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PARALLEL DRIVE TECHNIQUES OF BIPOLAR POWER TRANSISTOR MODULES

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1. FOREWARD

Transistorization of static power converters has advanced considerably with the appearance of power semiconductor devices, typified by the power transistor, and advances in their application technology.

Recently, the power transistor has come into use with equipment up to high capacity systems and are used by driving multiple devices in parallel.

For parallel drive, various considerations are necessary so that the devices driven in parallel share the current equally.

Parallel drive techniques of bipolar power transistor modules are described below.

2. DOMINANT CAUSES HINDERING CURRENT SHARING

Current sharing at parallel drive is hindered by deviation of the device characteristics, wiring impedances, etc. and are outlined below.

2.1 Current unbalance in on state

2.1.1 Static characteristics deviation

(1) h_{FE} deviation

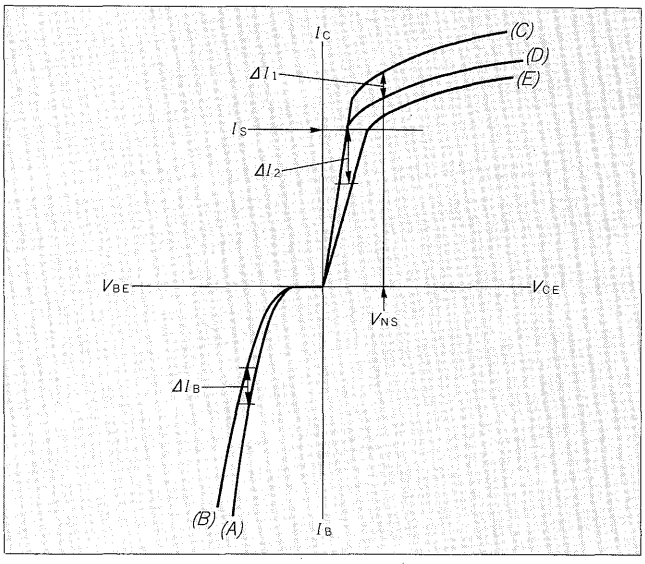
To simplify the description, if only h_{FE} is assumed to vary, the V_{CE}-I_C characteristic becomes the combination of (C) and (D) of *Fig. 1*. When operated in the active region indicated by V_{NS} in the figure 1, a current unbalance of ΔI_1 is produced.

However, if used at saturation by supplying an ample forward bias, a collector current unbalanced will not be produced so long as the collector current does not exceed Is.

Table 1 Dominant causes of current sharing obstruction

Obstruction mode	Dominant obstruction cause
Current unbalance in on state	· Static characteristics (h_{FE}, $V_{BE(sat)}$, $V_{CE(sat)}$) deviation · Main circuit wiring resistance deviation
Current unbalance at turn-on and turn-off processes	· Switching characteristics (t_{on}, t_{stg}, t_f) deviation · Main circuit wiring inductance dispersion

Fig. 1 Typical static characteristics combinations



(2) $V_{BE(sat)}$ deviation

If it is assumed that only $V_{BE(sat)}$ varies, the V_{CE} characteristic is the combination of (A) and (B) of *Fig. 1* and a base current unbalance of ΔI_B is produced. If the other characteristics are made the same, because the current unbalance of I_B produced by ΔI_B is the same as if h_{FE} was different, the unbalance of the collector current has the same effect as if h_{FE} was dispersed as previously described.

(3) $V_{CE(sat)}$ deviation

If the case when only the V_{CE} characteristic varies is assumed, the V_{CE} characteristic is the combination of (D) and (E) and a collector current unbalance (ΔI_2) is produced even at a collector current lower than Is.

2.1.2 Wiring resistance deviation

If the main circuit wiring resistances exist at the collector side and emitter side in *Fig. 2* and the value of these resistances is deviated, sharing of the collector current is adversely affected. Therefore, for good current sharing, the wiring must be such that the emitter wiring and

Fig. 2 Wiring resistances

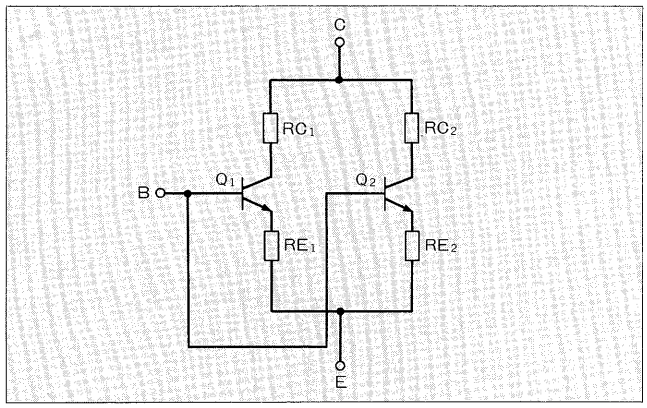
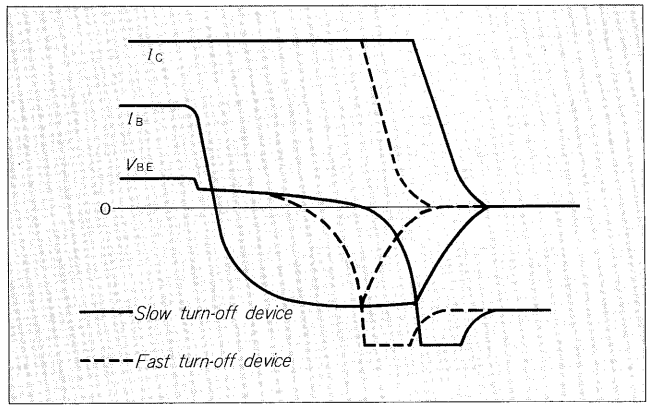


Fig. 3 Example of operating waveforms at turn-off



collector wiring resistances are the same.

When the base drive wiring resistance is deviated, since an unbalance is produced in base current sharing, it has a large effect on sharing of the collector current.

2.2 Causes of current unbalance at turn-on and turn-off processes

2.2.1 Switching characteristic deviation

Deviation of the switching characteristic of a bipolar power transistor module produce a current unbalance when bipolar power transistor modules driven in parallel are switched. During the switching time, the storage time (t_{stg}) is the longest and the deviation width is also the widest, but when bipolar power transistor modules are driven in parallel, the base current conduction action described below has the effect of improving the deviation. Examples of the base voltage and current waveforms at turn-off are shown in *Fig. 3*. As shown in *Fig. 3*, as the turn-off action progresses, the base-emitter impedance increases and the base voltage (V_{BE}) changes in the negative direction.

The conduction action is shown in *Fig. 4*. The reverse bias base current of a device with a short storage time (t_{stg}) drops quickly and the reverse bias base current of a device with a long storage time (t_{stg}) incrases. However, it must be noted that since the reverse bias base current is concentrated at the device with the longest storage time, RBSOA becomes narrow.

2.2.2 Wiring inductance deviation

The wiring inductances produce a current unbalance at switching as shown in *Fig. 5*.

Especially, the emitter wiring inductance is inserted into the base current path and has an affect on sharing of the base current.

The base inductance prevents conduction of the base current.

Therefore, for good current sharing, the wiring must be as short as possible and the emitter inductances, in particular, must be uniform.

Fig. 4 Example of base current conduction action

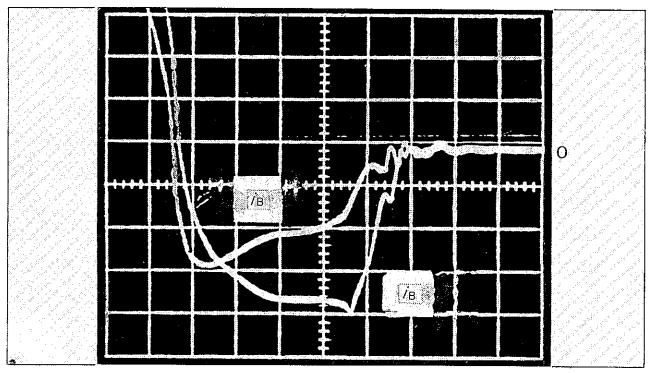
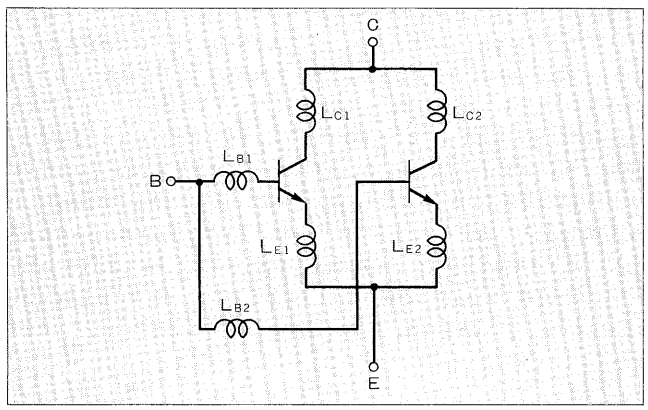


Fig. 5 Wiring inductances



3. PARALLEL DRIVE METHOD

3.1 Wiring method

The ideal wiring method at parallel drive is said to be uniform and short. However, considering the wiring method at the product level it is difficult to satisfy this completely under various restriction.

Therefore, refinements which approach the ideal as close as possible are necessary. Especially, the main circuit

Fig. 6 Bipolar power transistor module parallel drive method

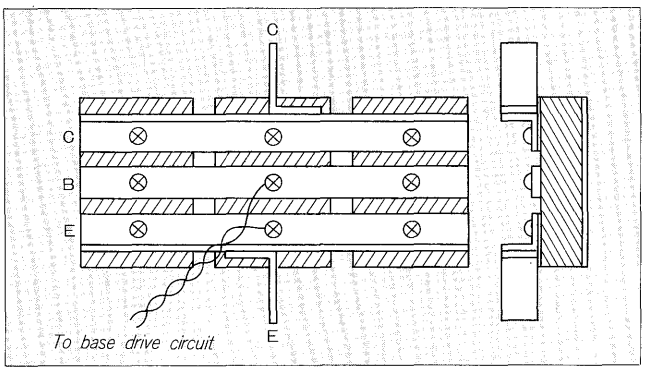
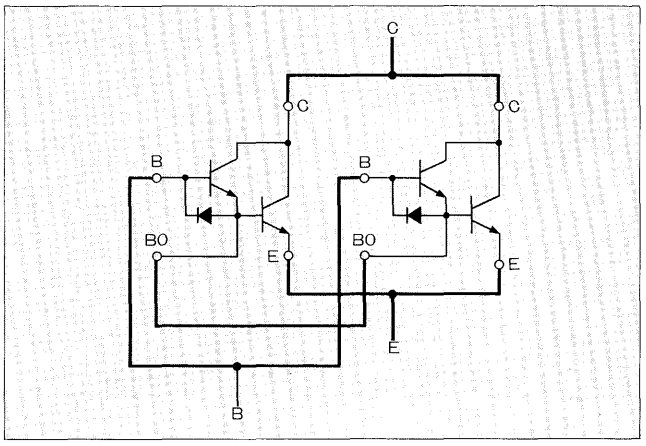


Fig. 7 Parallel drive of Darlington transistor with auxiliary base



wiring structure is conclusive at parallel drive.

An example of the wiring structure of a parallel drive circuit using a bipolar power transistor module is shown in *Fig. 6*. The basic cautionary items are:

(1) Arranging the power transistors as close together as possible so that the wiring between devices is short.
(2) Using a structure and wire for the wiring between devices in which low and uniform inductances are considered. (*Fig. 6* uses L angle.)
(3) Extracting the collector and emitter wires from the center and avoiding wiring parallel to the base wiring. (Parallel wiring produces a current unbalance by magnetic coupling.)
(4) Extracting the wires to the drive circuit from the center and twisting them tightly together.

3.2 Device characteristics management

The device characteristics that effect current sharing are h_{FE}, $V_{BE(sat)}$, $V_{CE(sat)}$, t_{on}, t_{stg}, and t_f. Managing the deviation of all these characteristics is almost impossible. In many cases, only one of these items is actually managed by using the fixed correlation between the direction and width of the deviation of these characteristics. Generally, h_{FE} is used to manage the characteristics of parallel drive devices, but since the management width of this deviation differs considerably with the drive conditions and wiring conditions, it must be selected by experimental certification by using devices with a different h_{FE}.

4. PARALLEL DRIVE BIPOLAR POWER TRANSISTOR MODULE

The mainstream of high capacity power transistors is the Darlington type. However, the deviation width of the characteristics of the Darlington transistor is larger than that of a single transistor.

Therefore, a Darlington transistor with auxiliary base terminal as shown in *Fig. 7* was commercialized. Parallel drive as a single transistor at the preceding and following stages is possible by connecting them between the auxiliary bases.

5. CONCLUSION

The parallel drive techniques of bipolar power transistor modules were outlined above. Parallel drive techniques of bipolar power transistor modules will play an important role as the capacity of equipment which use power transistors is increased in the future.

The authors will be happy if this paper is of some assistance.