JEDEC STANDARD

Measurement of Small Values of Transistor Capacitance

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EIA STANDARD

for

MEASUREMENT OF SMALL VALUES OF TRANSISTOR CAPACITANCE

ELECTRONIC INDUSTRIES ASSOCIATION
STANDARD RS-398

Formulated by

JEDEC Solid State Products Council

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MEASUREMENT OF SMALL VALUES OF TRANSISTOR CAPACITANCE

(From JEDEC Suggested Standard No. 6 and Standards Proposal No. 1090, formulated under the cognizance of JEDEC Committee JC-24 on Low Power Transistors.)

1. GENERAL

1.1 Introduction

Transistor capacitances are usually measured on two-terminal capacitance or impedance bridges. When the capacitances are in the low picofarad ranges, this two terminal measurement is not very accurate or reproducible. The stray capacitances to ground are of the same order of magnitude as the quantities being measured and vary with mechanical changes in the surrounding ground planes.

Therefore, it is necessary to employ three-terminal capacitance or impedance bridges which have a guard circuit. In these bridges the effects of extraneous capacitance to ground (or guard) are balanced out or otherwise made negligible so that the resulting measurement gives only the terminal-to-terminal capacitance. In this manner, accurate, reproducible measurements may be obtained. This method may also be used for larger capacitances where greater accuracy is desired.

The purpose of this standard is to define the elements of the transistor terminal capacitances, to specify the terminal connections to the measuring instrument, and to specify a test socket.

1.2 Transistor Mounting

The transistor should be mounted in a socket similar to the one shown in Figure 1. Note that the leads are completely shielded and the shield is connected to the guard circuit. A maximum spacing of 1.6 mm will help to standardize the measurement. The circuitry should be well designed to minimize stray capacitance at critical points and good engineering practice should be used. If the case is isolated and does not have a separate lead, it should be connected to the guard circuit and the manner of so doing should be specified.

The transistor test socket shall consist of four metal guide tubes so arranged as to accept (and enclose) the lead wires of a transistor; these tubes to be imbedded in an insulating material suitable for the frequency of measurement. See Figure 1. The spacing of the guide tubes shall conform closely enough to the spacing of the transistor's leads so that misalignment deformation will not prevent the transistor header from bottoming against the test socket. The guide tubes shall extend as close to the top surface of the socket as possible and still provide insulation from the transistor header but in no case shall be further than 1.6 millimeters from the reference plane. The guide tubes may or may not contain wiping type contacts, but if they do not, then the inner diameter of the tubes shall be small enough to ensure that electrical contact shall be made with the leads of the transistor. They shall be long enough to completely contain the transistor's lead wires when the transistor is pushed down firmly against the

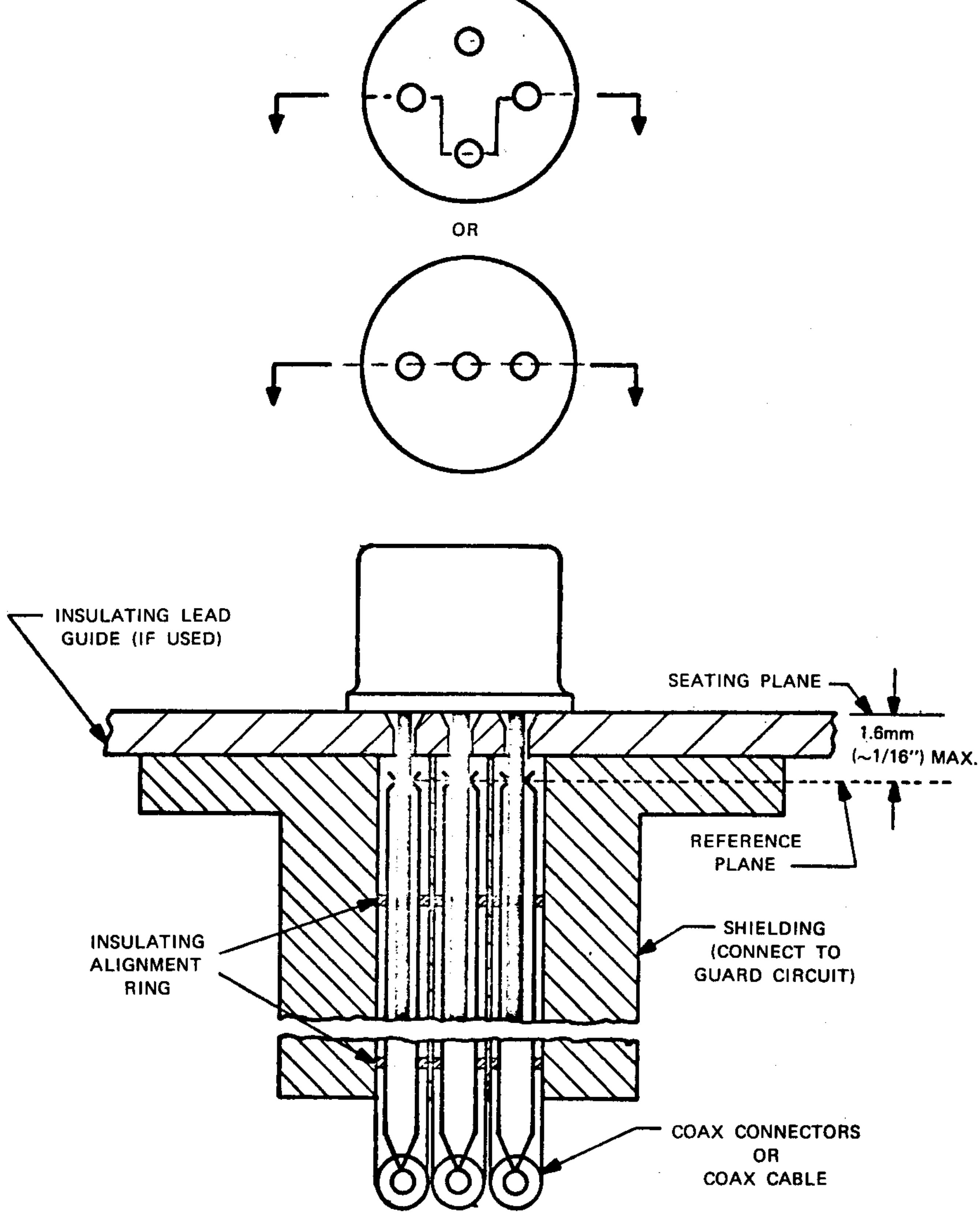


FIGURE 1 – TRANSISTOR MOUNT FOR MEASUREMENT
OF SMALL–VALUE CAPACITANCES

test socket. In this manner the capacitance measurement will be independent of the length of the transistor's leads. The transistor's header shall be bottomed against the test socket during the measurement.

The test socket shall be mounted in a metal panel and the bottom, or lead portion, of the socket shall be totally enclosed in a grounded metal container so as to reduce the effects of hand capacitance and stray fields. Provision shall be made for feeding the bias voltages and current through the shielding to the socket terminals. The wires connecting the bridge and the metering circuitry to the socket should be shielded.

1.3 Measurement Techniques

These are small signal measurements. This signal level should be small enough that doubling or halving it will not appreciably change the measured capacitance values, at least within the accuracy of measurement.

The dc bias should be applied so as not to affect the accuracy of the ac measurement. The measurement frequency shall be specified. Care should be taken that the frequency is low enough not to introduce error because of the inductance of the exposed leads, preferably less than 2MHz. The bridge should be carefully balanced according to the instructions of the bridge manufacturer.

It is important that the ac signal between emitter and base, when one of these terminals is guarded, be kept low (zero, if possible) so as not to affect the accuracy of measurement. The guard terminal is connected to the shielding system and the internal ac guard system which prevents stray capacitance from affecting the measurement. It is also desirable that the ac signal between base and collector be minimized in the C_{cb} measurement.

Various pieces of commercial equipment differ as to the designation of the measurement terminal which is nearest the ac potential of the guard terminal. For example, on some pieces of equipment the "high" terminal is close to the "guard" ac potential; on others, the "low" terminal is at "guard" ac potential.

1.4 Equivalent Circuits

The generalized equivalent circuits of the four different case connections are shown in Figure 2. The interelectrode capacitances, the stray capacitances to case, and stray capacitances to ground make up the equivalent circuit. If the signal level is small enough, the device will behave as a passive rather than an active circuit. Accordingly, judicious use of the guard circuit connection will allow isolation of capacitances in a manner not otherwise possible.

2. MEASUREMENTS

2.1 C_{cb}

This measurement is made with the collector-base diode reverse biased (V_{CB} must be specified) and is defined for use here with the emitter dc open circuited ($I_E = 0$) but ac connected to the guard terminal. Referring to Figure 2, we define this capacitance as being C_{cb} (which for grounded element devices must include the extra case capacitance).

2.1.1 Circuit of C_{cb}

Figure 3 shows the test hookup for the C_{cb} measurement. Note that the collector and base terminals are tied to the measurement terminals and the emitter is ac connected to the guard terminal. In the isolated-case or the emitter-and-case-common connection, the case is tied to the guard circuit. The guard circuit is also tied to the shielding. Note that the paralleled capacitances from the measurement terminals to the guard circuit are balanced out and do not enter into the measurement.

2.2 C_{eb}

This measurement is made with the emitter-base biased (V_{EB} must be specified) and is defined here with the collector dc open circuited ($I_C = 0$) but ac connected to guard circuit. Referring to Figure 2, we define this capacitance as being C_{eb} (which for grounded-element devices must include the extra case capacitance).

2.2.1 Circuit of C_{eb}

Figure 4 shows the test hookup for the C_{eb} measurement. The same comments made for C_{cb} apply, except that the isolated-case and common-collector-and-case conditions are the only occasions where the case is tied to the guard circuit.

2.3 C_{ce}

This measurement is also made with the collector-emitter reverse biased (V_{ce} must be specified) and $I_B = 0$. The base is ac connected to the guard terminal.

2.3.1 Circuit of C_{ce}

Figure 5 shows the test circuit for the C_{ce} measurement. This is the same as for C_{cb} and C_{eb} except that both isolated-case and common-case-and-base connections are the only ones with the case tied to the guard terminal.

2.4 Electrode-to-Case Capacitance

For the isolated-case condition, it is possible to measure the separate electrode-to-case capacitance.

2.4.1 Circuit of Electrode-to-Case Capacitance

Figure 6 shows the test circuit for the isolated-case condition.

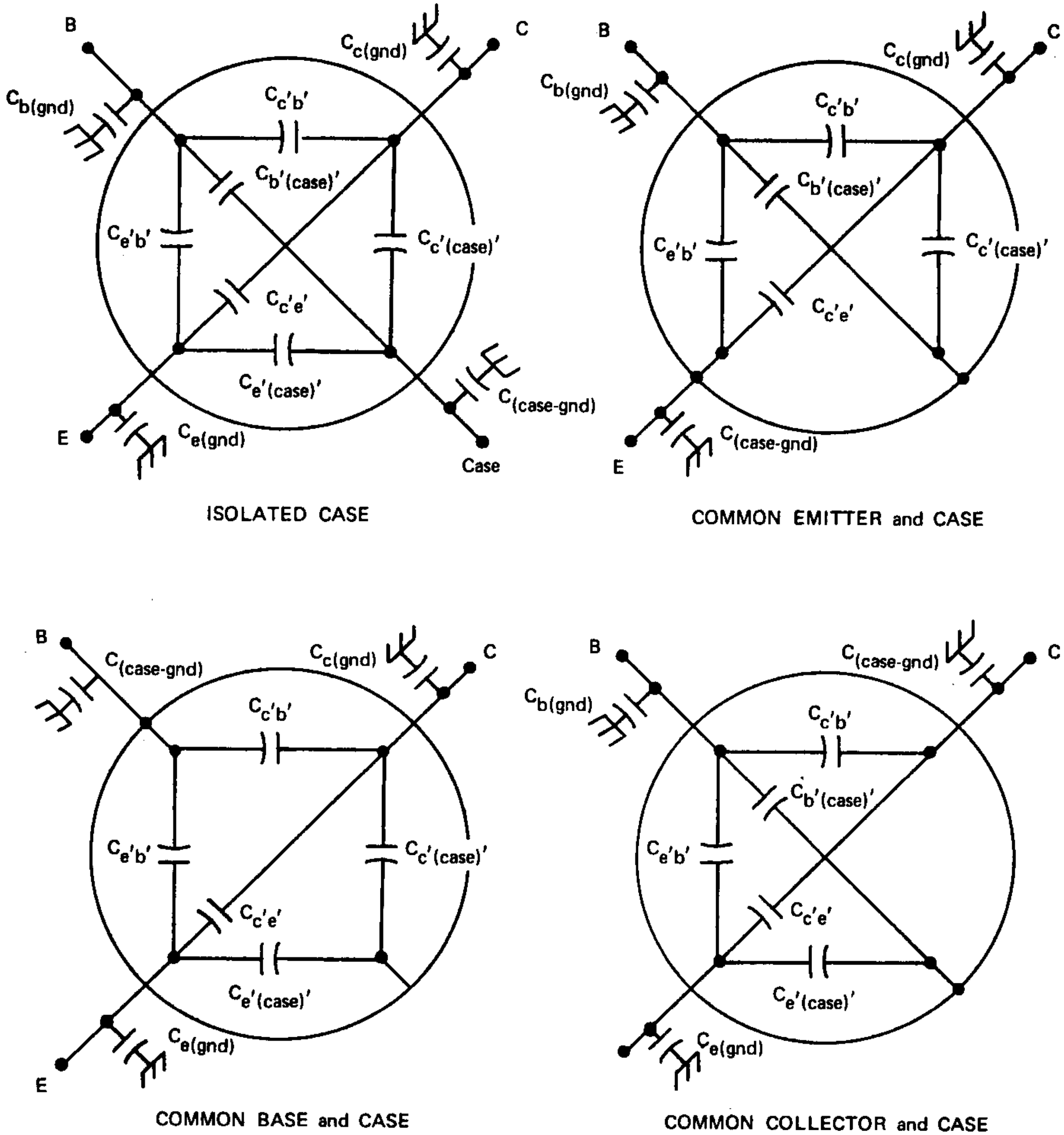


FIGURE 2 – EQUIVALENT CIRCUITS

TERMINAL–TO–TERMINAL TEST CONNECTIONS

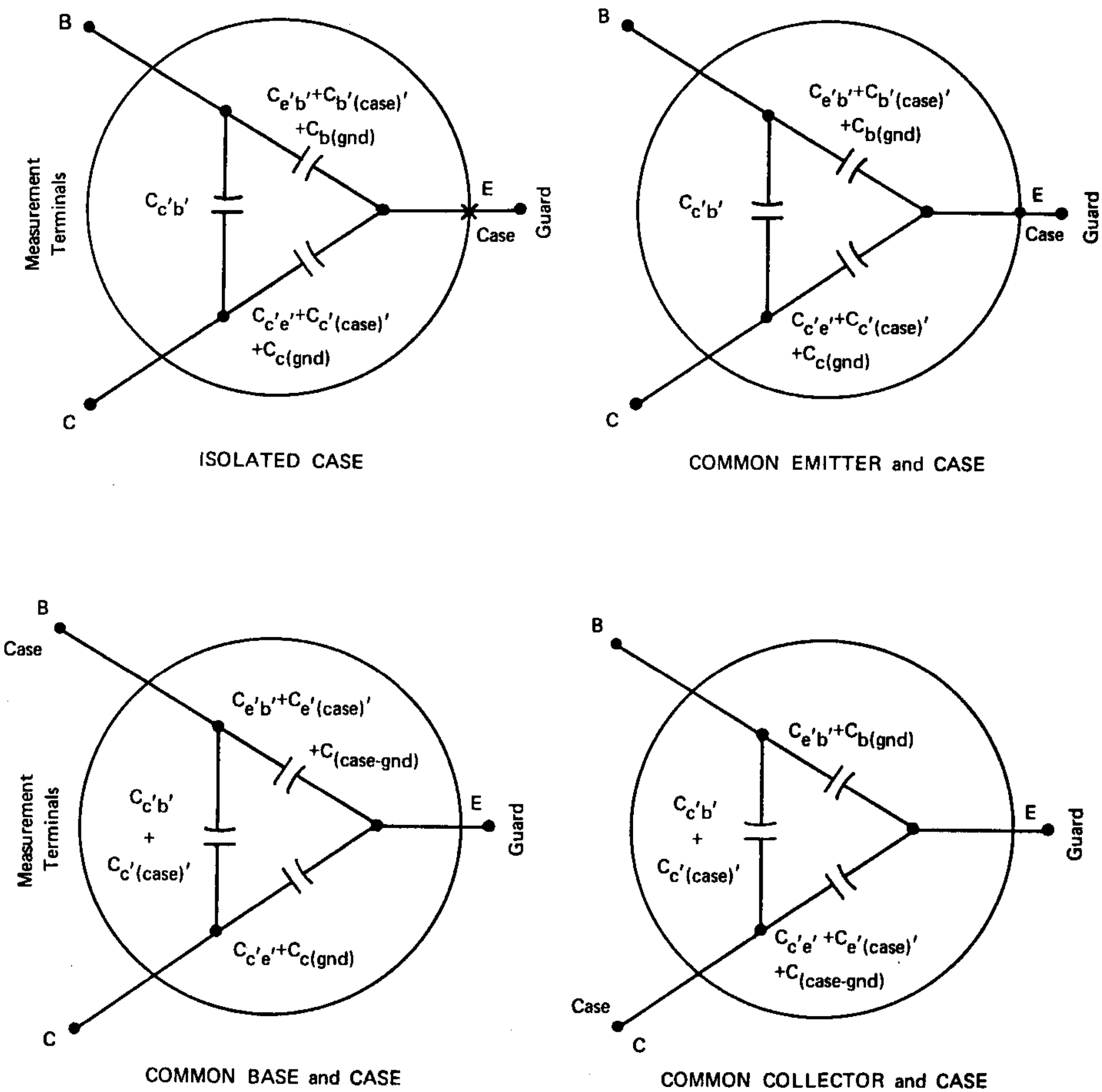


FIGURE 3 – MEASUREMENT OF C_{cb}

NOTE: Various pieces of commercial equipment differ as to the designation of the measurement terminal which is nearest the ac potential of the guard terminal. Here the base should be near the guard potential.

TERMINAL–TO–TERMINAL TEST CONNECTIONS

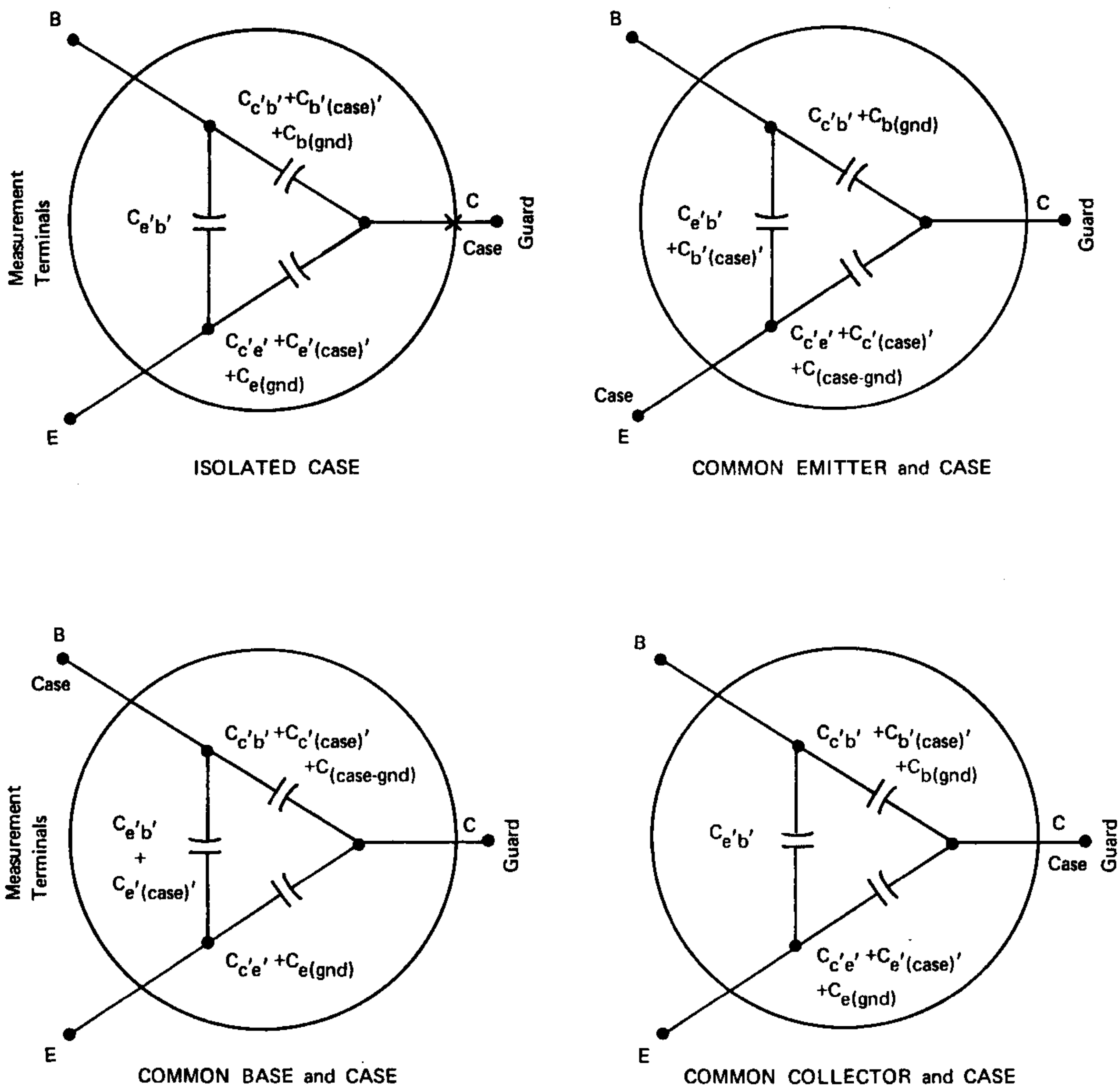


FIGURE 4 – MEASUREMENT OF C_{eb}

NOTE: Various pieces of commercial equipment differ as to the designation of the measurement terminal which is nearest the ac potential of the guard terminal. Here the base should be near the guard potential.

TERMINAL–TO–TERMINAL TEST CONNECTIONS

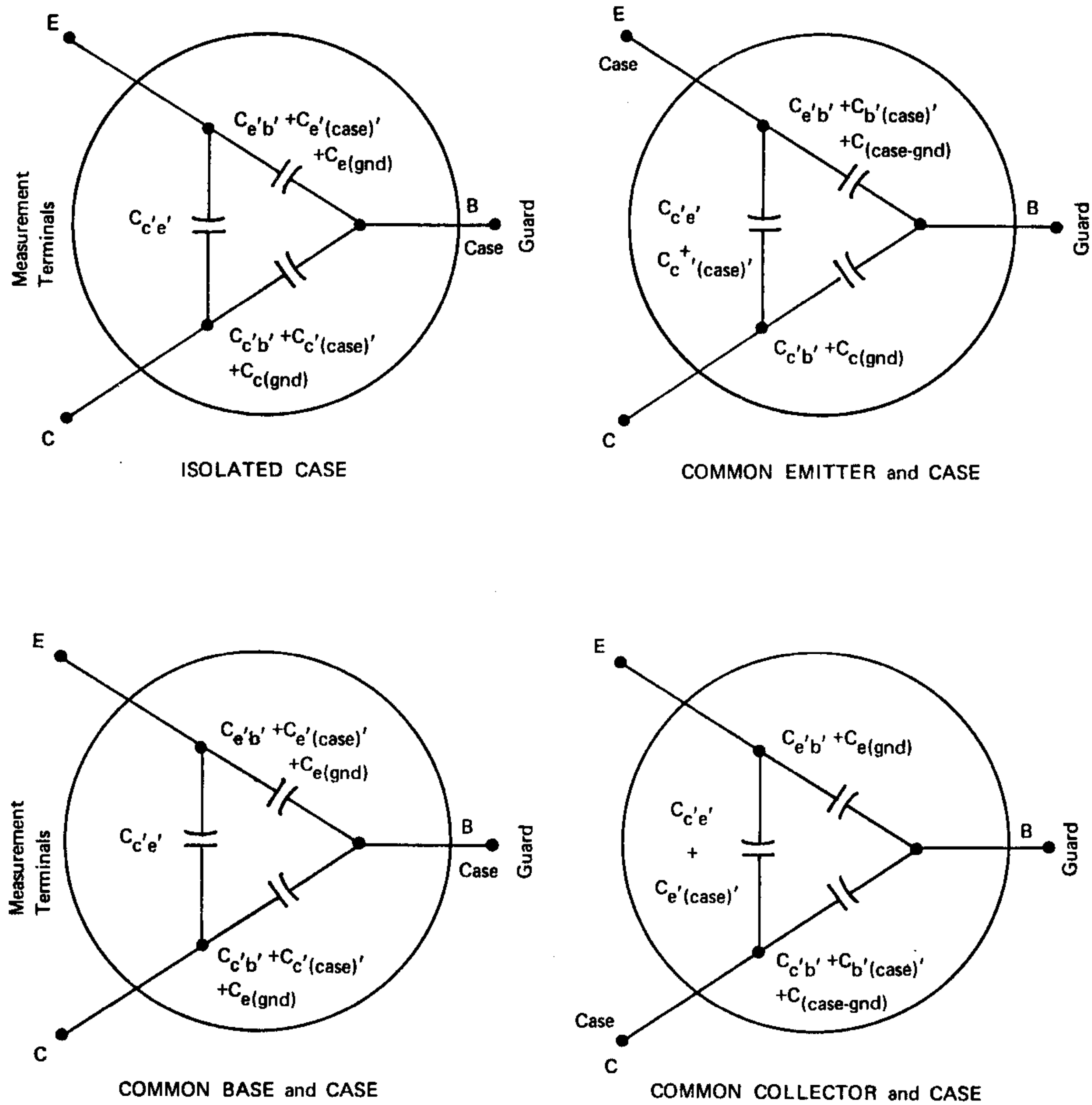
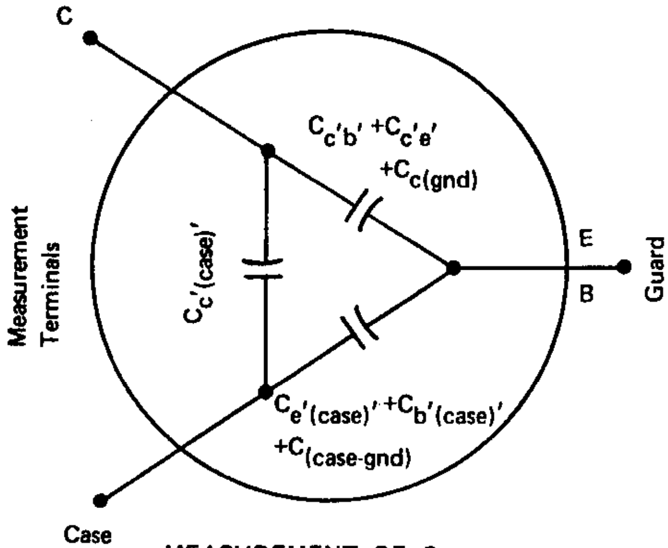


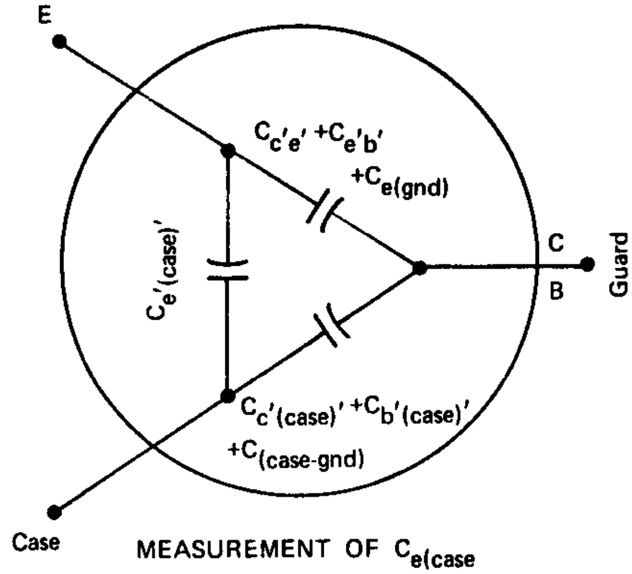
FIGURE 5 – MEASUREMENT OF C_{ce}

NOTE: Various pieces of commercial equipment differ as to the designation of the measurement terminal which is nearest the ac potential of the guard terminal. Here the emitter should be near the guard potential.

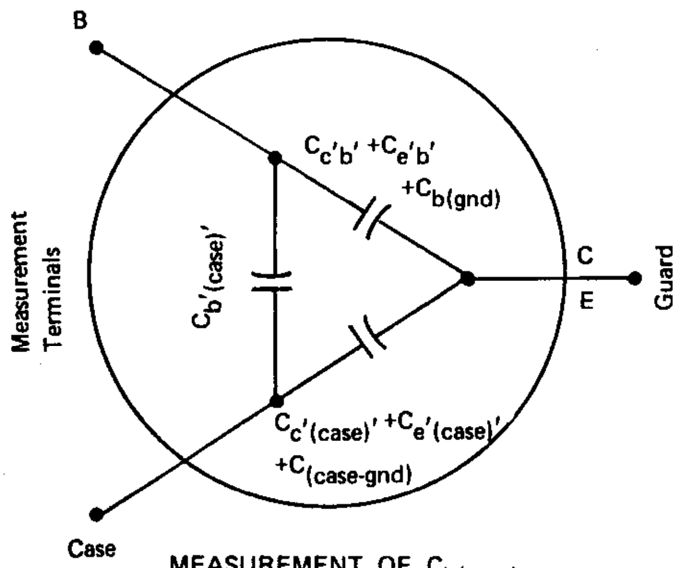
ELECTRODE–TO–CASE TEST CONNECTIONS
ISOLATED–CASE CONDITION



MEASUREMENT OF $C_{c(case)}$
(collector at guard potential)



MEASUREMENT OF $C_{e(case}$
(emitter at guard potential)



MEASUREMENT OF $C_{b(case)}$
(base at guard potential)

FIGURE 6 – MEASUREMENT OF ELECTRODE–TO–CASE CAPACITANCE

NOTE: Various pieces of commercial equipment differ as to the designation of the measurement terminal which is nearest the ac potential of the guard terminal.

DEFINITIONS OF CAPACITANCES USED

External Capacitances to Ground (depends to a large extent on physical test configuration.)

$C_{c(gnd)}$ collector terminal stray capacitance to ground
$C_{e(gnd)}$ emitter terminal stray capacitance to ground
$C_{b(gnd)}$ base terminal stray capacitance to ground
$C_{(case)(gnd)}$ case shield terminal stray capacitance to ground

Element Capacitance to Case Shield (internal to the device)[1]

$C_{c'(case)'}$ collector stray capacitance to case
$C_{e'(case)'}$ emitter stray capacitance to case
$C_{b'(case)'}$ base stray capacitance to case.

Interelement Capacitance (internal to the device[1], reverse bias only)

$C_{c'b'}$ collector-base capacitance
$C_{e'b'}$ emitter-base capacitance
$C_{c'e'}$ collector-emitter capacitance

Interelement capacitance is primarily depletion layer capacitance plus stray connector-to-connector capacitance. It specifically excludes any capacitance to shield whether or not the shield is tied to any element and not directly separable.

Measured Capacitances (use three-terminal guarded measurements – sometimes called *"direct"*)

C_{cb} collector-to-base capacitance, emitter terminal connected to guard, collector reverse biased.[2]
C_{eb} emitter-to-base capacitance, collector terminal connected to guard, emitter reverse biased.[2]
C_{ce} collector-to-emitter capacitance, base terminal connected to guard, collector reverse biased.[2]
$C_{c(case)}$ collector-to-case capacitance, emitter and base terminals connected to guard.[3]
$C_{e(case)}$ emitter-to-case capacitance, collector and base terminals connected to guard.[3]
$C_{b(case)}$ base-to-base capacitance, collector and emitter terminals connected to guard.[3]

[1] "Internal to the device" applies to the region of the device side of the reference plane.

[2] Includes only interelement capacitances plus capacitance to shield where the shield is tied to one of the terminals under measurement.

[3] Measurement possible only in the isolated-case configuration.

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