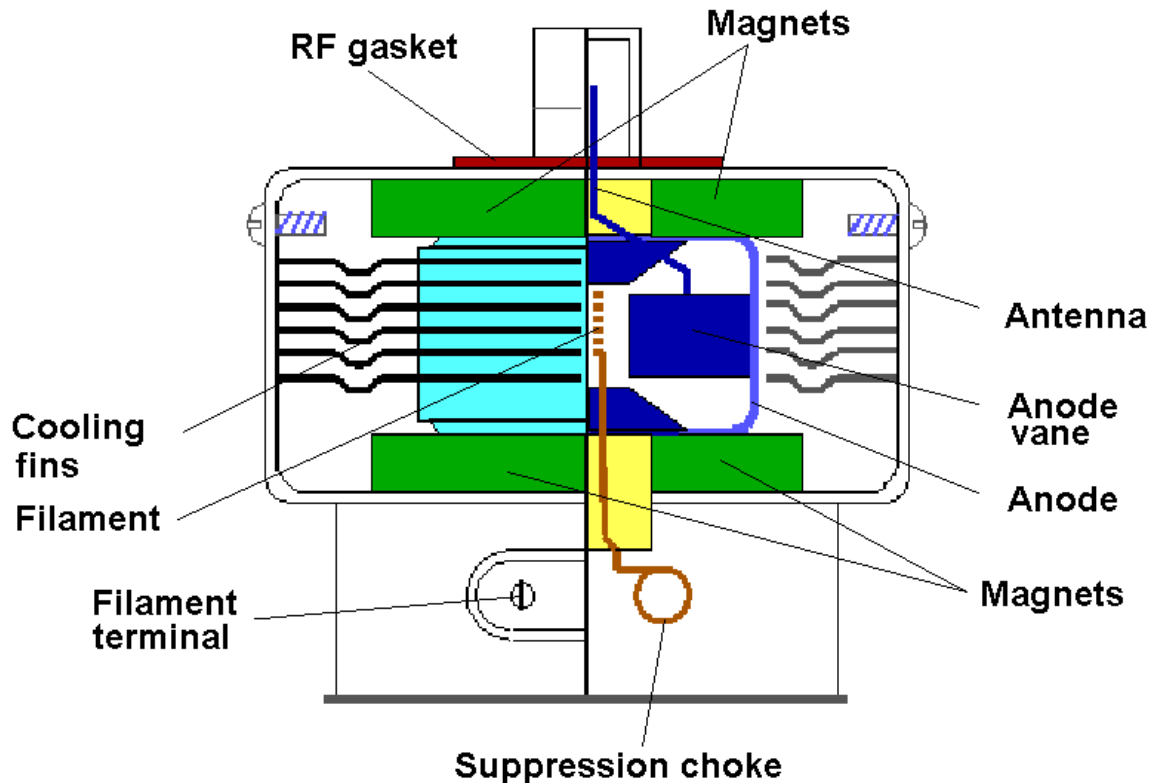
Without the magnets in position the electrons would travel directly to the anode in the normal way in a straight line. With the magnets in position, the strong magnetic field exerted across the magnetron envelope will cause the electrons emitted by the filament to take a spiral path as they move towards the anode structure.

The shape of the anode forms an even number of structures called cavity resonators, which form individual tuned circuits. These tuned circuits will oscillate as the passing of the electrons induces charges into them. All the tuned circuits are connected together in phase and the resultant power is transmitted via the antenna, which is connected to the anode structure, into the cavity. A more detailed explanation of this concept follows.

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## Magnetron Construction

Shown below is a diagram of a typical magnetron used in a Sharp microwave oven. The left-hand side shows the outside appearance while the right hand side shows a 'cut away' views



When examining a magnetron it would appear that there are only two terminals for connection. These are in fact for the filament and cathode. However, it should be noted that the anode structure is electrically connected to the outer case of the magnetron, this therefore comprises a third connection.

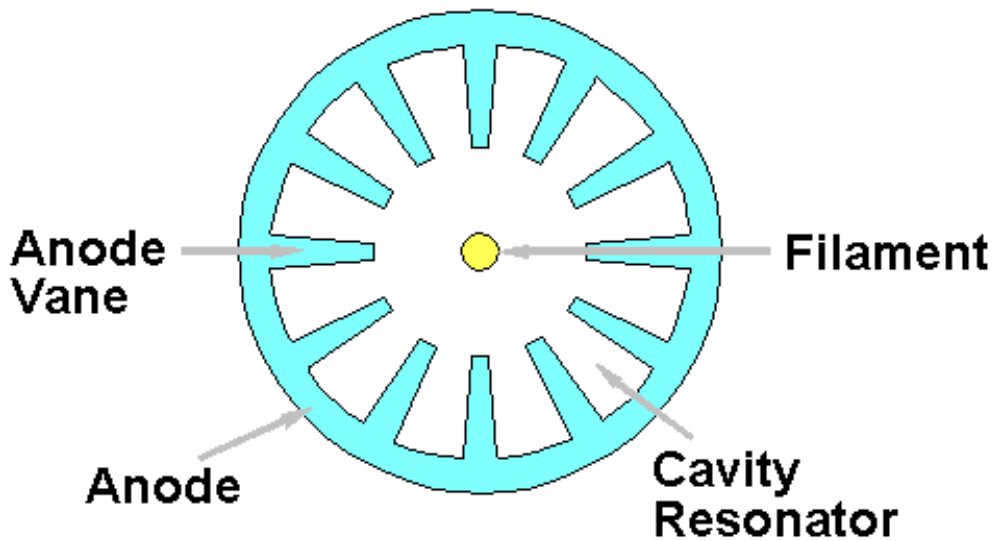
As discussed in the **Basic Thermionic Diode Operation** section, the anode is at a positive potential with respect to the filament. The anode of a magnetron is connected to its outer metal case, which is in turn connected to ground. It therefore becomes necessary to apply a negative potential to the filament.

Whilst the magnetron is operating, it runs quite hot at approximately 96 degrees Celsius. For this reason it has to be cooled, air is continually being blown over it by a fan. Cooling fins are fitted to the magnetron to allow the free flow of air around the anode structure, maximising the dissipation of excess heat.

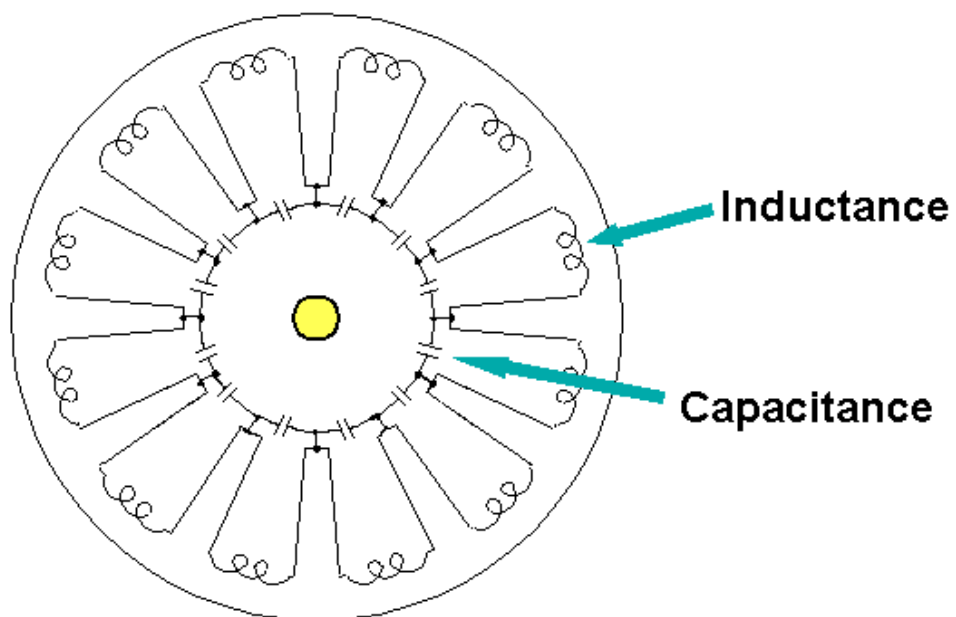
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## Principles of Magnetron Operation

The magnetron has a specially shaped Anode cavity resonator structure, as can be seen from the diagram below, which creates twelve cavity resonators formed by the anode vanes.



Each cavity resonator forms a conventional parallel tuned circuit, which consists of a capacitor connected in parallel with an inductor. In the case of the cavity resonator the capacitance is created by the vanes, which are seen as the two plates of the capacitor and the gap between the vanes is the dielectric. The length of each vane forms the inductance. The diagram below shows the magnetron anode as conventional components for ease of understanding.



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A conventional parallel tuned circuit required to oscillate at 2450MHz would require very small values of inductance and capacitance. These can be calculated by using the following equation.

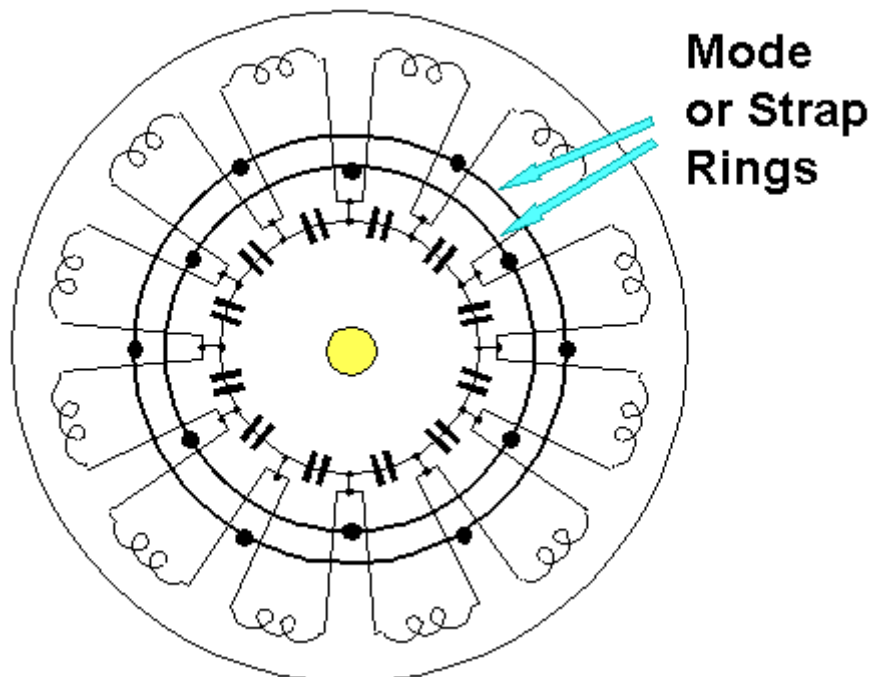
$$\text{Resonant frequency} = \frac{1}{2\pi\sqrt{LC}}$$

Therefore possible values could be:

C (Capacitance)	$64.95 \times 10^{-12}$ Farad (64.95pF)
L (Inductance)	$64.95 \times 10^{-12}$ Henry (64.95pH)

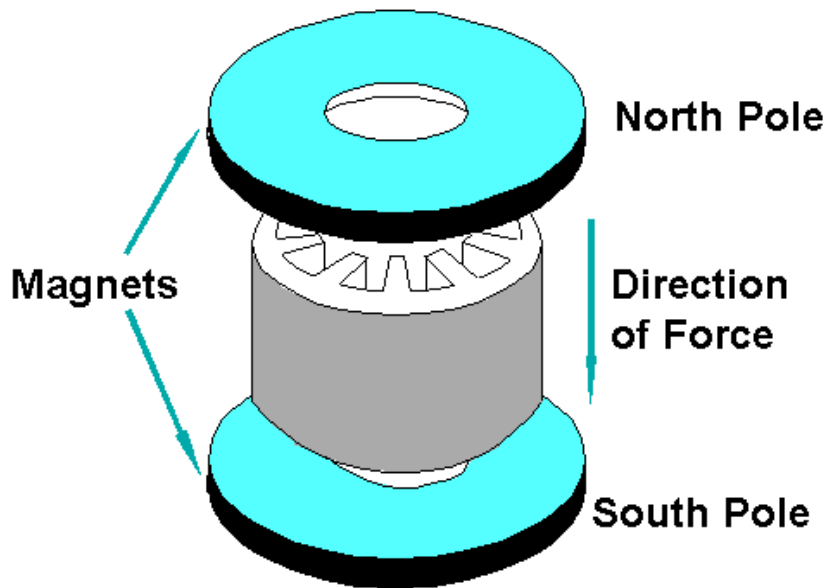
The above examples are not practical values, but they do illustrate that the values of capacitance and inductance created within a magnetron by the cavity resonators are very small.

By inter-connecting every other anode vane, using mode or strap rings, it is possible to ensure that adjacent cavity resonators oscillate 180 degrees out of phase when the magnetron is active. This configuration is shown in the diagram below.

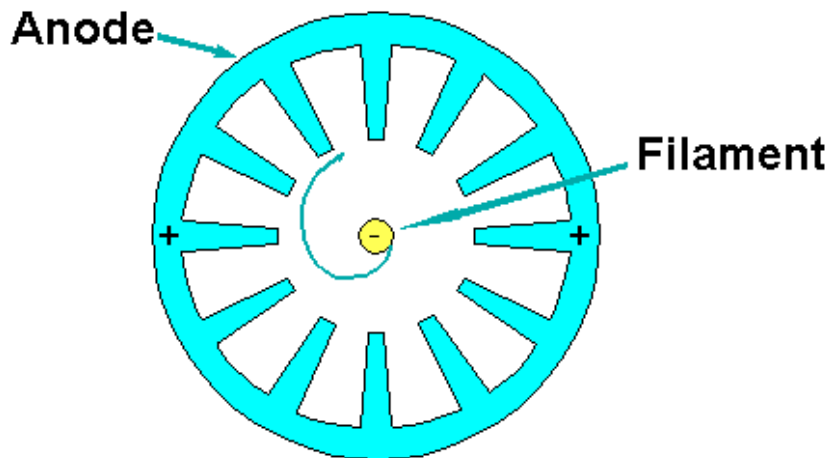


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The diagram below shows the anode structure of the magnetron and the position of the magnets. A strong magnetic field is present around the chamber. The effect of the magnetic field causes the electrons to take a spiral path as they travel towards the anode.



For the magnetron to operate correctly, a very high potential difference between the filament and anode is



needed, the anode being positive with respect to the filament. In practice this is achieved by connecting the anode to ground and applying a high negative voltage to the filament.

When the filament is heated, the electrons become excited and begin to jump from the filament. These free electrons form a cloud or 'space charge' around the filament. The electrons are then attracted towards the anode due to its positive polarity. However they are forced into taking a spiral path due to the influence of the external magnetic field that is created by the magnets above and below the anode chamber (Lorentz's law). As the electrons move closer to the cavity resonators they induce a charge within the resonator and this sets up the initial oscillation. Their movement over the gaps of the vanes creates a positive feedback effect, which causes the oscillation to continue.

As the oscillation develops some resonators will be in a negative state and some positive state, each cavity resonator being 180 degrees out of phase with its neighbour. These conditions reverse as the cycle of oscillation is completed, that is the resonators that were positive become negative and those that were negative become positive. This has a further effect on the paths taken by the electrons.

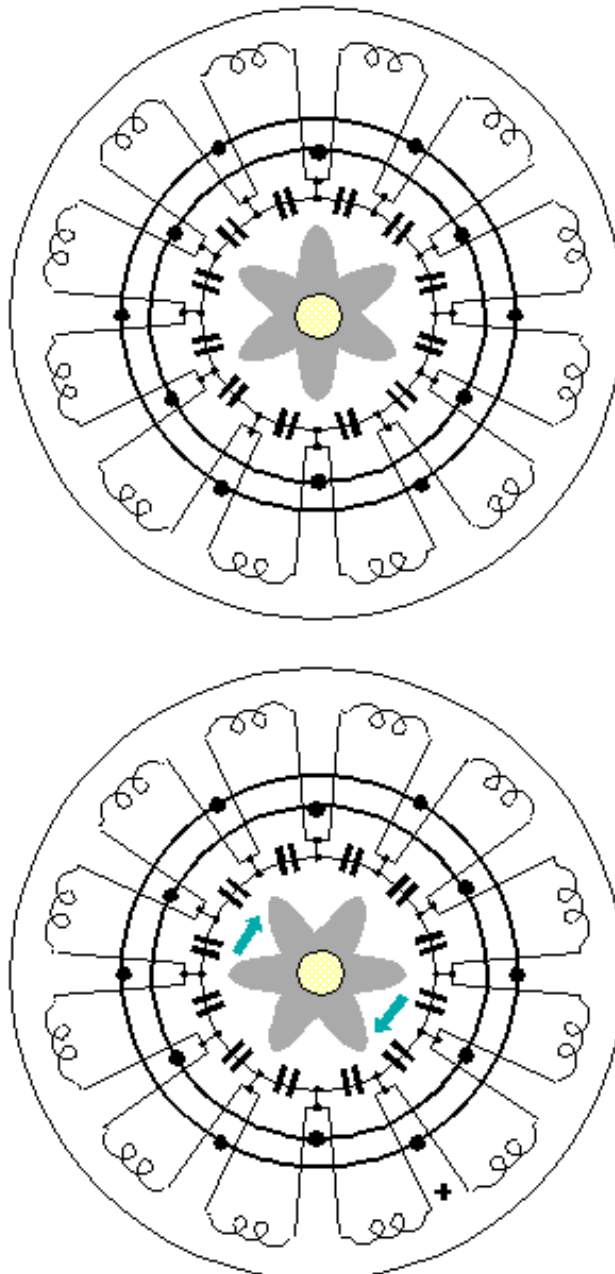
Any electron in the area of the negatively charged resonator vane is repelled because of their 'like charges', negative electrons and negatively charged resonator. The velocity of these electrons causes them to return to the

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filament, where they impact upon it, causing 'back heating' and 'secondary emission'. Conversely electrons in the vicinity of a positively charged resonator are attracted further towards the anode where they will finally land.

As shown in the diagrams below, these two conditions create a pattern of electrons within the magnetron chamber. This pattern is usually referred to as the 'spoked wheel effect'; the 'spokes' are formed because of the positively charged cavity resonators attracting electrons towards the anode. The spaces between the spokes are caused by electrons being repelled due to the negatively charged resonators.

It is important to remember that the polarity of charge is constantly changing within the cavity resonators. As the oscillation continues, during one half cycle of operation electrons are attracted by alternate resonators and repelled by the others. On the next half cycle the polarities will change. This effect together with the magnetic field causes the 'spoked wheel' to rotate so that the 'spokes' are always pointing to the positively charged cavity resonators, and therefore the gaps are aligned with the negatively-going cavity resonators. As the oscillation continues the 'spoked wheel' will progressively turn.

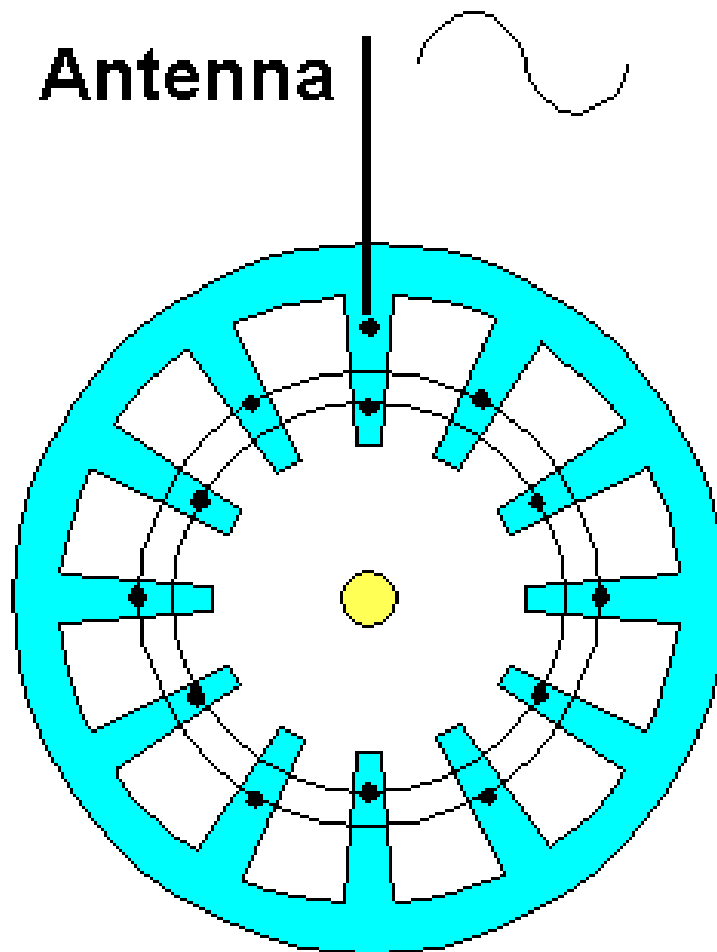


The two diagrams above show the 'Spoked wheel' pattern formed by the electron cloud in the two maximum states of oscillation.

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It can be seen from the diagram below, all twelve cavity resonators are effectively connected in parallel, therefore the power available from each one is added together.

As the cavity resonators are in parallel, it is possible to connect an antenna (aerial) to any of the anode vanes, enabling the total amount of microwave energy produced to be transmitted through the waveguide into the oven cavity.



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When replacing a magnetron care should be taken on the following points:

- There is a RF gasket fitted around the antenna to prevent microwave energy escaping from the seal between the magnetron and the waveguide. Always ensure the gasket is not distorted when fixing the magnetron in place.
- When handling, take care not to leave greasy deposits either around or on the antenna, which may carbonise, causing arcing at a later date.
- Ensure that the connections to the magnetron terminals are tight. If they are loose, overheating and damage will occur.
- Always remember the **3D checks** when working around the magnetron and high voltage circuit.

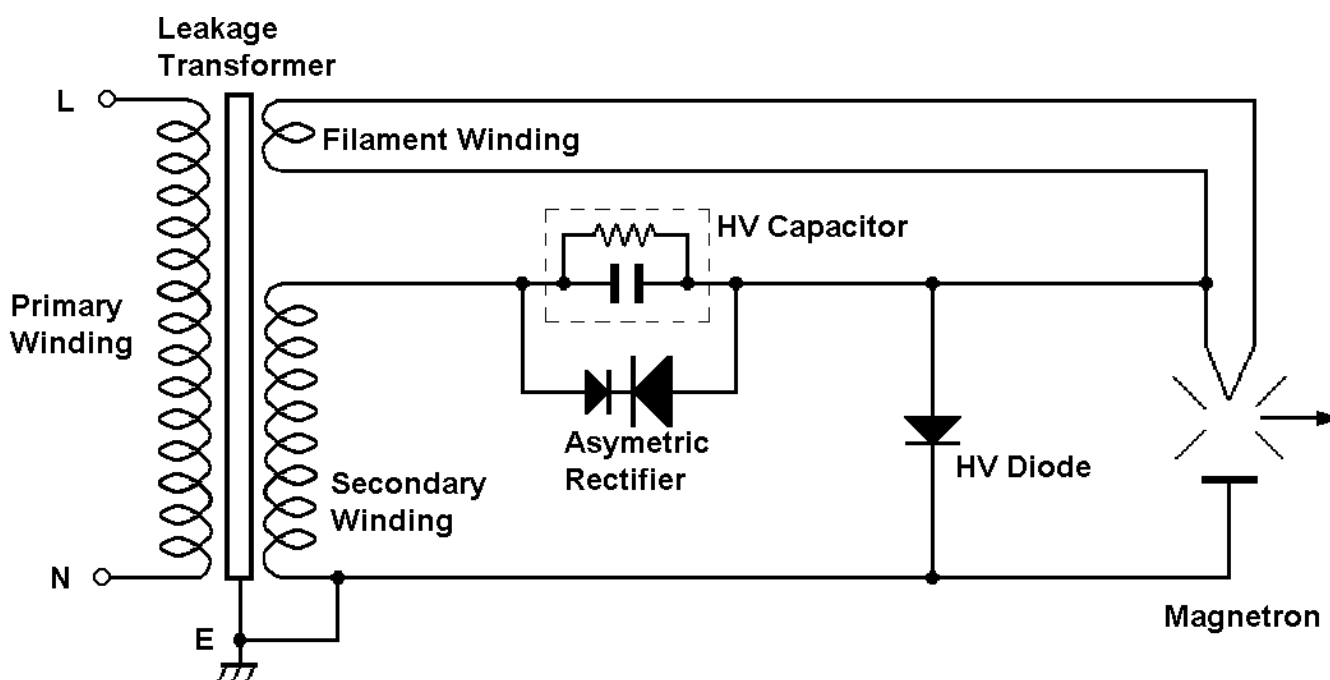
Several Sharp microwaves may use the same type of magnetron, but have different output RF powers. This is due to the RF output power being directly proportional to the anode current, which can be controlled in the HIGH VOLTAGE circuit design. The filament potential is altered to give the required power for individual models.

## High Voltage Generation

The magnetron needs a high negative voltage to be applied to its cathode for correct operation. Before we commence with a description of the high voltage circuit and its operation, it is essential that we point out the **Dangers** that exist when working with such a circuit.

The high voltage circuit when operating produces a **High Voltage** from a low impedance source, the High Voltage or Power Transformer. It is capable of maintaining a high voltage of about 2000V A.C., with a high current of between five and six amps. It should therefore be noted that touching any part of this circuit while it is operating would result in **Electrocution**. Working on this circuit live, even with well-insulated equipment is not recommended. Also, after the circuit is switched off, a large electrical charge remains in the high voltage capacitor. There is therefore a danger of **Electric Shock** even when the oven is no longer connected to the mains supply.

A typical high voltage circuit used to generate the magnetron supply is shown below.



### Circuit Description.

The circuit consists of a leakage transformer, usually referred to as the High Voltage or Power transformer, which has three windings. The primary winding to which the mains supply is applied. The high voltage secondary which steps up the mains input to 2000V A.C. and a filament winding that produces a low voltage with high current supply for the filament of the magnetron. The other components in the high voltage circuit are the high voltage capacitor and high voltage diode. A bleed resistor is added to the circuit, usually incorporated in the can of the high voltage capacitor, which discharges the capacitor when power is removed.

It is essential that the spade terminal connections on the magnetron are secure. If these connections become loose or oxidised the resistance of the joint will become high. Then because of the high current flow localised heating will occur. This heating will cause further oxidation and will also loosen the joints further, due to expansion, resulting in higher resistance in the joints and further heating of the connections and possible arcing. The result can be damaged terminals or insulation material on the magnetron requiring its premature replacement and damage to the connecting leads. When re-fitting the spade connectors to the magnetron after service, always ensure they are clean and tightly secured.

As previously stated the power transformer filament winding produces a low voltage A.C. It should however be noted that the HIGH VOLTAGE circuit is connected to one filament connection. This means that all of the wiring and connections in this part of the circuit will have a high negative potential with respect to ground. The voltage across the filament 2.5 to 3V A.C., the negative potential from all parts of the filament circuit to ground is

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approximately 2000V D.C.

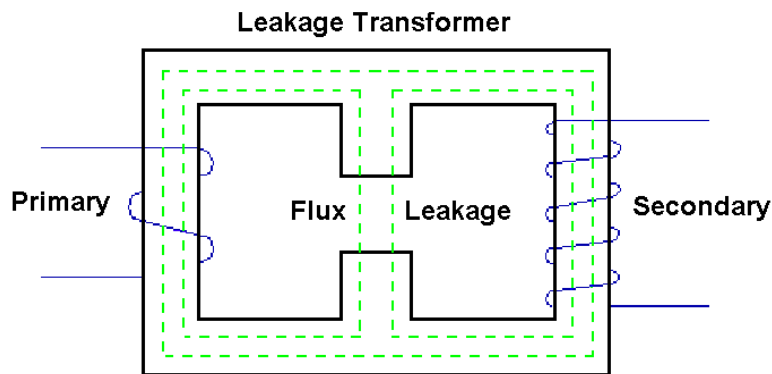
Connected to the high voltage secondary winding is the remaining circuitry, the high voltage capacitor, high voltage diode, bleed resistor and of course the magnetron. The capacitor and diode form what is often referred to as a 'Half Wave Doubler', it carries out D.C. restoration of the A.C. input from the transformer secondary. This process will be looked at in detail in the **Half Wave Doubler Circuit (D.C. restoration)** section of these notes.

Before discussing the half wave doubler it is necessary to look at what the circuit will achieve. For ease of explanation we shall consider that the output from the secondary winding is a nominal 2000V A.C. The actual voltage will vary according to the rated RF output power.

## Leakage Transformer

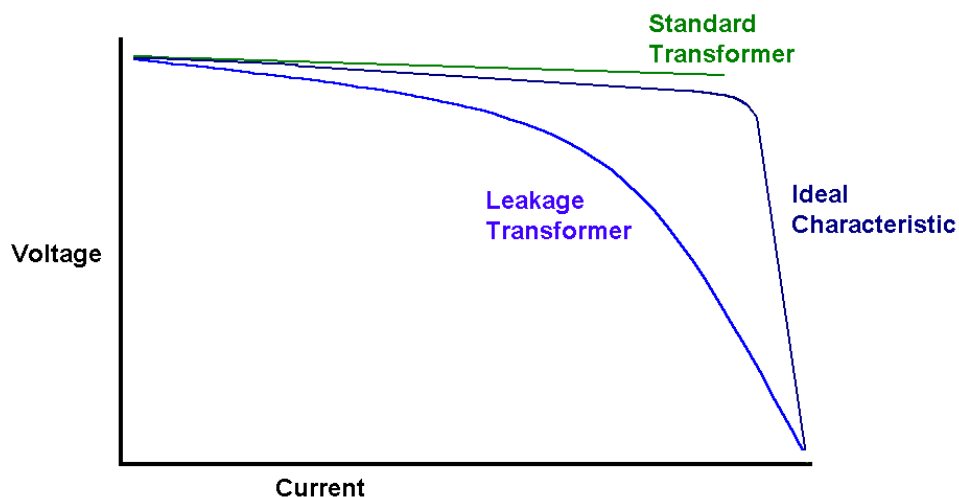
The type of transformer used in the high voltage circuit of a Sharp microwave oven is known as a leakage transformer. It is designed to have more magnetic flux leakage than the standard type of transformer, that is to say that not all of the magnetic flux produced by the primary winding finds a magnetic path to affect the secondary windings. There is a magnetic shunt built into the assembly that allows the magnetic flow to take an alternative path.

As far as the operation is concerned, this has the effect of allowing the voltage to vary in order to maintain a fairly constant current through the magnetron anode circuit. The reactance of the transformer effectively changes with the load.



It is important where a magnetron is being used that its anode current is maintained at a constant value during operation or the output power will vary dramatically. The leakage transformer operation will achieve this.

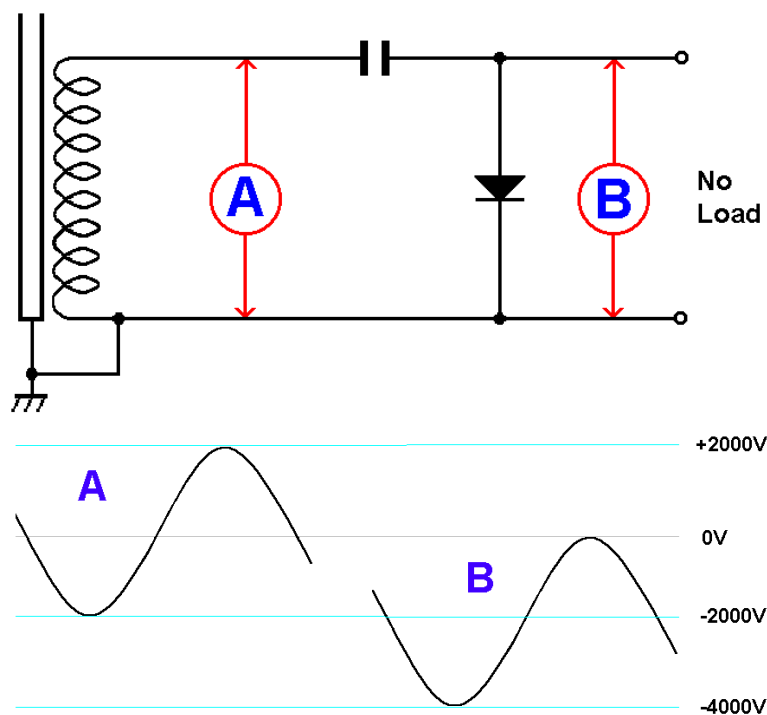
If the high voltage A.C. across the secondary winding were to be measured it would be seen to vary considerably as the load in the oven moved around the cavity on the turntable. This is in response to the changing load put on the magnetron. It would also be noticed however, that because of the action of the transformer and half wave doubler circuit, that the high negative D.C. voltage across the magnetron would remain stable, as does the anode current.



## Half Wave Doubler (D.C. restoration)

### Overview

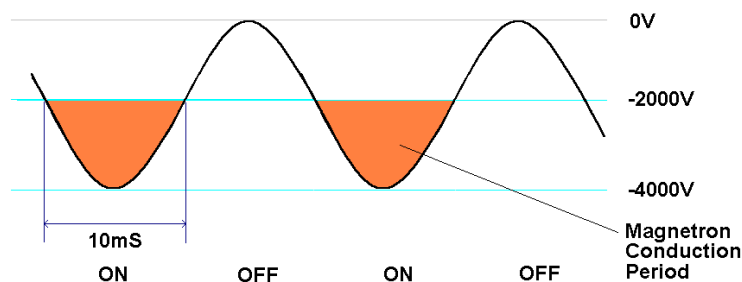
The circuit below shows a simplified schematic diagram of the 'Half Wave Doubler' circuit. To be more precise its action on the input waveform is more consistent with a D.C. restoration circuit. The doubler label comes from voltage measurements made on this circuit with no magnetron load. A voltmeter connected in position 'A' in the diagram below would show 2000V ac., and -4000V D.C. in position B. When analysing these results, it could be said that a doubling of the input voltage had occurred. However if the same measurements were made using an oscilloscope, it would be seen that the waveform at position 'B' is the same as at position 'A'. The circuit has shifted the waveform with respect to the zero line (ground) this is also shown in the diagram below.



The reason the meter shows a doubling of voltage is that the same reference point is used, that is ground. One lead of the meter is connected to ground when taking both voltage measurements. In the case of waveform 'A', the meter is set on the A.C. voltage range. This will show the RMS value of one half-cycle, with respect to ground, this would be approximately 2000V.

In the case of waveform 'B' the meter would be set to measure D.C. voltage, because the waveform is unidirectional, e.g. negative only. The meter would read -4000V, which is the RMS of the peak to peak voltage on this waveform, which is also equal to the peak to peak value of waveform 'A'.

When the magnetron is connected to the circuit, it will affect the waveform at position 'B'. The change is due to the current being drawn by the magnetron. The magnetron will begin to conduct at about -2,000 volts, it then acts as a shunt regulator and clamps the waveform at that point. Now when we check with a meter the voltage would be in the order of -2000V D.C.



We can see from the diagram on the previous page that the magnetron is pulsed on and off at mains frequency therefore the RF output will be present for only 50% of the time. The RF energy is pulsating at 50Hz and is only present during the negative half-cycle of the mains supply. This means we only get about 50% efficiency from the magnetron, the result is that the output power is only half of the power consumed by the oven. However, this pulsing helps to prevent damage occurring to the magnetron caused by overheating.

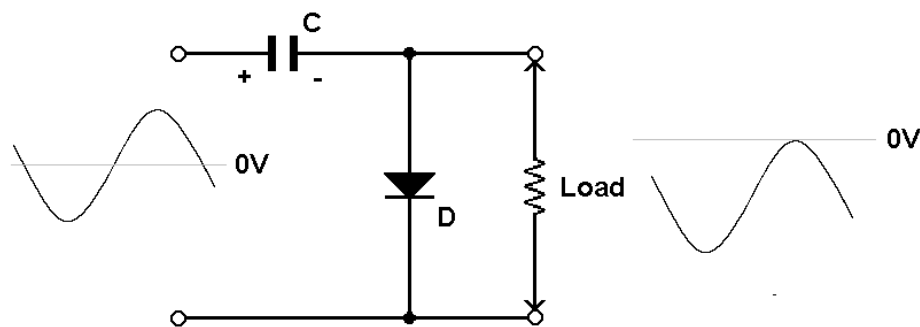
## Operation

The circuit has two different time constants. When the input signal produces a forward bias potential on the diode, the total resistance is the load resistance in parallel with the diode forward resistance, therefore the total resistance is low. When the diode is reverse biased, the total resistance is the load resistance, which is high.

### Time = Resistance x Capacitance

Using the above equation, it can be seen that when the diode is conducting the time constant is very short and when the diode is not conducting then the time constant becomes much longer. The capacitor charges quickly through the diode and discharges slowly through the load resistance.

To understand the operation of the circuit assume that the capacitor is initially uncharged. During the first quarter cycle the diode is forward biased. Current will now flow via the diode and the capacitor is charged. The polarity of the charge is shown in the diagram below. The level of the charge will be a little under the peak value of the input.



As soon as the voltage on the input side starts to fall, the diode will become reverse biased, with the charge on the capacitor holding the diode *off*. The input circuit will now return the positive plate of the capacitor to ground, therefore the other plate of the capacitor will be taken negative. In fact the negative plate of the capacitor will always remain at a voltage equal to input less the peak value. When the input approaches its next positive peak any lost charge will be replaced.

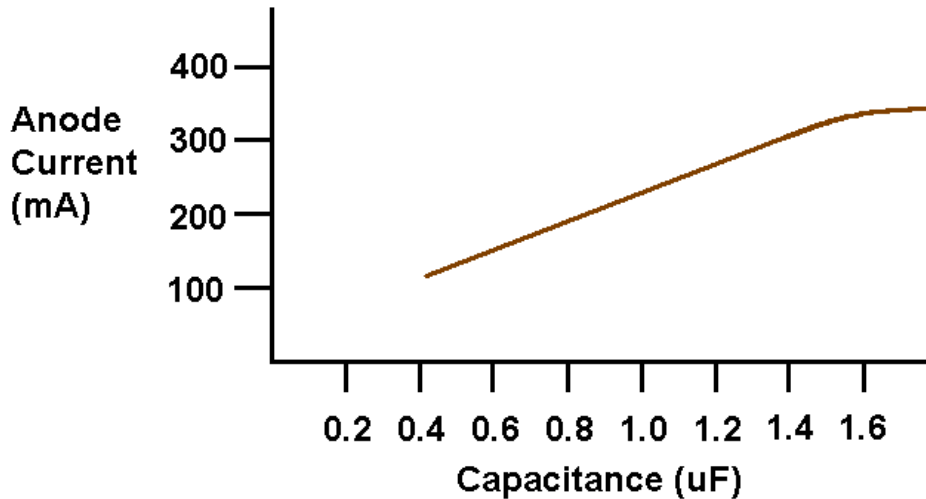
With the magnetron connected and drawing current the circuit will maintain a voltage nearing the peak to peak value of the input waveform. The output does however change wave shape due to the action of the leakage transformer and the current consumption of the magnetron.

As already stated the charge on the capacitor is effectively added to the input waveform, to give an output that is shifted up or down depending on the polarity of charge. In the case of a microwave oven the shift is negative, as a negative potential is needed for the cathode.

The charge gives us the difference between input and output. If the capacitor starts to discharge, the diode action ensures that on the next positive peak the lost charge is replaced. In other words if the capacitor charge is reduced by an increased load, the diode current increases. This fact means that diode current will be equal to the current being drawn by the load on the doubler circuit. In the case of the microwave oven the load is the magnetron, and therefore diode current will be the same as the magnetron anode current.

There is one further point to be considered while dealing with this circuit, that is the value of the capacitor. The larger the value, the more current available for the magnetron to draw on. Therefore, the value of the capacitor will affect the power output of the oven. The larger value the greater the output.

When replacing capacitors in the high voltage circuit of a microwave oven it is very important that the same value is used as the original one fitted during manufacture. It should be noted that different models with similar output powers, may have different values of capacitors, therefore different transformers will be used. Also models with different output powers may use the same magnetron, with the output being controlled by the capacitor value.

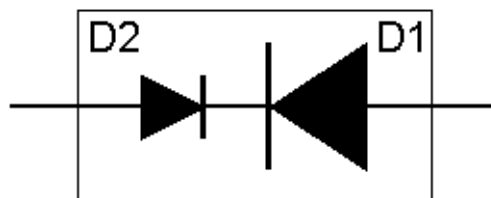


From the safety aspect it should also be noted that a bleed resistor is built into the capacitor, which will discharge the capacitor when the power is removed. In some models the bleed resistor is built into the diode. To prevent a potentially hazardous situation developing, when replacing the capacitor or high voltage diode, always use the correct type by part number.

When checking these components, if it is found that the bleed resistor has gone high in value or open circuit, the component should be regarded as faulty and replaced.

### Asymmetric Rectifier

The Asymmetric Rectifier or Short Protector, as it is sometimes called, is included in the circuit to prevent damage to the high voltage transformer and high voltage capacitor, in case of a short circuit occurring on the magnetron or high voltage diode. The short protector will cause the line fuse to blow in the above fault conditions.



As can be seen in the diagram to the right, the device will not conduct in any direction, therefore has no effect on the circuit under normal operating conditions. The peak inverse breakdown voltage of D1 is 6kV and D2 is 1.5kV. Under fault conditions when a short circuit occurs the peak inverse voltage of D2 will be exceeded, this will cause the diode to go short circuit. This in turn will cause a very high forward current through D1, causing it to go short circuit also. This will cause a dead short to appear across the high voltage transformer secondary, which will blow the line fuse, removing power to the high voltage transformer.

### High Voltage Diode

We have seen that very high voltages are generated in the high voltage circuit, and therefore during operation the high voltage diode is subjected to high peak inverse voltages. This means that a specially constructed diode is needed to withstand such voltages. However it is not possible to manufacture a single diode with the required characteristics, this is achieved by connecting twenty diodes in series. Therefore the peak inverse breakdown voltages of each of the diodes are added, which provides the required overall peak inverse breakdown voltage. This needs to be borne in mind when carrying out resistance checks on high voltage diodes.

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## Test Methods

### High Voltage Diode Test

The high voltage diode can be tested using a meter with an internal battery providing 15V or more when set to measure resistance and usually means selecting the high resistance range. A 'Megger' may be used to test the components in the high voltage circuit, either a 500V or 1kV type is suitable. It is necessary to forward bias all the diodes within the structure, i.e. 0.7V x 20. Therefore, digital meters which only use a low voltage source cannot be used, as there will not be sufficient voltage to forward bias the diode.

The forward resistance of the high voltage diode should read in the region of 100k $\Omega$ . The reverse reading should be infinity, unless there is a bleed resistor fitted, which will read 10M $\Omega$ .

### Asymmetric Rectifier Test

Isolate the high voltage rectifier assembly from the high voltage circuit. The short protector can be tested using an ohmmeter set to its highest range. An open circuit should be shown in both directions if the device is good. If a reading is obtained in either direction, the short protector is faulty and should be replaced. When a defective short protector is replaced, check the high voltage diode, magnetron, high voltage wiring and power transformer filament leads for a short circuit before operating the oven.

### High Voltage Capacitor Test

The following test will only show short circuit or open circuit conditions and cannot be used to measure the value of a capacitor.

When a meter is connected across the terminals of the capacitor, initially the meter will indicate low resistance. The resistance reading should increase until a reading of infinity reached, or if a bleed resistor is fitted, 1M $\Omega$  ohms. The readings should be checked in both directions. Also the two terminals should be checked to the metal can of the capacitor. A reading of infinity should result in both cases.

### Magnetron Test

It is possible to check the filament winding for continuity, which should be less than 1 $\Omega$ . From each of the filament windings to the anode should read infinity.

### HIGH VOLTAGE Transformer Test

The primary winding of the HIGH VOLTAGE transformer should read about 2 $\Omega$ . The high voltage secondary winding should be in the region of 80 $\Omega$  to 130 $\Omega$  depending on the nominal mains supply voltage that the transformer was design to work on, and the filament winding less than 1 $\Omega$ . The resistance of the windings will vary slightly with the transformer used in different models. Accurate figures are available in the relevant service manuals.

# Always remember the 3D's!

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## Warning to Service Personnel

Before undertaking work on any microwave oven, it is important that a number of safety precautions are taken. To help with remembering these precautions, refer to the 3D's as outlined below.

### Remember to check the 3D's

- 1. Disconnect the supply.**
- 2. Door opened and wedged open.**
- 3. Discharge the high voltage capacitor.**

Sharp recommends that wherever possible fault finding should be carried out with the supply disconnected. In some cases, it may be necessary to connect the supply after the outer case has been removed. In this event carry out the 3D checks and then disconnect the leads to the primary of the power transformer.

Ensure that these leads remain isolated from other components and the oven chassis. Use insulation tape if necessary. When testing is completed, carry out the 3D checks again and then reconnect the leads to the primary of the power transformer.

When work has been completed, the oven must be checked to ensure that it is working correctly. Follow the 4R's outlined below once the repair is complete.

### Remember to Check 4R

- 1. Reconnect all of the leads removed from components during testing.**
- 2. Replace the outer cabinet.**
- 3. Reconnect the supply.**
- 4. Run the oven and check all functions.**

Microwave oven cavities should not be run empty. To test for the presence of microwave energy within a cavity, place a cup of cold water on the oven turntable, close the door and set the microwave timer for two minutes. Set the power level to HIGH and press the START button. When the two minutes have elapsed carefully check that the water is hot. If the water remains cold carry out the 3D checks and re-examine the circuit.

When all service work is completed and the oven is fully assembled, the microwave power output should be checked and a microwave leakage test carried out.

# **SHARP**

## **Microwave Oven**

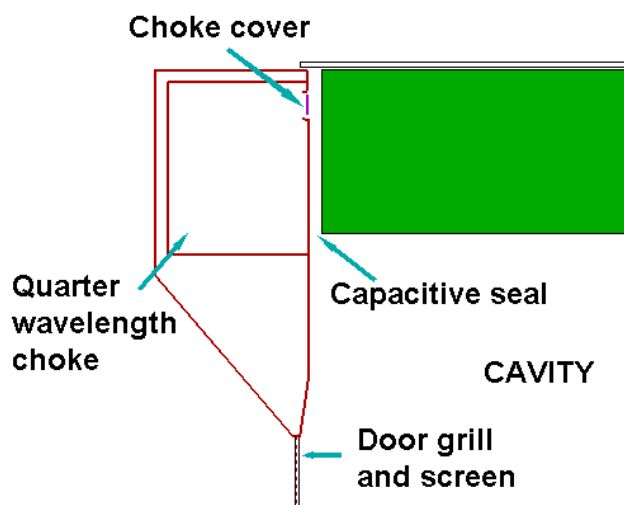
### **Technical File**

**Volume 3 – Door Systems and  
Microwave Power/Energy Detection**

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## Door Seal System

The door on a microwave oven does not form a hermetic seal, but incorporates an 'electronic' method of preventing energy escaping; the diagram below shows a typical design.



The reason for calling this door seal system 'electronic' is because part of the design makes use of the air gap, between the door and cavity. Under certain circumstances steam and hot air will escape. This is quite normal and does not necessarily mean the oven is leaking microwave energy. Door seal systems use a combination of the capacitive seal and a device called a quarter wavelength choke.

### Capacitive seal

This element of the door seal system uses the inner door and the cavity facing, which forms what is in effect the two plates of a capacitor. The dielectric of the capacitor being the air gap.

### Quarter Wavelength choke

The quarter wavelength choke is an integral part of the door structure, going around the full extent of the edge of the door. The entrance to the choke is covered by a piece of plastic, called the 'choke cover', which prevents steam or food particles entering the choke and changing its characteristics.

The quarter wavelength choke system works because energy entering through the choke cover will travel the length of the choke and then is reflected back by the end surface. This reflected energy would be half a wavelength (180 degrees) out of phase with the incoming energy. This means that power cancellation will occur.

Note that the choke appears as high impedance to the microwave energy.

### Reasons for Leakage

Modern microwave ovens are manufactured to very high standards and it will be found that ovens checked with an approved type of microwave leakage detector usually have no detectable level of leakage.

There may be times when an engineer will encounter an oven with an unusual amount of leakage. This is usually caused by damage to the door or cavity surround, an incorrectly fitting door or by a build up of food debris within the capacitive seal area.

To cure low level leakage from door areas, all of the door components are available, if damage has occurred only the damaged item needs to be replaced. Incorrectly fitting doors can be re-aligned, by adjusting the door hinges, or the latch hook assembly. Cleaning is probably all that is needed to remove any food deposits from the capacitive seal.

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## Microwave Leakage

Leakage tests should be carried out on every oven that has been repaired, irrespective of the original problem. The following information gives details of how a test should be carried out and also outlines the current standards regarding the maximum levels of leakage that are permissible.

Microwave leakage tests should be carried out using only approved types of detectors. These detectors must be returned to a registered laboratory for testing, calibration and certification annually. Whilst there are leakage detectors available to both engineers and end users which do not require calibration, the results from these should not be considered as accurate.

### Leakage Testing

Under British Standards BS EN60335-2-25:1997 (domestic) and BS EN60335-2-90:1998 (commercial), the maximum permissible amount of microwave leakage, and the method of making a test are as given below:

**Maximum permissible leakage:** 5mW/cm<sup>2</sup>  
**Measured at a distance of:** 5cm  
**With a water load of:** 275ml

Sharp, as a company sets a lower acceptable level and require engineers to ensure Sharp ovens comply with this higher safety standard. The Sharp recommended standard is set out below:

**Maximum permissible leakage:** 2.5mW/cm<sup>2</sup>  
**Measured at a distance of:** 5cm  
**With a. water load of:** 275ml

In practice, it is normal for there to be no measurable leakage from a modern oven. If any leakage is detected, the test should be stopped immediately and the reason for the leak investigated and resolved. The test should then be carried out again.

During production, ovens manufactured by Sharp are tested for leakage at several points along the production line. The maximum level of leakage is set at 0.5mW/cm<sup>2</sup>.

Leakage testing should only be carried out using an approved and calibrated microwave leakage detector.

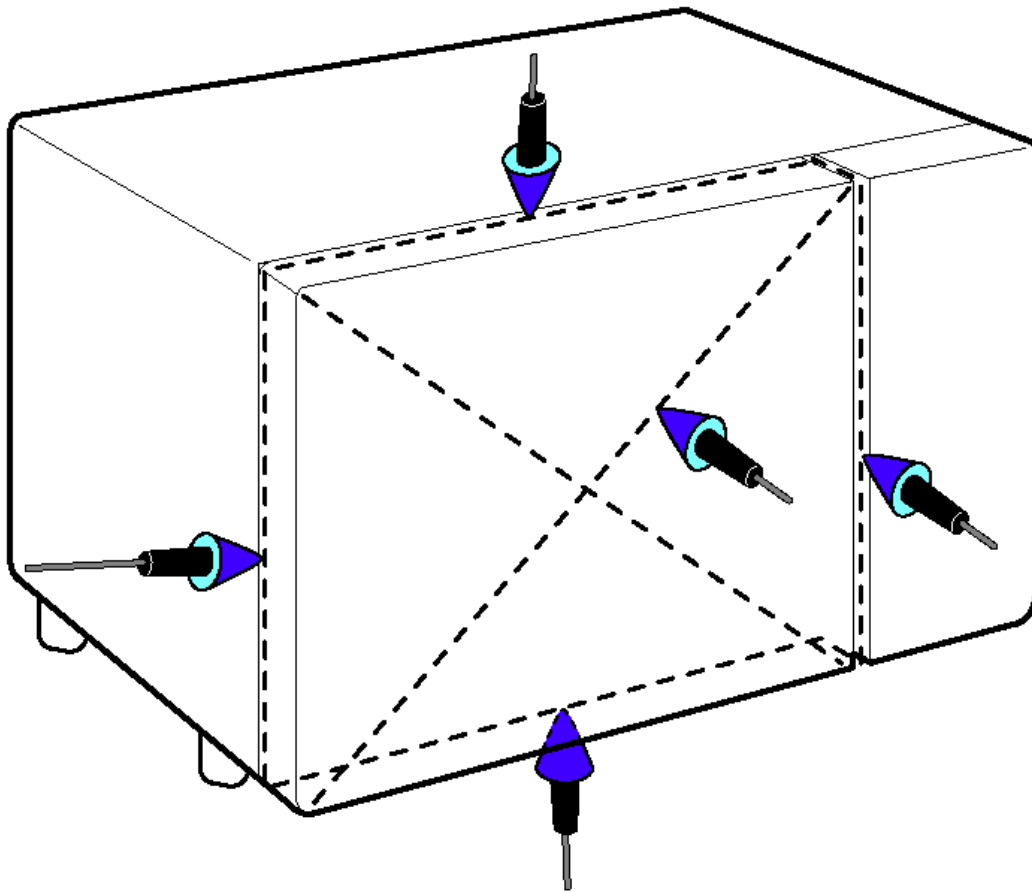
### Method

Before carrying out this test make sure that the oven is correctly connected to its rated supply, with all covers in place. The turntable or shelf should be fitted as applicable, with the required load in place.

1. Place a suitable container holding 275ml of water in the centre of the oven.
2. Set the oven for **Full Power** and put it into cook mode.
3. Using an approved and calibrated leakage detector in accordance with the manufacturer's instructions, scan the door perimeter around the seal. Then move diagonally across the door. The detector should be moved at a speed of less than **2.5cm per second**\*
4. If at any stage any leakage is detected, the test should be stopped immediately and the reason for the leakage located and repaired.

\*

It should be noted that BS EN60335-2-25:1997 specifies that the detector is operated at a distance of **5cm** from the source. Manufacturers of detectors usually supply a nose cone or spacer, which when fitted, puts the pick up device 5cm from the tip. Therefore with the tip of the cone or spacer in contact with the door the pick up is at the correct distance. Always check the detector manufacturer's instructions, before use.



The dotted line on the above diagram shows the direction in which the leakage detector should be moved. The tip of the cone or spacer should run along the gap between the door and cavity, then diagonally in both directions across the front of the door.

The leakage detector meter will need to be set to zero before carrying out the test.

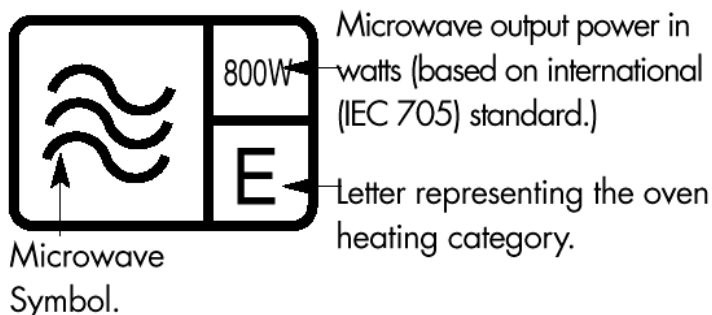
## RF Power Output Checking

Checking the RF power output of a microwave oven will give a measure of the efficiency of the magnetron (and to some extent the high voltage circuit) and therefore the long-term reliability of this device. It will also re-assure that customer that the oven is working to specification as compared to the rating plate.

There are many ways of testing for RF output power and Sharp recommends a simplified version of the IEC705 test method (covered under Standard BS EN60705). This test is used as it ensures that all ovens rated under it will give consistent results, which allows for universal cooking instructions to be used.

### Heating Categories

The heating category (a letter A to E) developed by MAFF (Ministry of Agriculture, Fisheries and Food) with microwave oven and food manufacturers indicates the ability of the oven to heat small quantities of food (up to 500g [1lb 2oz]). It does not represent the general performance of the oven.



OVEN OUTPUT POWER	Less heating time required →
	600 700 800 900 1000 Watts ← More heating time required
OVEN OUTPUT CATEGORY	Less heating time required →
	A B C D E ← More heating time required

Food packs carry cooking instructions for heating categories A to E. Follow instructions for the letter corresponding to the oven's heating category. The higher the output power and heating category of the oven the less heating time is required.

### Power test using the IEC705 method

The calculation used in the IEC705 test is based upon the amount of energy that is needed to increase a known volume of water by a set temperature rise. The standard for this is the calorific value of water. To heat one cubic centimetre of distilled water by one degree Celsius requires 4.187 calories.

Knowing the above value, it is possible to calculate the power output of an oven, using the formula below:

$$\text{Microwave Output Power (IEC705)} = \frac{4.187 \times V \times \Delta T}{t}$$

Where:

- P Is the output power
- 4.187 Is the calorific value of water
- V Is the volume of water
- $\Delta T$  Is the temperature rise
- t Is the time taken

To remove some of the variables in the above formula we use a 1000cL of water, we already know the stated power and we set the temperature rise that we require at 10 degrees Celsius. We can then calculate the time (t) required.

$$t = \frac{4.187 \times 1000 \times 10}{P}$$

By inserting a range of power ratings that have been used in Sharp microwave ovens, we have calculated the heating times and prepared the following table for quick reference:

<b>Oven Power (1EC705)</b>	<b>Heating Time (+Filament Heating Time)</b>
650 Watts	64 seconds (+3 seconds)
700 Watts	60 seconds (+3 seconds)
750 Watts	56 seconds (+3 seconds)
800 Watts	52 seconds (+3 seconds)
850 Watts	49 seconds (+3 seconds)
900 Watts	47 seconds (+3 seconds)
950 Watts	44 seconds (+3 seconds)
1000 Watts	42 seconds (+ 3 seconds)

It is important to note that it is necessary to add three seconds to the heating time to allow for the magnetron filament to reach the correct temperature. However, this 3 seconds should not be included in the calculation.

Having made the above calculation, carry out the check as described below.

1. Fill a suitable container with one litre of water at approximately ten to twelve degrees Celsius.
2. Stir the water and measure the temperature. Note the temperature as T1.
3. Place the container in the microwave and heat on full power for a time determined by the above calculation (t). Remember to add 3 seconds for magnetron filament heating time.
4. When the heating time is completed, remove the container from the oven and stir the water. The water temperature should be measured again and noted as T2.
5. The output of the oven can now be calculated using the following formula:

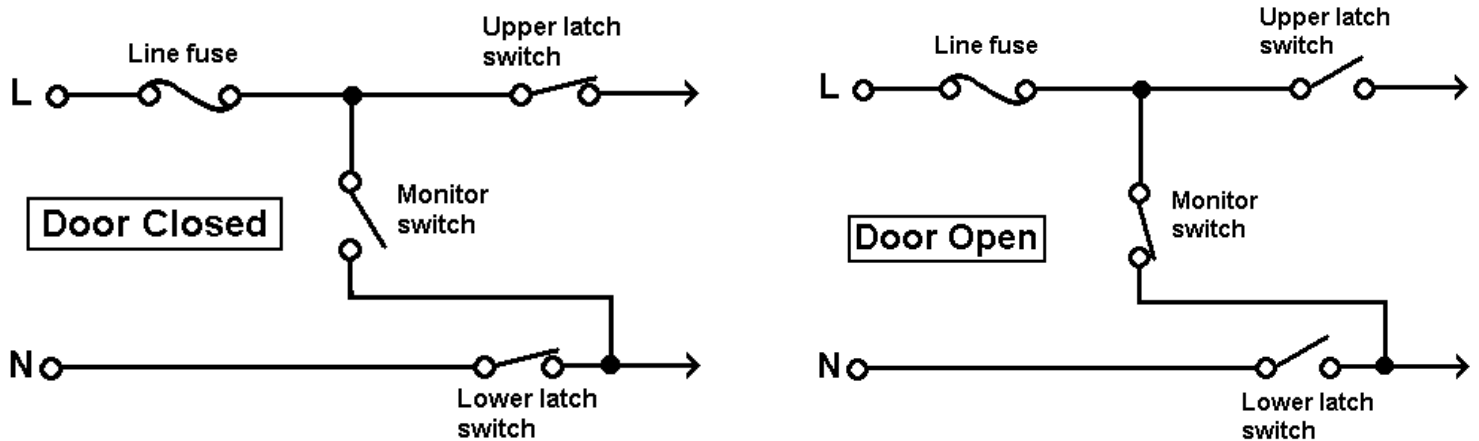
$$\text{RF Power Output (1EC705)} = \frac{4.187 \times 1000 \times (T2 - T1)}{T}$$

The result from this test should be within 15% of the RF power output, which is stated on the model specification label.

## Door Interlocks and Latch Switches

It is obviously important that a microwave oven cannot be operated with the door open, the oven control circuit must ensure that the magnetron is disabled whenever the door is opened.

The circuits below show the configuration of the switches used to ensure that the oven operates safely. Usually there are three switches, two interlock, or latch switches and one switch to 'monitor' the condition of one latch switch. The circuit is designed to cause the oven's internal line fuse to blow, should the latch switch or monitor switch fail or if the switches are tampered with.

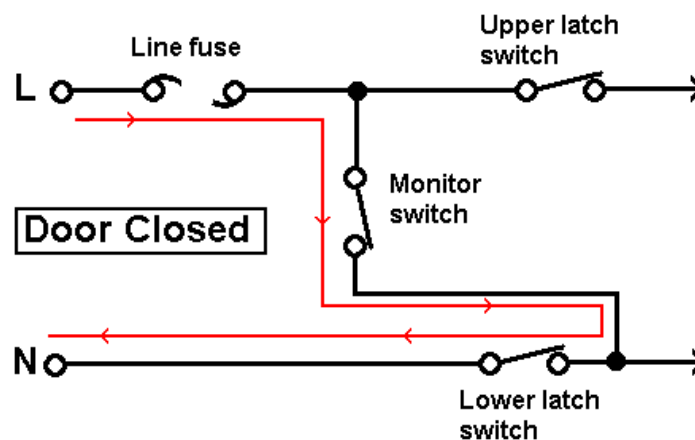


With the door open, the latch switch contacts are open and the monitor switch contacts are closed. The supply is removed from the high voltage transformer primary.

When the door is opened, it can be seen from the diagram, that the latch switches must be opened before the monitor switch closes.

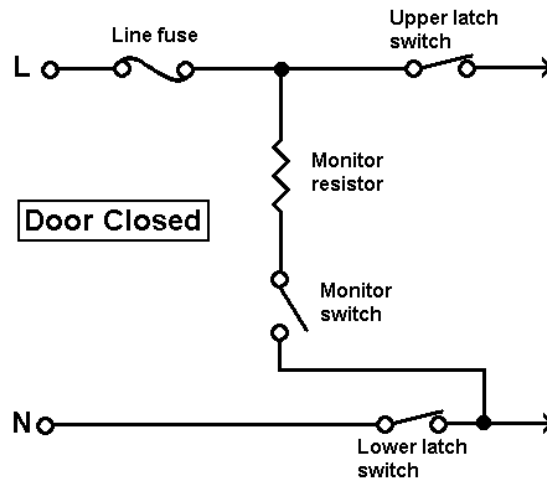
As the door closes, the monitor switch contacts are opened first, then both latch switches close. The oven can then be operated. The time difference in the operation of the monitor and the interlock switches is achieved mechanically.

The diagram below shows a fault condition. The lower latch switch, which is monitored, has remained closed when the door was opened. It can be seen that a short circuit exists across the input supply, via the monitor switch and the lower latch switch. This short circuit causes the mains input fuse to blow, preventing the oven from operating.



When an oven is encountered, with the line fuse blown, ascertaining when the fault occurred is necessary. If the fuse blew during a cook cycle, then the fault is probably due to a short circuit in the high voltage circuit. However if the fuse blew when the door was opened or closed, the fault will be a faulty monitor or latch switch. In which case both switches should be replaced, irrespective of which one is found to be faulty. This is because the contacts of the good switch will become pitted when the monitor circuit operates, due to the heavy current drawn. If not replaced, this would eventually lead to the fuse blowing again, because the operation of the switch is impaired.

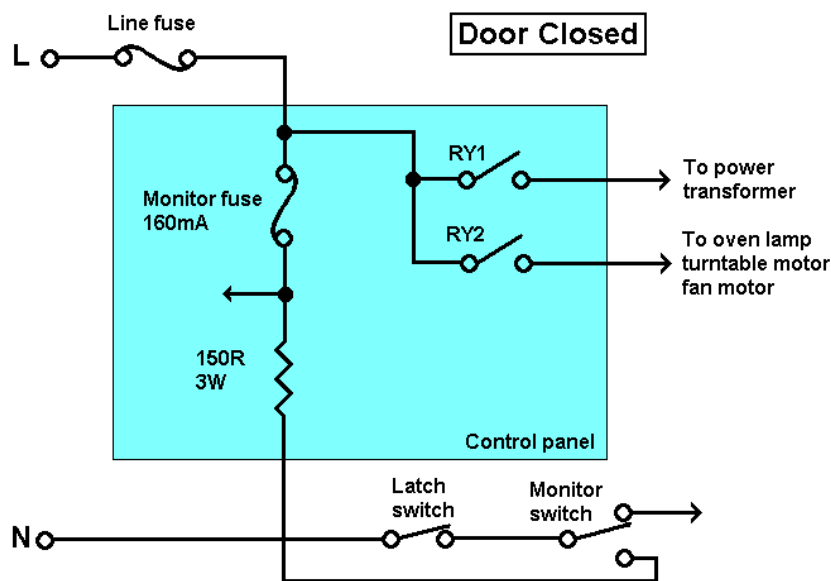
In early production models (before 1996) a monitor resistor was fitted between the line fuse and the monitor



switch. This was a low value resistor ( $0.8\Omega$ ) at 20 Watt, its purpose being to limit the current in the monitor circuit, while still ensuring fuse failure in a fault condition. This helps to prevent the fuse failing violently and exploding. As the regulations covering this part of the circuit was relaxed, the monitor was phased out of production.

### Monitored Switch Arrangement

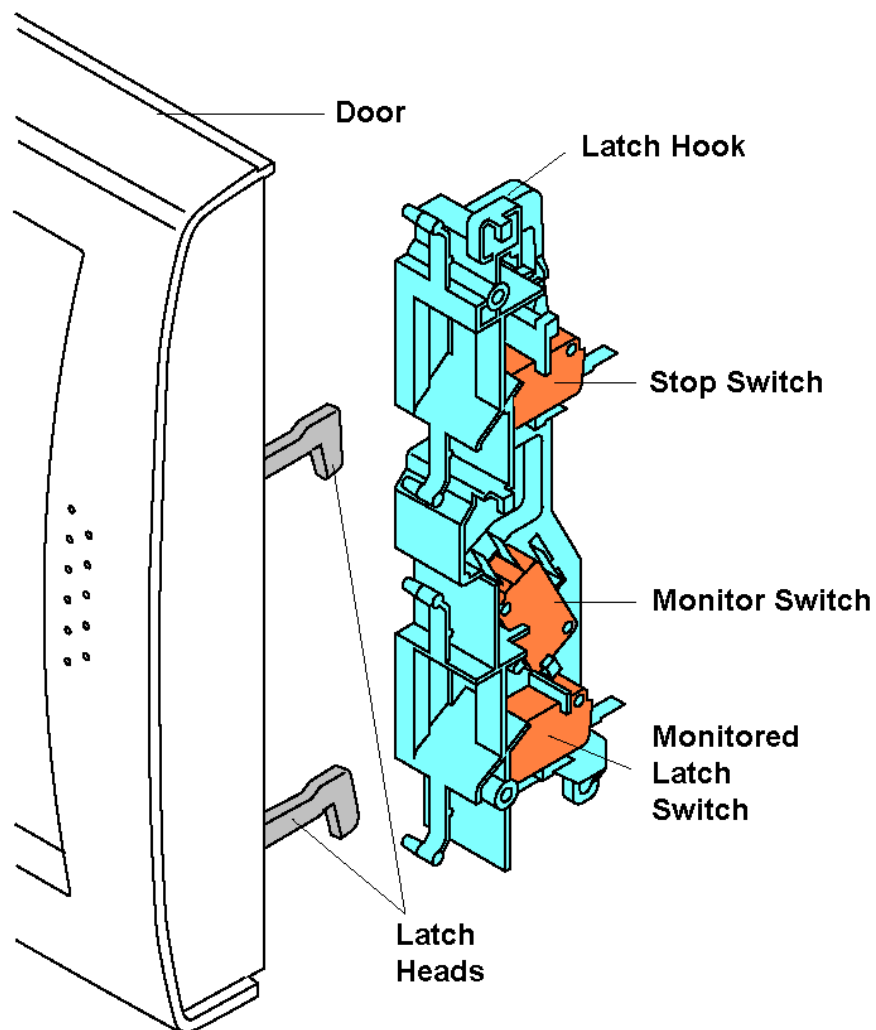
On later production of electronic control ovens (1998 onwards), a T160mA fuse has replaced the monitor resistor. In this circuit when the monitor switch or latch switch sticks the T160mA fuse will blow. This will remove power to the control panel, preventing the relays from operating. When this fuse is open circuit, replacing the monitor and latch switch would still be prudent.

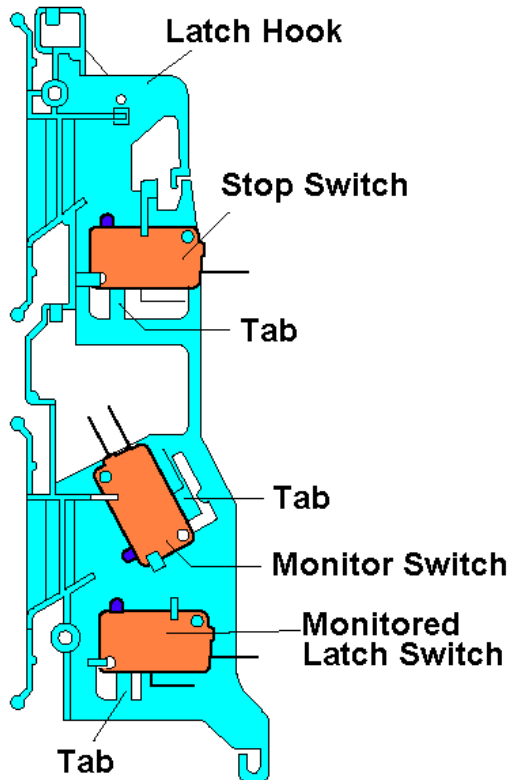


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## Mechanical Door Switch Operation

When the door is opened, the latch heads will lift disengaging the latch switch contacts. Then as the door moves away from the cavity the monitor switch actuator is released which closes the contacts. This action provides the necessary time delay between the latch switch and monitor switch operation. When the door is closed, the monitor switch contacts are opened as the latch head engages with the actuator. Then the latch heads drop into their final position in the latch hook assembly and the latch switches close. Again a time delay exists between the monitor and latch switch operation.





The diagram on the left shows more clearly the way the monitor and latch switches operate. The stop switch is used in electronic control ovens, to indicate to the microprocessor if the oven door is in the open or closed position. When the door is open, the keypad will not accept any commands.

On manual ovens the stop switch will be used as a second latch switch. In some older electronic control models, both the stop switch and a second latch switch are used.

## Door Switch Practical Problems

Switch types used in Sharp microwave ovens sometimes differ, depending upon the model. An example is, some ovens use a single-pole change over switch to enable the fan motor and oven lamp to operate when the door is opened.

The monitor switch is a 'normally closed' (NC) switch, which means that when the actuator button is not depressed then the contacts are closed. These should not be confused with latch switches that are normally open (NO) switches, in this type of switch the contacts are open when the actuator is not depressed. It is therefore very important that the correct type of switch is used when replacing these switches.

Although a simple idea, the door latch and monitor switching can sometimes create problems when an oven has a blown fuse. When a monitor or latch switch becomes permanently closed, the fault is reasonably easy to find. The oven's internal fuse would fail when the door was opened.

Imagine now a switch that, through wear, has become slow to operate, it would mean that when the door of the oven was opened, for a short time only, the monitor switch and latch switch would be closed at the same time. This of course would blow the oven's fuse, but the switch would then return to its correct position and make the fault impossible to check. This kind of fault can be very intermittent which compounds the problem. Keep in mind when dealing with this type of circuit that the fuse will always fail when the door is opened or closed, this sets an interlock problem apart from other fuse blowing faults. If the fault is of an intermittent nature then the best course of action is to change the monitor switch and the latch switch that is monitored.

Door switches can usually be adjusted, by altering the position of the latch hook assembly to which the switches are fitted. A full description of the procedure can be found in the relevant service manuals. The adjustment of the latch hook assembly will affect the amount of space between the door and the cavity and will therefore affect leakage levels. It is very important that door switch adjustments are carried out properly.

It is possible that you may encounter occasionally some older models of Sharp microwave ovens that do not have a monitor switch fitted. These ovens incorporate two or more switches in the supply circuit to the output section of the oven. In such cases one of these switches will have a dual role, acting also as a cook or start switch. When this arrangement is used, the cook/door switch is mechanically interlocked, which physically prevents operation of the switch with the door open.

# **SHARP**

## **Microwave Oven**

### **Technical File**

**Volume 4 –Timer/Power  
Control/Thermal Cut-outs/Lamps and  
Convection**

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## Timers

It is necessary in a microwave oven to time the cooking operation carefully. The speed at which microwave ovens cook means an error of just two or three minutes can make the difference between food being cooked correctly and food being spoilt by overcooking. Sharp microwave oven timers allow customers to pre-set the cooking time. At the end of cooking cycle there is a signal to inform the user that the food is ready.

In the case of the electro-mechanical ovens, the timer consists of a motor that turns a cam to operate a switch, at the end of the set time a bell is sounded. At that time the cam causes the timer switch to open.

Ovens using electronic control systems employ a microcomputer, part of which operates as a clock. This allows the cooking operation to be timed accurately, a beeper signals the end of cooking.

In mechanical ovens, the motor is energised when the timer is set and the oven is turned on, its function being to turn the timer mechanism slowly back towards the zero setting. Thus switching off the supplies to both to the output section of the oven and the timer motor itself. The time remaining is indicated by the timer control knob, which as it turns back aligns with a time scale marked on the control panel escutcheon.

### Practical Problems

When setting a mechanical timer for times of five minutes or less, it is necessary to turn the control knob past the five minute point and then rotate it back to the time required. This action makes sure that the mechanism is primed correctly, giving a more accurate time.

These types of timers usually have a thirty-minute or a one-hour maximum setting. If it is necessary to replace a timer, check that the one being fitted is of the correct span. Only timers having the correct part number for the model under repair should be used.

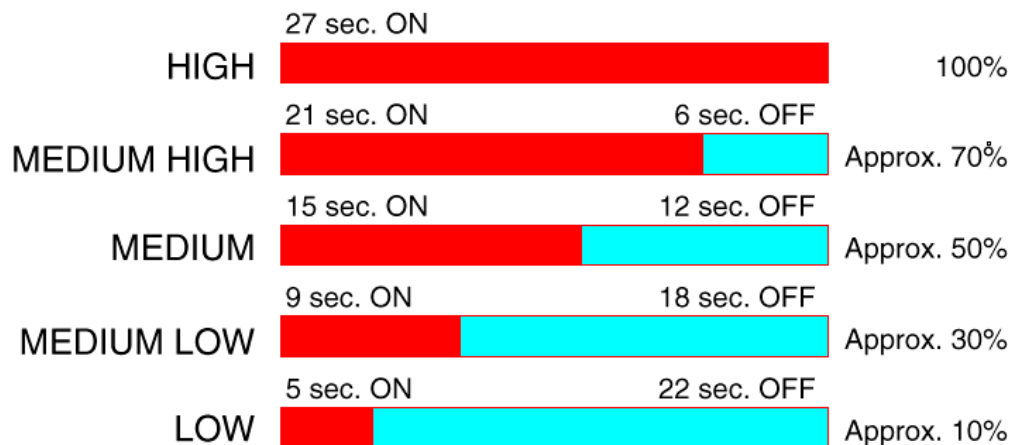
## Variable Power Control

It is desirable when cooking with microwave ovens, as with conventional ovens, to have some control over the ovens power level. Some foods benefit from being cooked slowly. As we have already seen in the section entitled '**Characteristics of Microwave energy**', that microwave energy is absorbed at different rates depending on the substance being heated, some form of cooking control is desirable, as with conventional ovens.

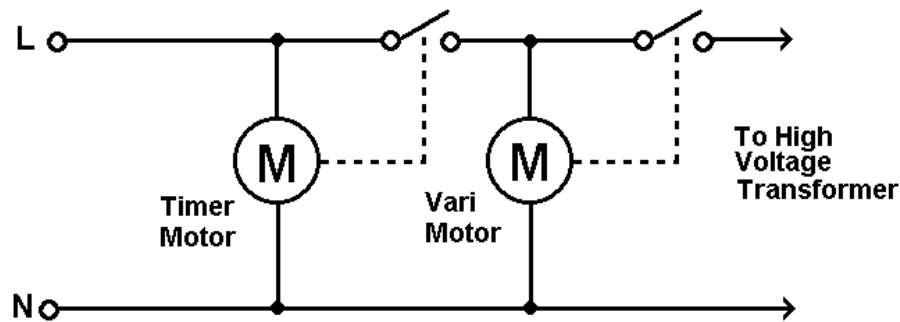
For this reason most microwave ovens have at least a defrost mode in addition to full power, and more usually a range of power settings. Sharp ovens achieve these different levels of power by always operating the magnetron at full power on a cyclic system. As can be seen in the diagram below.

This system involves the magnetron being turned 'on' and then 'off over a pre-set period. The 'on' time is varied according to the power level selected. There is included in the on time an extra two seconds for magnetron warm up time.

Electronically controlled ovens achieve the different power settings with the use of a microprocessor. The switching is achieved with the use of a relay, controlling the oven power in the same way as for mechanical ovens.



The method adopted by Sharp in mechanical ovens is a relatively simple one. As already stated, only a motor and cam gear assembly to operate a switch is required. This unit is in the control section of the oven, in the live side of the mains input to the high voltage transformer primary winding.



Some manufacturers use other methods of power control, which involve altering the dynamic conditions within the magnetron circuit. One example of this is to switch in an extra capacitor when full power mode is selected. This increases the voltage across the magnetron, therefore more power is produced. This type of method employs high voltage relays or some mechanical means of carrying out the required switching within the high voltage circuit.

Another method of achieving a power control is by using a Triac. This method again controls power by altering the dynamic conditions of the magnetron. These dynamic methods of power control make fault finding more difficult due to the increased complexity of the circuitry. Also where more testing of the high voltage circuitry is necessary, there is an added safety risk.

As already mentioned, Sharp ovens using electronic control systems also employ switching in the primary supply of the power transformer to achieve control of power levels. However, instead of a vari-motor, a relay is used, which is controlled by a microprocessor.

## Practical problems

It is worth considering the possible faults that may occur with a vari-motor system. There are only two main possible sets of symptoms and they are (a) no power at all in any mode and (b) possible over cooking in all modes except full power.

If the switch within the vari-motor is always open, perhaps because of the switch failing or due to a motor or gear fault there would be no voltage supply to the primary of the HIGH VOLTAGE transformer, therefore no power output.

Conversely if the switch within the vari-motor remains closed, again due to either switch or mechanism failure, then the supply to the HIGH VOLTAGE transformer primary would be present as soon as the oven was put into cook mode. The power output level would not alter when a lower power level was selected, therefore food would be overcooked on lower power settings.

A quite normal phenomenon, when using a power setting other than full power, is to hear thumping sound as the side of the outer wrap is distorted due to the magnetic field set up within the transformer when it is energised. This is just like the action of a drum. Some ovens have a piece of fire retardant packing between the high voltage transformer and the outer wrap, which minimises this effect.

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## Thermal Protection

All Sharp ovens are fitted with at least one thermal cut-out or thermal fuse which is intended to stop the oven operating in the event of the magnetron overheating, or if excessive temperature is present within the cavity. The former can be due to either thermal runaway in a faulty magnetron, or simply because of inadequate cooling, caused by a problem with the cooling fan or ducting. Whereas the latter is simply the result of food being significantly overcooked.

In early models, the cut-out was fitted directly onto the magnetron and possibly one above the cavity roof. More recently the cut-outs are positioned slightly away from the magnetron. By reducing the cut-outs operating temperature, it is possible to provide satisfactory protection to both the cavity and the magnetron with a single device.

### Thermal Cut-outs

These devices were fitted to some earlier models and are described as 'thermal cut-outs' in the parts lists of the manuals of the ovens to which they are fitted. On reaching the specified temperature, a bi-metallic strip bends causing the contacts to open, thus disabling the HIGH VOLTAGE circuit of the oven.

This will allow the heat to dissipate from the oven, the cooling of the bi-metallic strip will then allow the contacts to close again which in turn will result in further excess heat being produced (unless the cause has been removed) starting the cycle again.

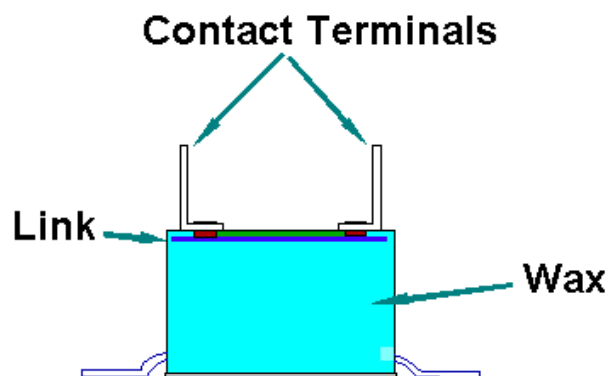
Some later ovens use this type of cut-out, which are riveted to the top of the cavity. Sometimes when they trip, they do not reset themselves, In these circumstances, spraying 'freezer' directly onto the cut-out will usually make the bi-metallic strip spring back into position. If however the cut-out has to be replaced, the old one will have to be drilled out. A self-tapping screw to fix the new cut-out is supplied with the replacement part.

### Thermal Fuses

As suggested by their name, once these devices reach the specified temperature, they 'fuse' or go open circuit permanently. As before the parts list usually provides an accurate title for these devices.

When these fuses are heated beyond their specified temperature, the waxy material inside melts allowing the internal link to drop away from the contacts, resulting in an open circuit between the terminals. These devices do not reset and have to be replaced once the reason for the failure has been rectified.

Some older thermal fuses and cut-outs are similar in appearance and in size, there are also various operating temperatures used dependant upon the power output of the oven. Therefore it is possible to fit an incorrect type. It is most important when one of these components requires replacement the new part is the correct type, using the part number supplied in the relevant manual.



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## Oven Lamps

Oven lamps are used to illuminate the microwave oven cavity during cooking and (in most models) when the door is opened.

A number of lamp circuit designs and types of lamps have been used in Sharp microwave ovens so voltage ratings and method of fixing will depend on the model of oven.

Modern models use a single lamp rated at 240V A.C., but in older models two lamps are used, connected in series and are each rated at 125V A.C. The majority use a screw type fitting, but some models use an integrated lamp and fitting.

The replacement of oven lamps is not something customers should be encouraged to do, except where an inspection hatch is provided in the outer case of the oven allowing safe access to the lamps. In such cases, it is possible for customers to fit lamps. In all cases where the fitting of the oven lamps requires the removal of the outer case of the oven, under no circumstances should customers attempt lamp replacement.

### Practical Problems

Although the oven lamp circuit appears to be one of the least complex parts of a microwave oven, it is worth considering the sort of problems an engineer may encounter.

Under certain circumstances it is possible for oven lamps to fail and in doing so cause the oven's internal fuse to fail also. This is usually due to debris from the filament short-circuiting the supply to the bulb internally. Therefore a microwave oven may appear to have a major fault when in fact only minor parts require replacing.

Another problem an engineer may have to deal with is a complaint of "one of the bulbs in my microwave has blown". There is in fact no fault at all, but to understand the problem it is necessary to consider the oven cavity design. Most Sharp microwave oven cavities have a grill formed in to them to light up the food as it cooks, there are also grills to allow air to circulate and steam to escape. A customer may look into the oven and see two or more grill openings, but light is only shining through one of them, the customer may assume that a lamp has failed.

As already stated a single lamp, or two in series, are used in all Sharp ovens, therefore if a lamp fails then all light would be extinguished. This problem has been known to arise even when a customer has used the oven for a considerable time.

All current Sharp microwave ovens do not have an hatch in the outer wrap to allow the user to change the bulb if it fails. This should not be the case as long life bulbs are used, but in the event of failure a qualified engineer must replace it.

It should also be noted that the top of the oven outer wrap may become very warm due to the heat from the bulb, this is not a fault.

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# Convection Ovens

## Convection Temperature

In order to measure the convection temperature accurately a 'K' type thermocouple connected to a digital meter should be used. The sensor should be placed in the exact centre of the cavity so that the correct temperature can be measured, failure to do this will result in an inaccurate measurement. The oven should reach its maximum temperature; within 35 minutes (normally 15 to 20 minutes) for 250° oven without using preheat. The permitted tolerance is +/-15 degrees Celsius.

### Note

1. When using a thermocouple, do not enter any microwave cooking modes (dual cook or microwave) as the thermal couple sensor will be damaged.
2. Accurate convection temperature test can not be achieved with ovens that simulate convection cooking by using top and bottom grill elements

## Damper Door Operation

During microwave mode, the air that is blown past the magnetron for cooling purposes is directed through the cavity, to remove excess moisture and help prevent a build up of condensation. This airflow would greatly reduce the cavity temperature in convection mode, if it were allowed to continue to blow through the cavity. Therefore a damper door is used to prevent air from flowing through the cavity in convection mode, while allowing air through the cavity during microwave cooking. In manual ovens this is achieved mechanically, in electronic ovens the damper door is controlled by the microprocessor. The door is operated by a cam driven by a motor, which is controlled by the microprocessor via a relay. The cam also activates a switch, which is connected to an input of the microprocessor, to indicate the position of the damper door.

If the microprocessor does not receive information from the switch, within one minute, it will turn off the oven whichever mode it is in. Fault diagnosis is relatively easy, if the damper door doesn't move, then the relay drive transistor, the relay motor or cam are suspect. If the damper door keeps turning, the fault is due to the switch or bad connection between the switch and microprocessor.

# **SHARP**

## **Microwave Oven**

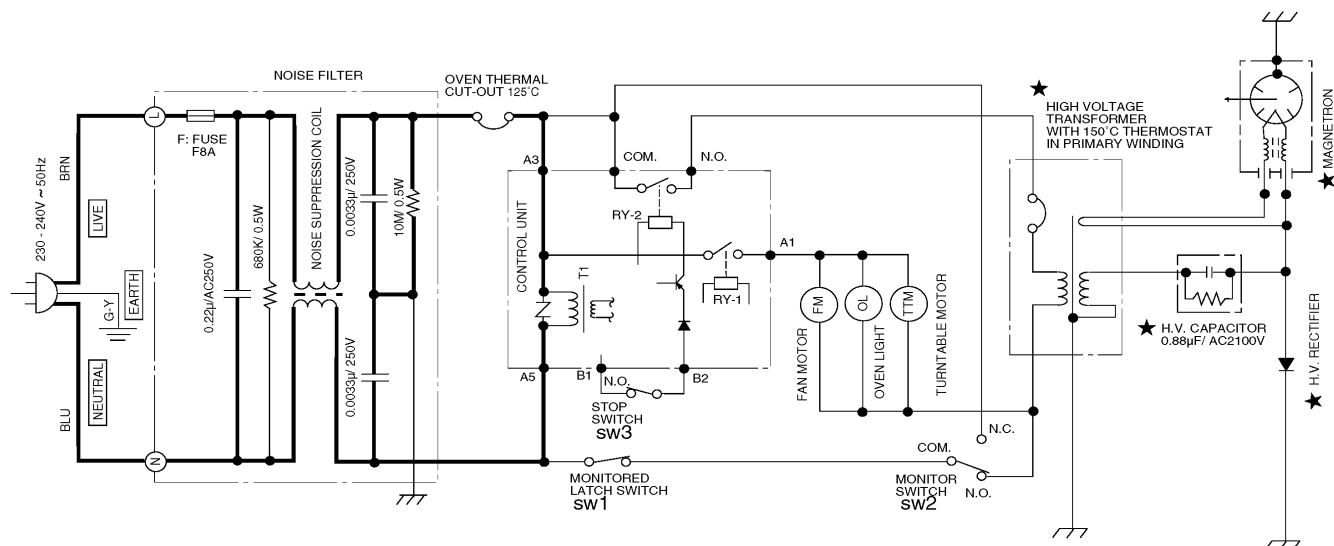
### **Technical File**

**Volume 5 – Practical Circuits and  
Fault Fining**

# Practical Circuits and Fault Finding

So far the emphasis has been on high voltage production and the RF side of the microwave oven. The magnetron, high voltage circuitry, the waveguide and cavity and the door, can be thought of as the output section of the oven.

There is a dividing line between the high voltage circuit and what may be called the 'control' section of the oven, which is the high voltage transformer. This can be seen in the diagram below.



This simple division of the oven into the high voltage section and control circuitry, can be used to decide the approach that should be taken to identify the fault in an oven that is not cooking. This is based on whether or not power being available to the high voltage transformer, which is the first check to make. It is normally possible to ascertain whether or not current is flowing through the high voltage transformer primary, without removing the outer cover. Simply by putting the oven into the cook mode and listening carefully for the characteristic "thump" that occurs when the transformer is energised. If the "thump" is not present, then attention should be directed to the 240V A.C. control circuit, not forgetting the possibility of the transformer primary being open circuit.

Conversely, if this can be heard, then the high voltage circuitry is suspect. If the "thump" is followed by a louder than normal continuous hum, this will normally indicate the presence of a heavy overload caused by a short circuit in the secondary of the high voltage transformer.

Once this preliminary diagnosis has been made, the next step is to dismantle the oven for further investigation.

## Fault Finding on the Control Circuit – Electro-mechanical Ovens

There are two approaches to fault finding on the control part of this type of oven, 'live' or 'cold' testing. The choice between these procedures is up to the discretion of the individual engineer. However, where the live testing method is chosen, we strongly recommend that the connections to the high voltage transformer primary be disconnected. More importantly this will remove any possibility of high voltages being produced when the oven is operated, thus removing a major safety risk. A good tip here is to connect a 240V A.C. bulb (in an insulated holder) in place of the transformer, this will act as an indication of the correct operation of the control circuit.

Should the choice be to use cold testing, continuity checks with the power disconnected will enable the fault to be easily located. By placing the oven in the cook function (timer set to five minutes, power set to full, door closed and cook switch in the on position) continuity should be measured from the live and neutral plug connections to the high voltage transformer. Note that the high voltage transformer needs to be disconnected so that no low resistance path is measured between the live and neutral lines.

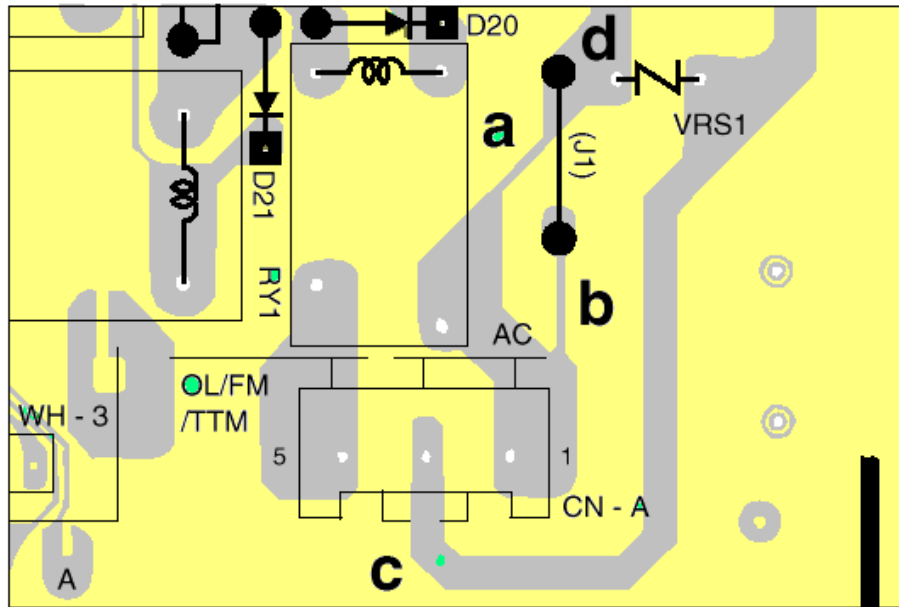
To reduce the amount of checks needed, first of all check which functions work and which don't (e.g. lamps, cooling fan, turntable, etc.), then carefully examine the circuit.



switch is also fed into the microprocessor, so that when the door is open, the buttons on the touch panel are inoperative.

### Low voltage transformer mains input protection

To protect the electronic circuits, the PWB is provided with a fine foil pattern added to the primary side of the low voltage transformer. This foil pattern acts as a fuse. If the foil pattern is open circuit, follow the troubleshooting guide given below for repair.



#### CARRY OUT 3D CHECKS.

STEPS	OCCURANCE	CAUSE OR CORRECTION
1	The rated A.C. voltage is not present at POWER terminal of connector.	Check supply voltage and oven power cord.
2	The rated A.C. voltage is present at primary side of low voltage transformer.	Low voltage transformer or secondary circuit defective. Check and repair.
3	Only pattern at "a" is broken.	*Insert jumper wire J1 and solder. <b>CARRY OUT 3D CHECKS BEFORE REPAIR</b>
4	Pattern at "a" and "b" are broken.	*Insert the coil RCILF2003YAZZ between "c" and "d". <b>CARRY OUT 3D CHECKS BEFORE REPAIR</b>

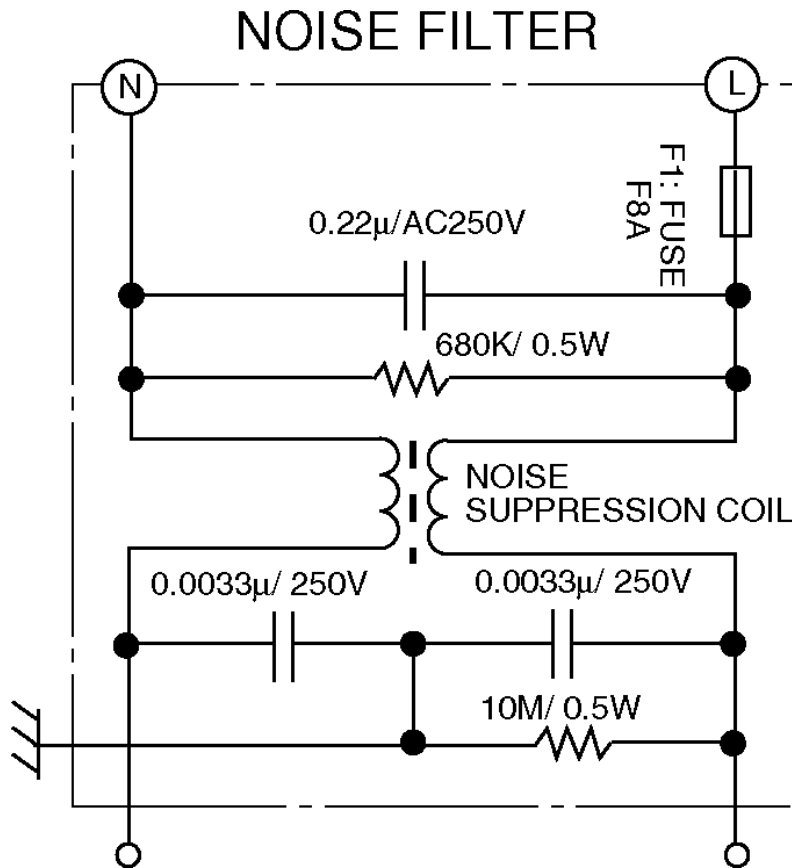
\*While undertaking these repairs, make a visual inspections of the varistor (VRS1) for burning damage. The varistor provides short-term protection against high voltage 'spikes' that may enter the mains supply and damage T1. Also check the primary winding of the low voltage transformer with a meter for the presence of layer short-circuit and if any abnormal conditions are detected, replace the defective parts.

#### CARRY OUT 4R CHECKS.

## Filter Network

The circuit below shows one type of filter used in Sharp microwave ovens. These filters prevent any interference produced by the oven appearing on the mains, they also prevent mains borne interference affecting the oven.

The two  $0.0033\mu\text{F}$  capacitors are connected from the positive and negative mains supply down to ground. The values of these capacitors are chosen to have a high reactance at 50Hz, but have a low reactance, low impedance, at high frequency, thereby removing the high frequency component by conduction to ground.



It should be noted that because of the centre connection of the two capacitors being returned to the chassis of the oven, problems could occur if an oven is operated without an efficient earth. With a poor earth connection, the case will acquire half mains' supply potential (very low current) and under certain circumstances a person that makes contact with the microwave may experience a small electrical shock. This effect is not due to any defect in the oven, and is easily remedied by making a good earth connection.

A microwave oven, should always be fitted with a 3-pin plug, fitted with a 13A fuse and connected to an earthed supply.

# **SHARP**

## **Microwave Oven**

## **Technical File**

**Volume 6 – Commercial Microwave  
Ovens**

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# Sharp Commercial Microwave Ovens

Sharp domestic microwave ovens are intended for normal home use, their design, construction features and price reflect the usage likely to be encountered in the average home.

Microwave ovens are also used extensively in hotel kitchens, cafes, public houses and many other commercial environments. However ovens operating in these situations are usually required to reheat or defrost large quantities of food very quickly compared with a domestic oven. In addition they are likely to encounter much heavier use and abuse.

To suit this type of environment, Sharp manufacture a range of commercial microwave ovens. These ovens are physically larger than a domestic microwave oven being capable of holding bigger loads, and are also of heavier construction. The commercial ovens also have a much higher RF power output, up to double that of domestic ovens.

Another difference between domestic and commercial microwave ovens is the method of energy distribution within the cavity. Sharp domestic ovens generally use turntables whereas the commercial range of ovens employs stirrer fans. See the section Distribution of Energy within an Oven Cavity.

Magnetrons fitted to commercial ovens are usually of a higher quality to handle the heavier usage. The power output obtained from a magnetron is reduced as the magnetron gets warm. This effect is more noticeable on domestic ovens, but usually doesn't cause any problems due to their relatively light usage. However if a domestic oven was used in a commercial environment, the reduction in power output could be quite severe, causing food to be undercooked. This could lead to problems with food poisoning. For this reason a domestic oven should never be used in commercial circumstances. The guarantee for a domestic oven is invalidated if it is being used commercially.

## Increased Power Output Using Two Magnetrons

In some respects Sharp commercial microwave ovens can be thought of as 'double' domestic models. The increased power is achieved by employing two magnetrons, therefore two power transformers and two separate high voltage circuits.

As already discussed in the section entitled Half-wave Doubler Overview, the magnetron in a domestic microwave oven is in fact only producing microwave energy during the negative half cycle of the mains supply. In a commercial oven the two power transformers used are connected in such a way as to achieve 180 degrees out of phase outputs from their secondary windings. As the secondary winding outputs are out of phase, this means each magnetron operates alternately. This means that there is always microwave energy present in the cavity, as opposed to the pulsating energy when a single magnetron is used.

In earlier models of commercial microwave ovens a separate transformer to provide the filament voltage was used. In later models, the high voltage transformers have the filament windings built in as with domestic models,

## Improved Heating Pattern

As commercial microwave ovens use two magnetrons, there are effectively two heating patterns super imposed upon each other within the cavity. This means any area of lower energy within a pattern is compensated by the other pattern. The result is a more uniform heating pattern because of the difference caused by the positions of the two magnetrons. In later models, one magnetron output is fed into the top of the cavity, the other into the bottom.

## Additional Cooling

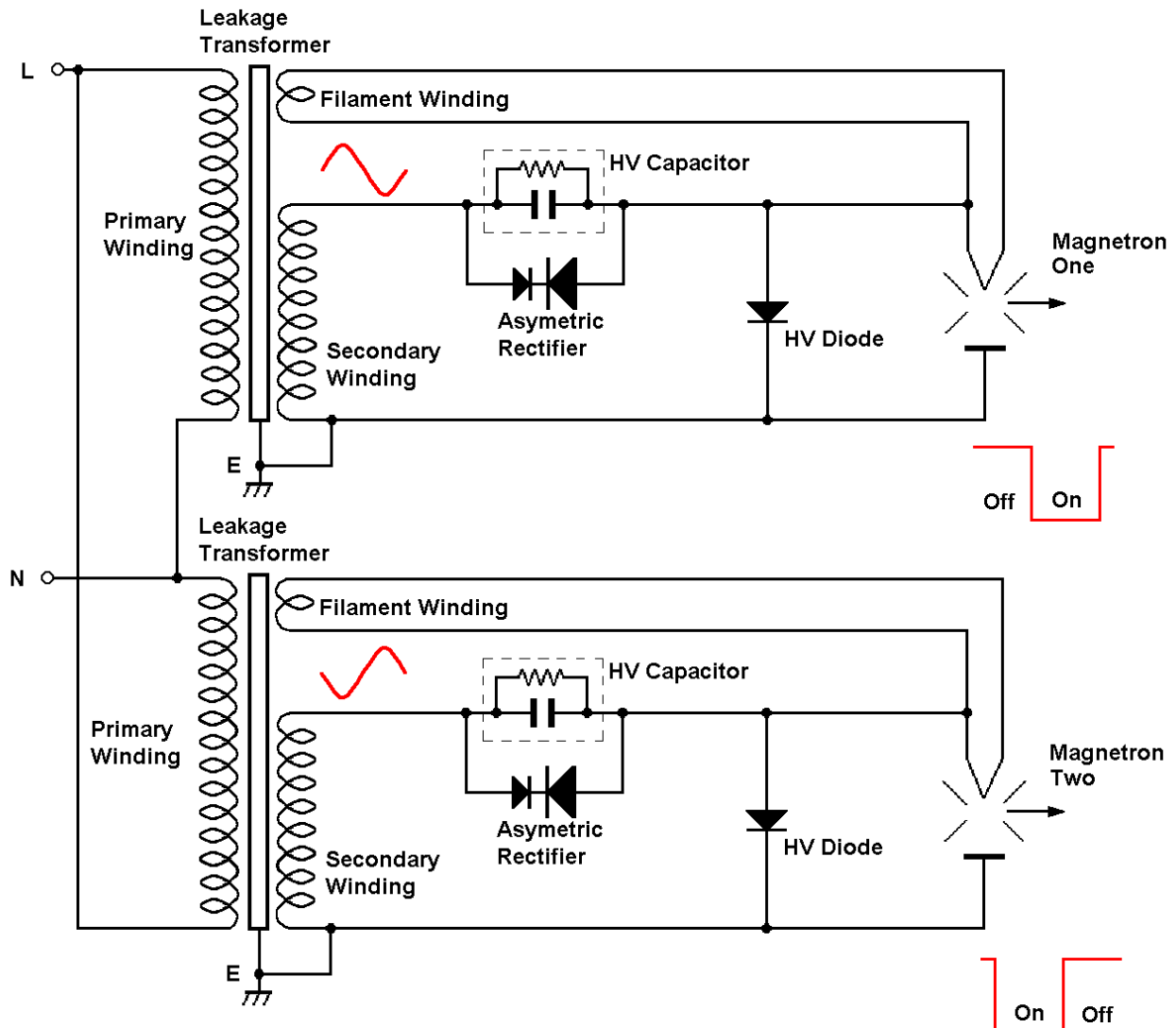
The two magnetrons are usually positioned some distance apart, it is therefore necessary to use two separate cooling fans. The magnetrons are also fitted with independent temperature fuses which if they cut-out will only disrupt the power to the high voltage circuit that was at fault, not necessarily both circuits together, this is dependant on the specific model and the relevant service manual should be consulted.

Cooling is normally continued at least thirty seconds after the end of the cooking cycle so that the efficiency of the magnetrons is maintained at a reasonable level. If this were not done, it would take several seconds for the fan to cool magnetrons down sufficiently for the power output to rise.

## On-Off switching

Some Sharp commercial microwave ovens are filled with a mains On-Off switch, which allows the oven to be completely isolated from the mains, as far as the user is concerned. The switch is located underneath the oven, usually to the right hand side at the front. For service work, remember to still carry out the 3D checks.

This type of switch is not fitted to domestic models, so this may catch out engineers not familiar with commercial ovens. It is worth mentioning that this switch has been the cause of occasional service calls, due to it being inadvertently operated when the oven is being cleaned.



## Timers

Commercial ovens sometimes have additional repeat timers fitted, thus enabling a batch of items requiring the same cooking time to be cooked in succession without the operator having to re-set the time. Some ovens have a series of keys that can be pre-programmed with various times, so when one of the pre-set times is required there is only one button to be pressed. This type of timer is useful in a canteen for example, where food can be reheated in an oven operated by the person buying the food, a label on the food packaging can show the required time or key.

Timers of this sort are generally not mechanical. Instead a microprocessor circuit is used and therefore a **detailed description** is beyond the scope of this book.