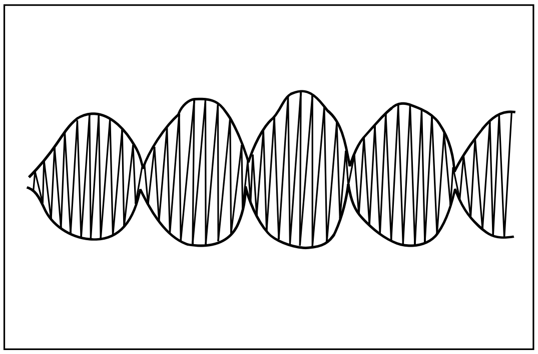
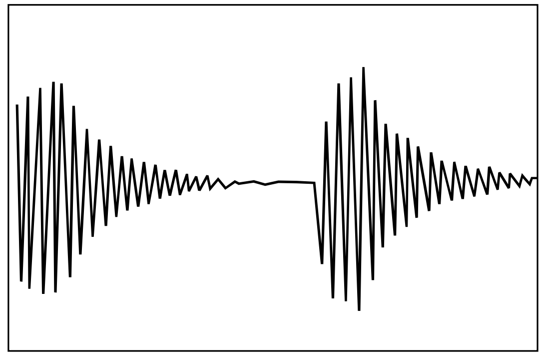
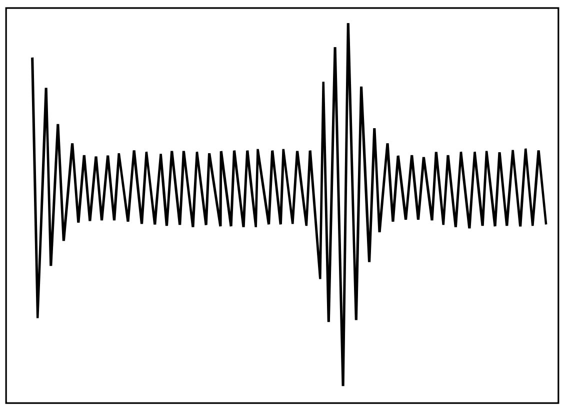


(c)



(d)



(e)

➤ **Fig. 27.3** ***Types of waveforms generated by surgical diathermy machines:***
(c) ***Coagulate waveform generated by spark gap generator***
(d) ***Coagulate waveform generated in a solid state diathermy machine***
(e) ***Blend waveform generated in a solid state diathermy machine***

electrode and biological tissue. If the voltage is less than 200 V_P, the electric arcs cannot be triggered and the tissue cannot be cut. The voltage suitable for cutting biological tissue ranges between 200 V_P and 500 V_P. If the voltage rises above 500 V_P, the electric arcs become so intense that the tissue is increasingly carbonized and the cutting electrode may be damaged. A visible arc forms when the electric field strength exceeds 1 kV/mm in the gap and disappears when the field strength drops below a certain threshold level.

Biological tissues are coagulated by thermal means if the requisite temperature is maintained at around 70^{o}C.

27.2 SURGICAL DIATHERMY MACHINE

Basically, a surgical diathermy machine consists of a high frequency power oscillator. The earlier types of diathermy machines consisted of spark-gap oscillators whereas the current practice is to use thermionic valves or solid-state oscillators. A majority of the earlier units have access to both these power sources, viz. an RF generator and a spark-gap generator.

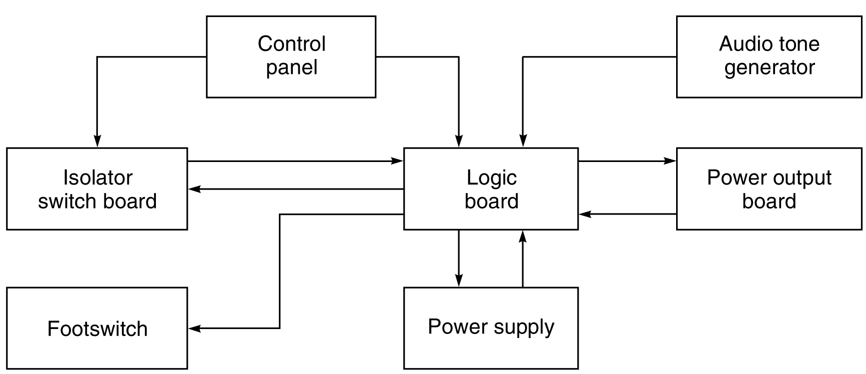
The RF generator provides an undamped high frequency current (typically 1.75 MHz) which is suitable for making clean cuttings. The spark-gap generator produces damped high frequency current which is specifically suitable for the coagulation of all kinds of tissues. The mixing of both these currents signifies one of the most important possibilities for use in electro-surgery. By blending the currents of the tube and spark-gap generator, the degree of coagulation of wound edges may be chosen according to the requirements.

Whilst the detailed waveform and frequency spectrum used varies from one manufacturer to the other, the basic concept requires a high temperature arc, possibly exceeding 1000°C (Dobbie, 1969) at the operative site. In practice, the cross-section of the arc is extremely small, considerably less than 1 mm diameter, leading to a high current density in the arc. As the heating effect is proportional to the square of the current density, the effect is localized to form the arc. Other factors affecting the rise in temperature are the composition of the tissues and the magnitude of cooling provided by the local blood flow or any other heat transport system.

Despite the fact that surgical diathermy machines have been routinely employed for over half a century, the most significant technological developments have occurred within the past decade only. Solid-state generators have replaced a substantial number of vacuum tube and spark-gap units. Disposable, self-adhering dispersive electrodes (generally known as 'ground pads') are now widely used in place of the large area buttplate. A number of design features have enhanced safety. These features include a variety of circuit integrity monitors like dispersive electrode cable continuity, patient circuit continuity and alternate-path current monitors, among others.

The frequency of operation of solid-state diathermy machines is 250 kHz to 1 MHz. They deliver 400 W in 500 Ω load at 2000 V in the cutting mode and around 150 W in the coagulation mode. In coagulation, the burst duration is 10–15 s and repetition frequency of the burst is 15 kHz.

Figure 27.4 shows a block diagram of the solid-state surgical diathermy machine. The heart of the system is the logic and control part which produces the basic signal and provides various timing signals for the cutting, coagulation and haemostasis modes of operation. An astable multi-vibrator generates 500 kHz square pulses. The output from this oscillator is divided into a number of frequencies by using binary counters. These are the frequencies which are used as



➤ **Fig. 27.4** *Block diagram of solid state electro-surgical unit* system timing signals. A 250 kHz signal provides a split phase signal to drive output stages on the power output circuit. A 15 kHz gating signal produces the repetition rate for the three cycles of the 250 kHz signal which make up the coagulating output. The pulse width of this output is set at about 12 μs.

The 250 kHz signal used for cutting is given to power output stage where it controls the push-pull parallel power transistor output stage. The output of this high power push-pull amplifier is applied to a transformer which provides voltage step-up and isolation for the output signal of the machine. In order to meet the high power requirements, as much as 20 transistors are used in a parallel Darlington circuit. However, the power output amplifier circuitry varies considerably among the different commercial equipment. The modern machines employ both bi-polar junction transistors and power metal oxide-semiconductor field-effect transistors (MOSFET) in a cascade configuration or the use of a bridge connection of MOSFETs.

In order to facilitate identification of each mode of operation, the machines incorporate an audio tone generator. The tone signals are derived from the counter at 1 kHz (coagulation), 500 Hz (cutting) and 250 Hz (haemostasis). The isolator switch provides isolated switching control between the active hand switch and the rest of the unit. A high frequency transformer coupled power oscillator is used in which isolated output winding produces a DC voltage. The load put on the DC output by the hand switch is reflected back to the oscillator, accomplishing isolated switching. There is a provision to interrupt the power output if so desired.

Besides these basic functional circuits, logic circuits are used to receive external control signals and to operate the isolating relays, give visual indications and determine the alarm conditions. The logic circuits receive information from the foot-switch, finger switch and alarm sensing points. A thermostat is sometimes mounted on the power amplifier heat sink. In case of over temperature, it becomes open-circuited, signalling an alarm and interrupting the output.

The output circuit in the diathermy machine is generally isolated and carefully insulated from low frequency primary and secondary voltages. Blocking capacitors serve to effectively prevent any low frequency from appearing in the output circuit, and the isolated output reduces the possibility of burns due to an alternate path to ground. Complaints of electrical shock during surgery can almost always be attributed to muscle contractions of the patient. This is caused by the rectification of the high frequency energy at the junction of the active electrode and the tissue in the presence of an arc, which is the actual means of performing electro-surgery. This phenomenon is observed most when operating in a site of sensitive nerve tissue. There is, however, no danger to the patient or to the operator due to this action. On the other hand, anyone in close proximity to the radio-frequency carrying cables or electrodes will have some energy induced into his body. If by chance, he touches the metal cabinet of the surgical unit or any other conductive surface, current will flow through his body, resulting in a spark at the point of contact. It is advisable to avoid contacts with conducting surfaces by those who happen to be near the machine or cables.

The gases used in anaesthesia tend to settle near the floor. Therefore, the construction of the foot switch should be such that no explosion should occur in the atmosphere surrounding this switch caused by the operation of the electrical contacts within the switch.

Solid-state machines mostly incorporate an independent bi-polar RF generator for microsurgery procedures offering a fine output power control. The output waveform is a damped sinusoid at a