ELECTRONIC BUILDING BLOCKS

PART ONE

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Any piece of electronic equipment, no matter how simple or complex its design, can be broken down into a number of basic electronic "building blocks". All readers will, no doubt, be familiar with the type of "block diagram" shown in Fig. 1.1. This particular drawing depicts the functional layout of a conventional superhet receiver and, as can be seen, shows that the receiver consists of the following building blocks suitably arranged: r.f. amplifier, mixer, oscillator, i.f. amplifiers, detector, a.f. amplifier, power amplifier, and loudspeaker.

Once the principles of each of the above building blocks has been grasped, it becomes simplicity itself to understand the working of the complete superhet. By the same token, the intricacies of any piece of equipment are easily grasped if the basic building blocks employed are understood and, similarly, a designer must have a wide knowledge of all electronic building blocks if he is to develop a new piece of equipment to carry out a particular function.

It is the object of this series to lay before the reader the essential details of most of the basic building blocks in use at the present time. Basic functional and design details will be outlined in easily understood terms; a non-mathematical approach to the subject will be maintained, and in many cases practical circuits for the experimenter will be given.

The first part of this series is devoted to introducing the reader to some of the building blocks that will be described in more detail in subsequent issues.

SIMPLE ATTENUATOR

As the name implies, this circuit is used to give an output which is smaller than the input by a predetermined amount, but of the same general form. An example of this circuit is the volume control. In this case the precise amount of attenuation is of little importance and the control is not calibrated. In many cases the precise amount of attenuation will be of great importance, and the resistive values will have to be chosen with great care. The circuit shown in Fig. 1.2 gives an attenuation of 10 (or −20dB) the upper resistor being made 9 times as great as the lower one.

BRIDGE

A variation of the simple attenuator circuit is the basic resistance bridge. It can be seen from Fig. 1.3 that this circuit consists of two attenuator or voltage divider networks, with a common supply. The output is taken from between the two centre resistance junctions. If the *ratios* of the two dividers are the same, there will be zero voltage difference between the junctions. If the ratio of only one divider (R3 : R4, for example) is known, and the value of only one of the resistors in the other divider is known and the circuit gives zero voltage difference at the junction, the value of the fourth resistor can be calculated. This principle is used in the well known Wheatstone measuring bridge. By using reactive, instead of resistive, components in the dividers, the circuit can be used to measure values of capacitance, inductance, frequency or phase shift.

PASSIVE ADDING OR MIXING NETWORKS

The simple resistive network shown in Fig. 1.4 enables voltages to be added together without effecting or loading one another. The output is smaller than, but directly proportional to, the sum of the inputs. The circuit may be used for addition in an analogue computer, or as a mixing network.

FILTERS

As the reader will realise, filters are devices which enable one narrow band of frequencies to be selected from all others (such as in high pass or low pass networks), but the scope of this subject is so vast that it will be possible to discuss it only very briefly in this series.

DIFFERENTIATING CIRCUITS

These consist of a resistor and a capacitor as shown in Fig. 1.5. Also shown is the effect that the circuit may have on a square-wave fed into it. The waveshape is considerably altered. The "decay" time of the modified waveform can be calculated from the component values chosen, one of the most valuable properties of the circuit being that it contains an inherent time constant. This time constant is one of the most important and useful properties in electronics. It may be used, for instance, as a wave shaper. It also presents one of the limiting factors in amplifier frequency response.

DISCRIMINATING DIODE

It can be seen from the diagram for the differentiating circuit that, if a square wave is fed in, the output waveform has a positive and a negative "spike". In many cases only one of these spikes will be required; by wiring the diode as shown in Fig. 1.6, the negative spike will be virtually eliminated, i.e. the diode enables the circuit to discriminate between positive and negative voltages. If required, the diode can be reversed and the other spike rejected instead. This circuit is often used in direct reading frequency meters.

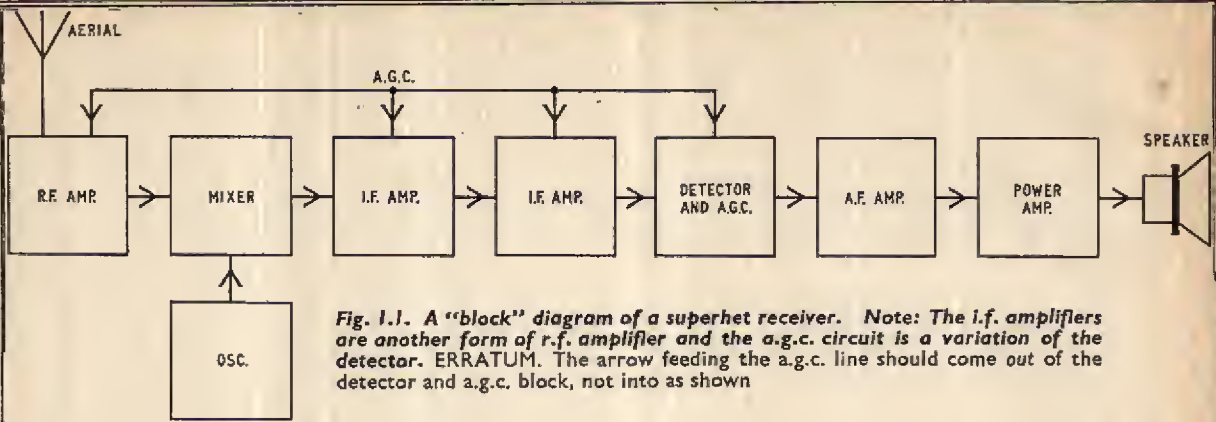

Fig. 1.1. A "block" diagram of a superhet receiver. Note: The i.f. amplifiers are another form of r.f. amplifier and the a.g.c. circuit is a variation of the detector. ERRATUM. The arrow feeding the a.g.c. line should come *out* of the detector and a.g.c. block, not into as shown

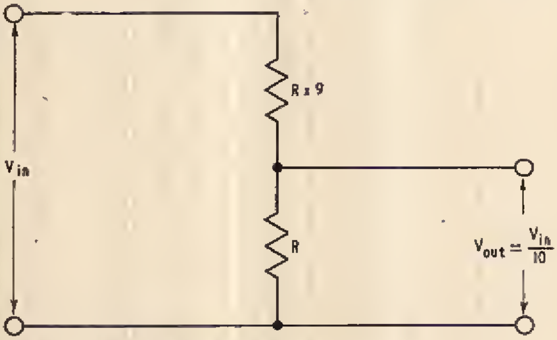

Fig. 1.2. A simple attenuator

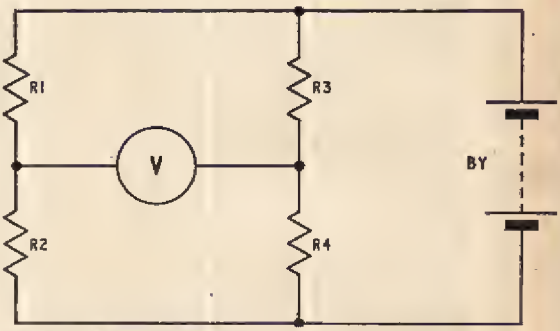

Fig. 1.3. A basic bridge

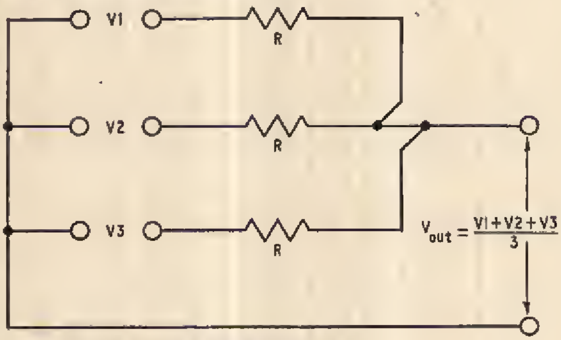

Fig. 1.4. A passive adding network

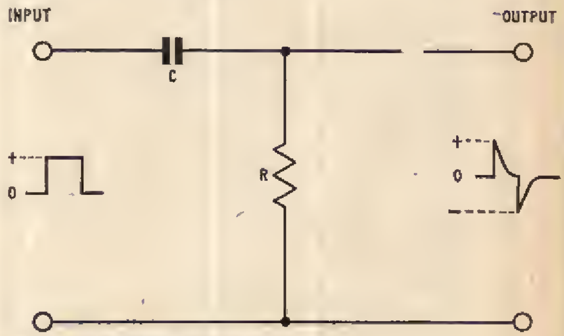

Fig. 1.5. A differentiating network

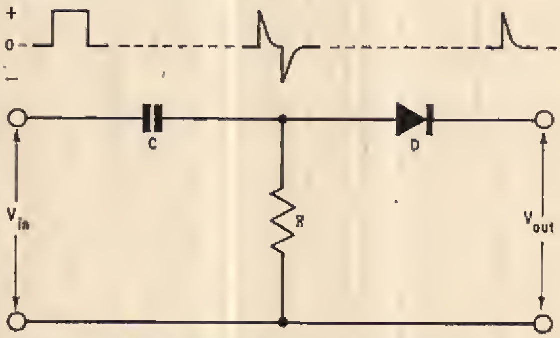

Fig. 1.6. A differentiating network with a discriminating diode added

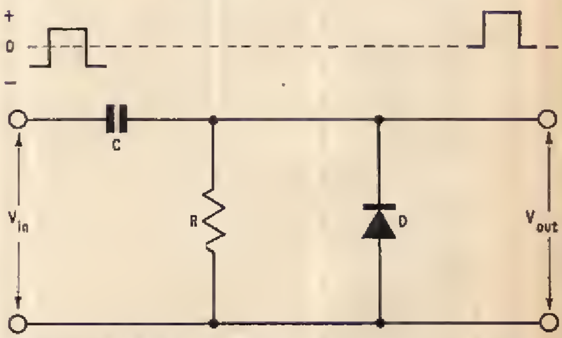

Fig. 1.7. A differentiating network with a clamping diode added

CLAMPING DIODE

If a rectangular waveform, which varies above and below the zero voltage point, is fed into the circuit, as shown in Fig. 1.7, the output will be of similar form and amplitude (if component values are suitably chosen) but will vary only in a positive direction. The diode serves to "clamp" the output to the zero reference point. The diode can be reversed if required, in which case the output will vary only in a negative direction.

DIODE LIMITING AND CLIPPING

If a sine wave is fed into the circuit shown in Fig. 1.8a, the diode will have the effect of clipping off all the negative half cycles and passing only the positive ones. This is, of course, the action of a conventional rectifier. If the positions of the diode and resistor are transposed, as in Fig. 1.8b, all the positive half cycles will be rejected and the negative ones passed.

DIODE GATE

One of several types of gate, the AND gate, is shown in Fig. 1.9. This type of gate may have several inputs, but only one output; an output is available only when *all* inputs are applied. Another gate circuit, known as the OR gate, has several inputs and only one output, the output being available whenever any input is applied. Two other widely used gates are the NOT and the NOR types.

AMPLIFIER

An amplifier may be put to many uses other than a.f., r.f., or power amplification. By employing a large degree of negative feedback, for example, any desired degree of gain can be accurately and reliably obtained, making the amplifier suitable for use as a mathematical multiplier. The block diagram of such an amplifier is shown in Fig. 1.10.

IMPEDANCE CONVERTER

It is often necessary to change the impedance in one part of a circuit prior to reaching the next stage. For example, it may be necessary to feed the output of an oscillator to a low impedance attenuator, but direct coupling would upset the working of the oscillator. The use of an impedance converter between the two stages will overcome this difficulty. The best known device of this kind is the emitter follower circuit, an example of which is shown in Fig. 1.11. This is the transistorised version of the well known cathode follower valve circuit. Both of these circuits have a high input impedance and a low output impedance, with a stage gain of almost unity.

PHASE SPLITTER

It is often required that two outputs, each out of phase with the other by 180 degrees should be available from a single input. In this case the device known as the phase splitter is called for, an example of which is shown in Fig. 1.12.

LONG-TAILED PAIR

This circuit may be arranged to give a number of different functions. If required, it can be made to operate as a phase splitter, fed from a single input. Alternatively, it can be fed from two inputs, giving an output which is proportional to the difference between these two inputs (see Fig. 1.13). The circuit can thus be used in an analogue computer to carry out subtraction functions.

IMPEDANCE AMPLIFIERS

One of the drawbacks of the transistor is that it has a very low input impedance compared with the valve. To overcome this, it has been necessary to develop impedance amplifying circuits in recent years. Two of these are illustrated in Fig. 1.14. That shown in Fig. 1.14a is known as the bootstrap amplifier. In many cases it is found that, while the single transistor circuit shown gives the required high input impedance, the overall frequency response of the circuit is inadequate; complex correcting networks have to be employed to correct this fault, with the result that the complete bootstrap amplifier may contain as many as four transistors.

Fig. 1.14b illustrates the circuit known as the Darlington pair or super-alpha pair. It is possible, with both of the circuits shown, to obtain input impedances of several megohms with little difficulty.

SINE WAVE OSCILLATOR

Broadly speaking, these devices can be broken down into two basic types: audio frequency and radio frequency oscillators. Each of these types can be subjected to further breakdown into a vast range of sub-divisions. Some oscillators can be tuned by a voltage change instead of an actual component value change.

SAWTOOTH OSCILLATOR

Another type of oscillator is that which generates a sawtooth waveform. This type is generally used to supply the time base for cathode ray tube displays. Some types give an output that can be controlled by an externally applied potential, and can thus be used to provide a time base for wobbulators.

"STAIR-CASE" GENERATORS

Yet another kind of generator is that which generates a sawtooth waveform which rises in a series of distinct steps rather than in a linear fashion. Such a device may be used as a time base generator for a transistor characteristics curve tracing oscilloscope, each step representing a particular test voltage or current.

A variation of this circuit is the "diode pump", in which the stair-case waveform is obtained from externally applied rectangular pulses. Such a device can be arranged as a counting or frequency measuring circuit.

BLOCKING OSCILLATOR

Another type of oscillator circuit is that known as the blocking oscillator, an example of which is shown in Fig. 1.15. This circuit can be arranged to perform in a number of different ways. It can, for example, give a regular series of bursts of oscillation, or large magnitude pulses of very short duration, triggered from an external source.

ASTABLE MULTIVIBRATOR

This is a two-state circuit, in which either the first transistor is on and the second transistor off, or the first transistor is off and the second on (see Fig. 1.16). The circuit will be in first one state, then the other, changing state of its own accord. The circuit is thus said to be "free running". If an output is taken from one of the collectors, it will have a rectangular waveform. The period between one change of state and the other is determined by the values of the coupling capacitors and resistive networks.

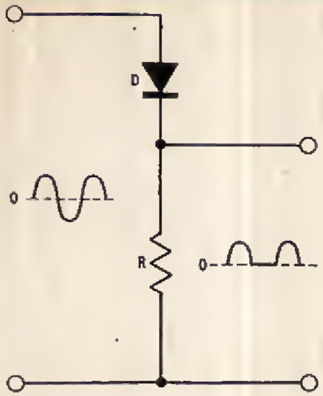

Fig. 1.8a. Diode limiter, negative part of signal clipped

Fig. 1.8b. Diode limiter or clipper, positive part of signal clipped

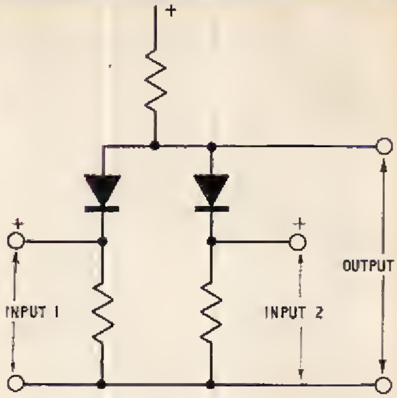

Fig. 1.9. An "AND" gate

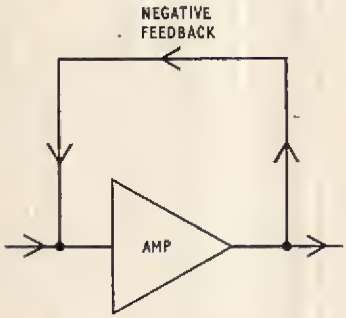

Fig. 1.10. A "block" diagram of amplifier with negative feedback

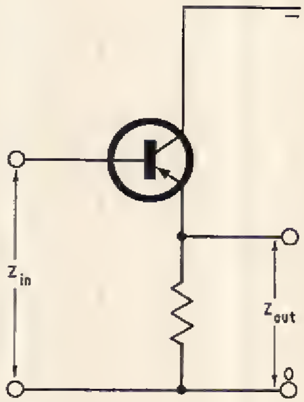

Fig. 1.11. Emitter follower impedance converter

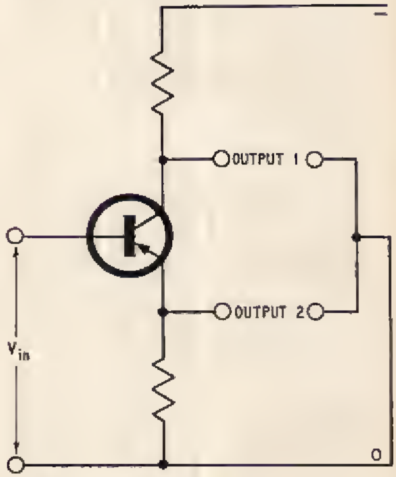

Fig. 1.12. Phase splitter

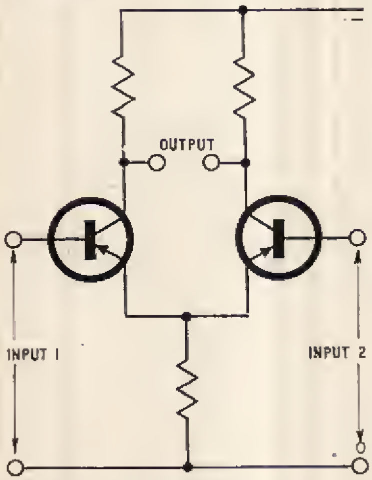

Fig. 1.13. Long tailed pair

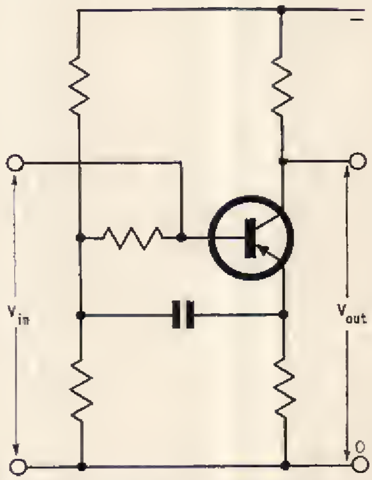

Fig. 1.14a. Basic "bootstrap" impedance amplifier

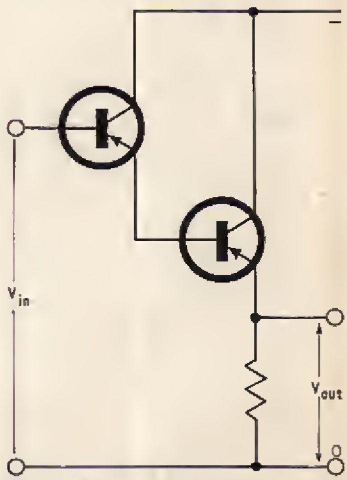

Fig. 1.14b. Basic "Darlington" or "super-alpha" pair impedance amplifier

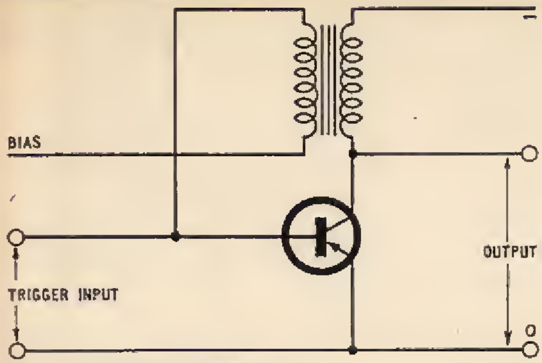

Fig. 1.15. Blocking oscillator

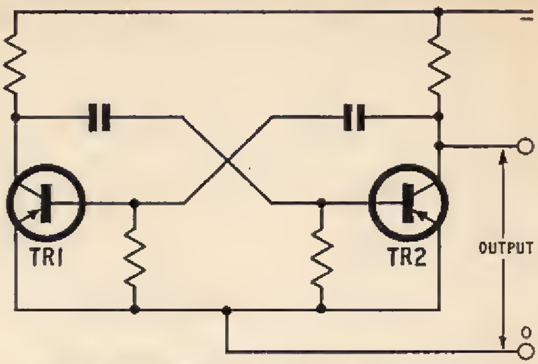

Fig. 1.16. An astable or free running multivibrator

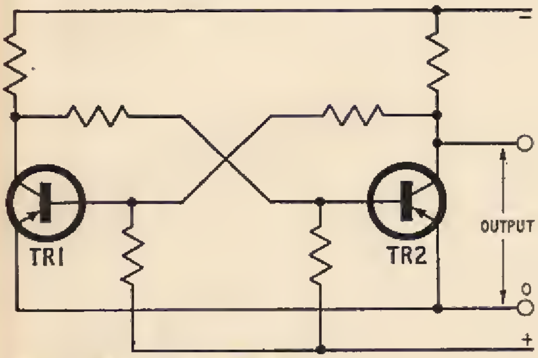

Fig. 1.17. A bistable multivibrator

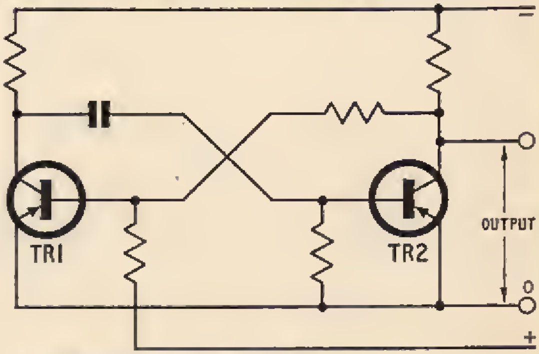

Fig. 1.18. A monostable multivibrator

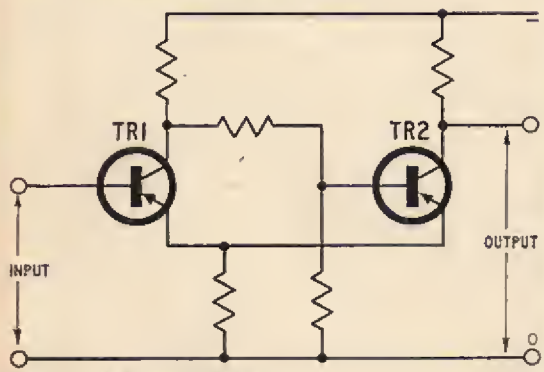

Fig. 1.19. A Schmitt trigger

BISTABLE MULTIVIBRATOR

This again is a two-state device, but in this case it is not free running (see Fig. 1.17). The change from one state to the other must be activated by an externally applied pulse or signal. Two input pulses are necessary in order to cause a complete cycle of changes of state, resulting in only a single output pulse. The circuit thus divides by two, and is known as a binary divider.

MONOSTABLE MULTIVIBRATOR

This third member of the multivibrator family is a combination of the other two (see Fig. 1.18). It has one stable and one semi-stable state. To cause a change from one state to the other, an external pulse must be applied, as in the case of the bistable multivibrator, but after a predetermined time the circuit will again revert to its first state, as in the case of the astable multivibrator.

SCHMITT TRIGGER

This is yet another two-state device, but in this case the state depends on the input voltage level. In its normal state, TR1 will be off and TR2 on (see Fig. 1.19). If the voltage is now applied to the input and slowly raised in amplitude, a point will be reached where TR1 will suddenly switch on and TR2 switch off. This condition will be maintained as long as the input voltage is not reduced below the "trigger" level. If the voltage is so reduced, the circuit will switch sharply back to its former condition. One of the many uses of this circuit is that of producing a square wave from a sine wave input.

OTHER CIRCUITS

As well as the basic building blocks that have been briefly mentioned in this article so far, many other types also exist. In the field of mathematically operating circuits, for example, alternative circuits can be used for addition, subtraction, multiplication, division, differentiation and integration, as well as circuits which follow square or square-root laws.

This concludes our initial survey of the subject of building blocks. Detailed treatment of the various types of circuit mentioned will be given during the course of this series.