Engineering

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Ampere of collector (or Drain in the case of Feet) current. Methods for choosing heat sinks. Methods for fitting heat sinks. Calculate Thermal Resistance requirements for heat sinks. Because power transistors, such as those shown in Fig. 5. 1. 1 handle larger currents and higher voltages, they have a different construction to small signal devices. They must have low output resistances so that they can deliver large currents to the load, dissipate heat very quickly so they do not overheat.

As most heat is generated at the collector/base Junction, the area of this Junction is made as large as possible. Power and Temperature The maximum power rating of a transistor is largely governed by the temperature of the collector/base Junction as can be seen from the power De-rating graph in Fig. 5. 1. 2. If too much power is dissipated, this Junction gets too hot and the transistor will be destroyed, a typical maximum temperature is between CHIC and 1 CHIC, although some devices can withstand higher maximum Junction temperatures.

The maximum power output available from a power transistor is closely linked to temperature, and above CHIC falls in a linear manner to zero power output as the axiom permissible temperature is reached. 3 Power De-rating For example, a transistor such as the TIP having a quoted maximum power output POT of IOW can only handle IOW of power IF the case temperature (slightly less than the Junction temperature) is kept below CHIC. The performance of a power transistor is closely dependent on its ability to dissipate the heat generated at the collector base Junction.

Minimizing the problem of heat is approached in two main ways: 1. By operating the transistor in the most efficient way possible, that is by choosing a class of biasing that gives high efficiency and is east wasteful of power. 2. By ensuring that the heat produced by the transistor can be removed and effectively transferred to the surrounding air as quickly as possible. Method 2 above, highlights the importance of the relationship between a power transistor and its heat sink, a device attached to the transistor for the purpose of removing heat.

The physical construction of power transistors is therefore designed to maximize the transfer of heat to the heat sink. In addition to the usual collector lead-out wire, the collector of a power transistor, which has a much larger area than hat of a small signal transistor, is normally in direct contact with the metal case of the transistor, or a metal mounting pad, which may then be bolted or clipped directly on to a heat-sink. Typical metal cased and metal body power transistors are shown in Fig. 5. 1. 1 Because power amplifiers generate substantial amounts of heat, which is wasted power, they are made to be as efficient as possible.

With voltage amplifiers, low distortion is of greater importance than efficiency, but with power amplifiers, although distortion cannot be ignored, efficiency is vital. Heat-sinks A heat-sink is designed to remove heat from a renovators and dissipate it into the surrounding air as efficiently as possible. Heat-sinks take many different forms, such as finned aluminum or copper sheets or blocks, often painted or anodized matt black to help dissipate heat more quickly. A selection of heat-sinks is illustrated in Fig. 5. 1. 3.

Good physical contact between the transistor and heat-sink is essential, and a heat transmitting grease (heat-sink compound) is smeared on the contact area before clamping the transistor to the heat-sink. Fig 5. 1. 3 Heat-sinks Where it is necessary to maintain electrical insulation between transistor and heat- ink a mica layer is used between the heat-sink and transistor. Mica has excellent insulation and very good heat conducting properties. 4 Choosing the Right Heat-sink transistor package types, (package' refers to the shape and dimensions of the transistor). Fig 5. 1. 4 shows the various stages in fitting a typical clip on heat-sink. . Shows a tube of heat-sink compound. B. Shows a 20TH clip on heat-sink. C. Shows a TIP transistor, which has a 20TH package type, ready for mounting. D. Shows the metal body of the transistor smeared with heat-sink compound. This is essential to rate efficient heat transfer between the transistor and heat-sink. Fig 5. 1. 4 Fitting a 20TH Heat-stank e. Shows the transistor fitted to the heat-sink. F. Shows an alternative method of mounting, used when the metal body of the transistor, (which is usually also the collector terminal), must be insulated from the heat-sink.

This example uses a 20TH shaped mica washer, and the transistor is clamped to the heat-sink with a bolt fitted through the small insulating bush. Calculating the Required Thermal Resistance Roth for a Heat-sink Typical Roth Calculation for: The heat-sink chosen must be able to dissipate heat room the transistor to the surrounding air, quickly enough to prevent the Junction temperature of the transistor exceeding its maximum permitted value (usually quoted on the transistor's data sheet), typically 100 to 1 CHIC.

Each heat-sink has a parameter called its Thermal Resistance (Roth) measured in Octant and the lower the value of Roth the faster heat is dissipated. Other factors affecting heat dissipation include the power (in Watts) being dissipated by the transistor, the efficiency of heat transfer between the internal transistor Junction and the transistor case, and the case to the heat-sink. The difference between the temperature of the heathens and the air temperature surrounding the heat-sink (the ambient temperature) must also be taken into account.

The main criterion is that the heat-sink should be efficient enough, too efficient is not a problem. A TIP transistor (20TH package) required to dissipate 5 Watts. Ambient (air) temperature = CHIC. Thermal resistance between Junction and case calculated from power De-rating graph Fig. 5. 1. 2. Roth J-c = (1 - = 3. CHIC. Max. Case temperature when dissipating 150-(5 x 3. 125) = CHIC (approve). Thermal resistance Roth c-has between case ND heat-sink (allowing for mica washer) = ICC. Max. Heat-sink temperature = 134 - (5 x 2) = CHIC. To reach ambient air temperature = CHIC Thermal resistance of heat-sink must be better than (124 - 25) 19. C, W A better choice, to avoid operating the transistor at its maximum permitted temperature, would be to choose a heathens with a thermal resistance of about 10 to 1 Soc, w. Therefore any heat-sink with a thermal resistance lower or equal to the calculated value should be K, but to avoid continually running the transistor at, or close to the maximum permitted temperature, which is almost guaranteed to shorten the life of he transistor, it is advisable to use a heat-sink with a lower thermal resistance where The power De-rating graph for a TIP transistor shown in Fig. 5. 1. Illustrates the relationship between the power dissipated by the transistor and the case temperature. When the transistor is dissipating SW, it can be estimated from the graph that the maximum safe case temperature, for a Junction temperature of 1 CHIC would be about 134 to CHIC, confirming the above calculation of Max. Case temperature. The TIP transistor has a maximum power dissipation POT of IOW but it can be seen from the graph in Fig. . 1. 2 that this is only attainable if the case temperature of to 1 CHIC (the same as the maximum Junction temperature) if the power dissipation is zero.

Parallel Transistors for High Power Applications With high power applications it may be impossible to find a suitable heat-sink for a particular transistor, then one solution would be to use a different power transistor, or different case (package) type if available. Another alternative is to use two or more transistors connected in parallel, sharing the total power between them. This can be a cheaper option than a single very expensive heat-sink. Fig 5. 1. 5 Power Transistor Connected in Parallel Thermal Runaway In many modern circuits power Moslems are preferred to BSTJ because of the BSTJ problem of thermal runaway.

This is a process where current flow rises as a natural effect in semiconductors as the temperature of the device increases. This rise in temperature then leads to a further increase in current flow and a subsequent further rise in temperature, until the rise in temperature and current, spirals out of control and the device is destroyed. When several poorly matched transistors are connected in parallel, the transistor initially passing the most current will get hotter, whilst the others, passing less current get cooler.

Therefore the hotter transistor can be in danger of thermal runaway, however BITS, carefully matched may still be preferable to Moslems for some high voltage applications. 6 Module 5. 2 Class A Power Amplifiers What you'll learn in Module 5. 2 be able to understand: The limitations due to the efficiency of class A power amplifiers. Efficiency of class A Effects on power supply requirements. Transformer coupled Class A power output stages. The effect of an inductive load on App. Impedance matching with transformer coupling.

Fig 5. 2. 1 Class A Bias Amplifier Classes The Class A Common Emitter Amplifier described in Amplifier Module 1, Module 2 and Module 3 has some excellent properties that make it useful for many amplification tasks, however its use as a power amplifier is limited by its poor efficiency. Although Class A may be used for power output stages (usually low to medium power), it is less used for higher power output stages, as more efficient classes of amplifier such as Classes B, ABA or even classes D, E, F, G and H are available.

The classes A, B, ABA and C refer to the way the amplifiers are biased, although class C is mainly used in oscillator circuits. Classes D to H are used in switch mode amplifiers where power is saved by having the output transistors switched rapidly between fully on and fully off. In either of these states the transistor is dissipating little or no power. The purpose of class A bias is to make the amplifier relatively free from distortion by keeping the signal waveform out of the region between OVA and about 0. V where the transistor's input characteristic is non linear. Class A design produces good linear amplifiers, but are wasteful of power. The output power they produce is theoretically 50%, but practically only about 25 to 30%, compared with the DC power they consume from the power supply. Class A power amplifiers use the biasing method illustrated in Fig. 5. 2. 1 . This method causes a standing bias current to be flowing during the whole waveform cycle, and even when no signal is being amplified.

The standing bias current (the Quiescent Current) is sufficient to make the collector voltage fall to half the supply voltage, and therefore power (P = ICC x PVC/2) is being dissipated by the renovators whether any signal is being amplified or not. This was not a great problem in class A voltage amplifiers, where the collector current was very small, but in power amplifiers output currents are thousands of times larger, so efficient use of power is crucial. 7 Transformer Coupled Class A Output The circuit shown in fig 5. . 2 is a class A power output stage, but its efficiency is improved by using an output transformer instead of the resistor as its load. The transformer primary winding has high apparent impedance (ZIP) at audio frequencies because of the action of the transformer in 'magnifying the impedance of the loudspeaker. As shown by the formula: zip = SSL (NP/INS)2 The apparent impedance of the primary winding (ZIP) will be the actual impedance of the loudspeaker (SSL) multiplied by the square of the turns ratio. Fig 5. 2. Basic Class A Power Amplifier Although the impedance of the transformer primary winding is high, its DC resistance (at GHz) is practically zero ohms. Therefore while a class A voltage amplifier might be expected to have a collector voltage of about half supply, a class A power amplifier will have a DC collector voltage approximately equal to the supply Olathe (+VI in Fig. 5. 2. 2) and because of the transformer action, this allows a voltage swing of VI above and below the DC collector voltage, making a maximum peak to peak signal voltage (App) available of VI.

With no signal, the quiescent collector current of the (medium power) output transistor may typically be about mama. When a signal is applied, the collector current will vary substantially above and below this level. Class A power amplifiers, using the relatively linear part of the transistors characteristics are less subject to distortion than other bias classes used in power amplifiers, and although their inferior efficiency improves when output transformers are used, the introduction of a transformer can itself produce additional distortion.

This can be minimized by restricting amplitude of the signal so as to utilities less than the full power of the amplifier, but even under optimum conditions the efficiency of class A presents problems. With substantially less than 50% of the power consumed from the supply going into the signal power supplied to the loudspeaker, the wasted power is simply produced as heat, mainly in the output transistor(s).