JEDEC STANDARD

Measurement of Small Values of Transistor Capacitance

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JEDEC SOLID STATE TECHNOLOGY ASSOCIATION

Electronic Industries Alliance

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JEDEC STANDARD No. 6

MEASUREMENT

OF

SMALL VALUES

OF

TRANSISTOR CAPACITANCE

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Prepared by

JEDEC JC-25 Committee on Low Frequency Power Transistors

FOREWORD

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MEASUREMENT OF SMALL VALUES OF TRANSISTOR CAPACITANCE

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 capacities to ground are of the same order of magnitude as the quantities being measured and vary with mechanical changes in the surronding 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 "bucked out" or otherwise compensated for 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.

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 pracitice 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.

1.3 Measurement Techniques

These are small signal measurements. The 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 D.C. bias should be applied so as not to affect the accuracy of the A.C. measurement. The measurement frequency shall be

1.3 Measurement Techniques (continued)

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 A.C. 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 A.C. guard system which prevents stray capacitance from affecting the measurement. It is also desirable that the A.C. signal between base and collector be minimized in the C_{eb} measurement.

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

1.4 Equivalent Circuits

The generalized equivalent circuits of the four different case connections are shown in Figure 2. The inter-electrode 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 D.C. open circuited ($I_E = 0$) but A.C. 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 capacity).

2. Measurements (Continued)

2.1.1 Circuit of C_{cb}

Figure 3 shows the test hook up for the C_{cb} measurement. Note that the collector and base terminals are tied to the measurement terminals and the emitter is A.C. 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 capacities 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 reverse biased (V_{EB} must be specified) and is defined here with the collector D.C. open circuited (I_C=0) but A.C. connected to guard circuit. Referring to Figure 2, we define this capacity 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 hook up 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 A.C. 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 the 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 Capacitances

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

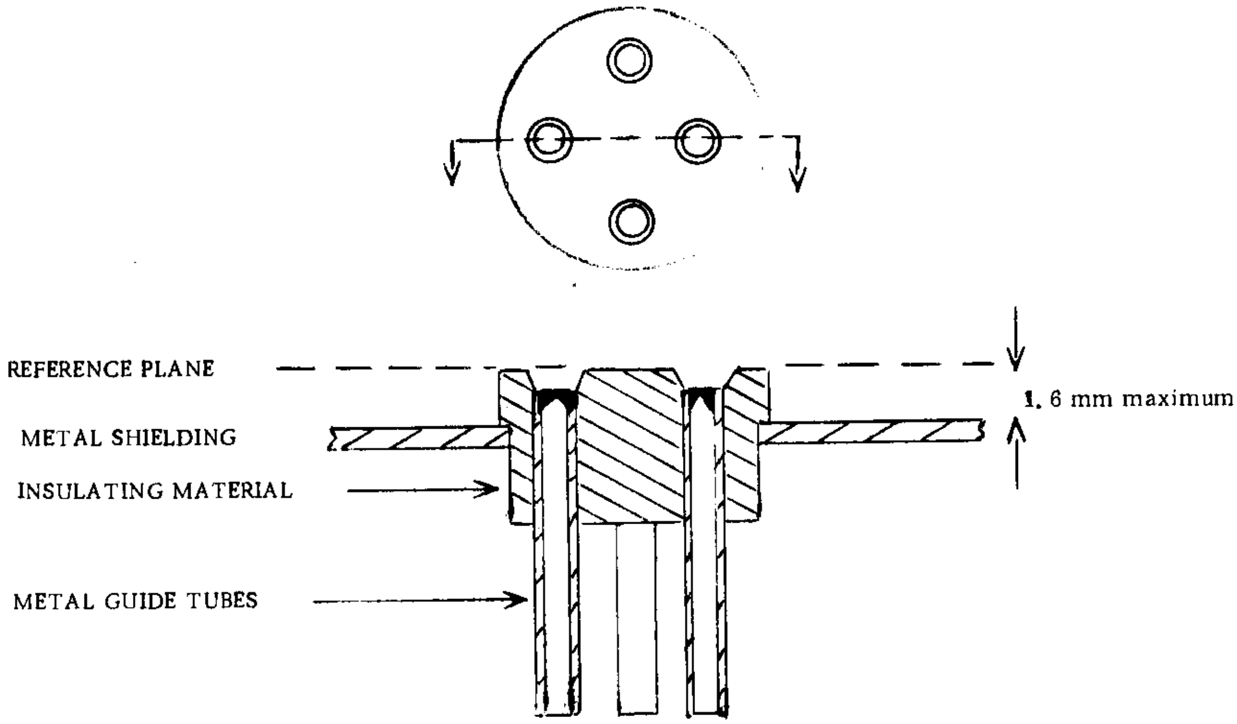
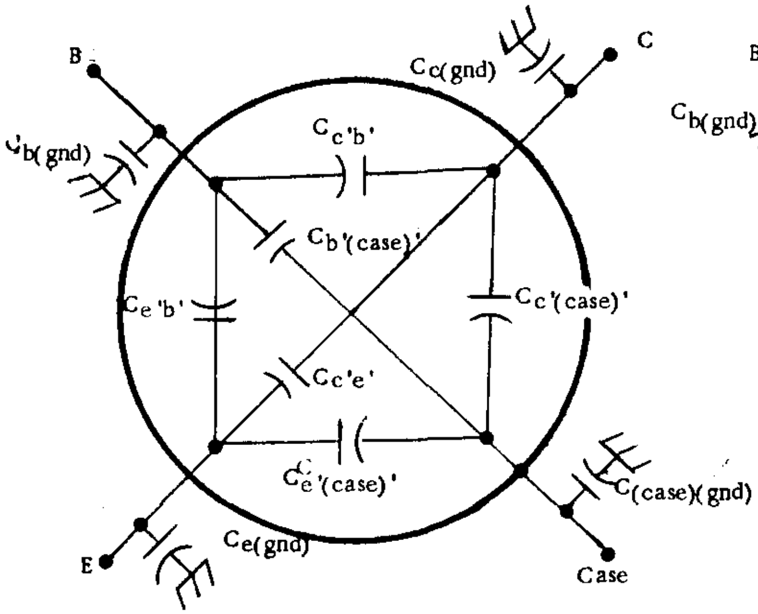
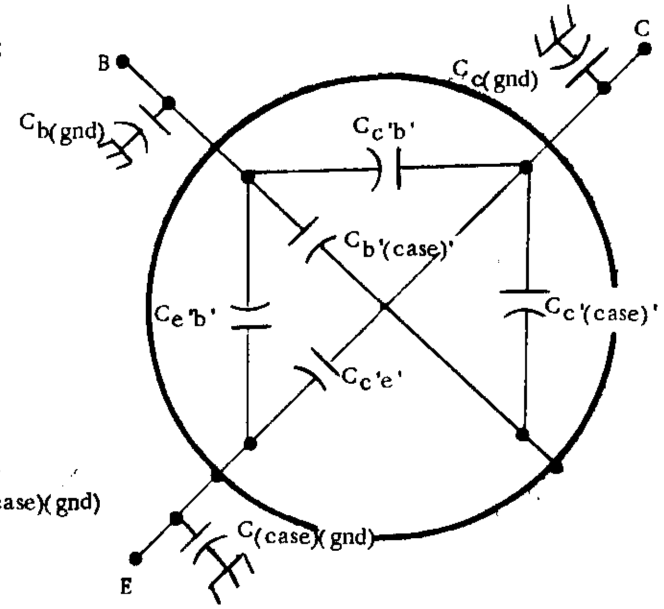


FIGURE 1 SOCKET

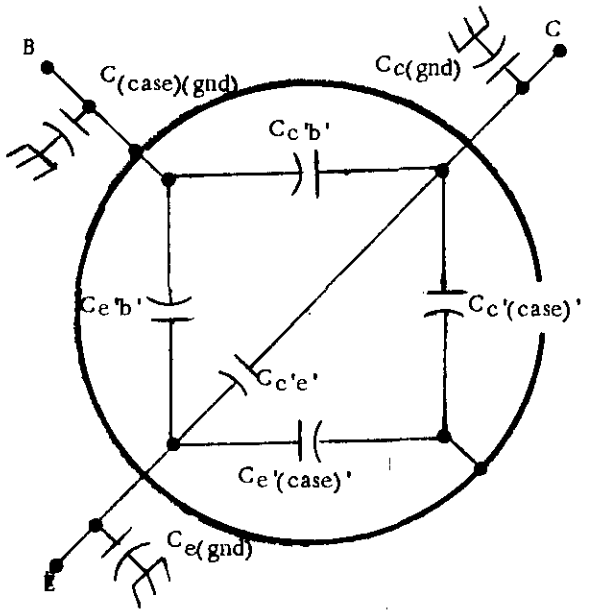
The transistor test socket shall consist of four metal guide tubes so arranged as to accept (and enclose) the lead wires of a transistor; these tubes to be imbedded in an insulating material suitable for the frequency of measurement. See Figure 1. The spacing of the guide tubes shall conform closely enough to the spacing of the transistor's leads so that misalignment deformation will not prevent the transistor's header from bottoming against the test socket. The guide tubes shall



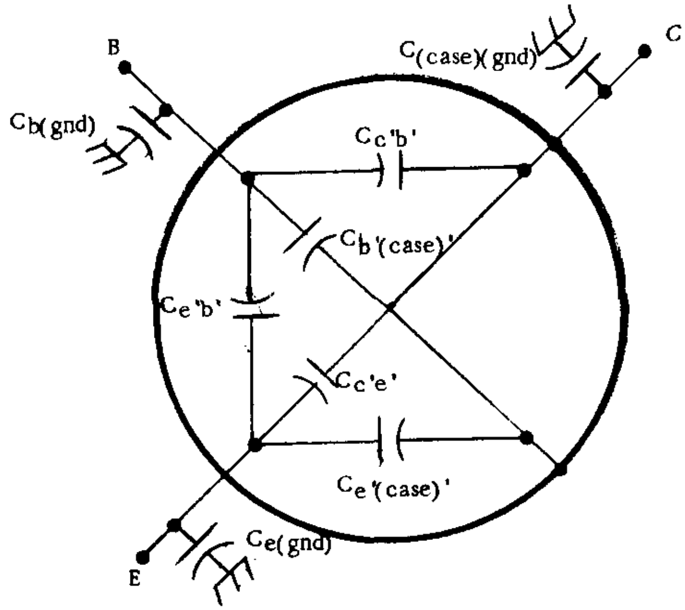
ISOLATED CASE



COMMON EMITTER-and-CASE



COMMON BASE -and-CASE



COMMON COLLECTOR -and-CASE

FIGURE 2 EQUIVALENT CIRCUITS

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 insure 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 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 inclosed 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.

DEFINITIONS OF CAPACITANCES USED

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

$C_{c(gnd)}$ collector terminal stray capacity to ground

$C_{e(gnd)}$ emitter terminal stray capacity to ground

$C_{b(gnd)}$ base terminal stray capacity to ground

$C_{(case)(gnd)}$ case shield terminal stray capacity 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

Inter-Element 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

Inter-element 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 returned to guard, collector reverse biased.[2]

C_{eb} emitter-to-base capacitance, collector terminal returned to guard, emitter reverse biased.[2]

C_{ce} collector-to-emitter capacitance, base terminal returned to guard, collector reverse biased.[2]

$C_{c(case)}$ collector-to-case capacitance, emitter and base terminals returned to guard.[3]

$C_{e(case)}$ emitter-to-case capacitance, collector and base terminals returned to guard.[3]

$C_{b(case)}$ base-to-case capacitance, collector and emitter terminals returned to guard.[3]

1. Internal to the device applies to the region on the device side of the reference plane.

2. Includes only inter-element 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.

TERMINAL-TO-TERMINAL TEST CONNECTIONS

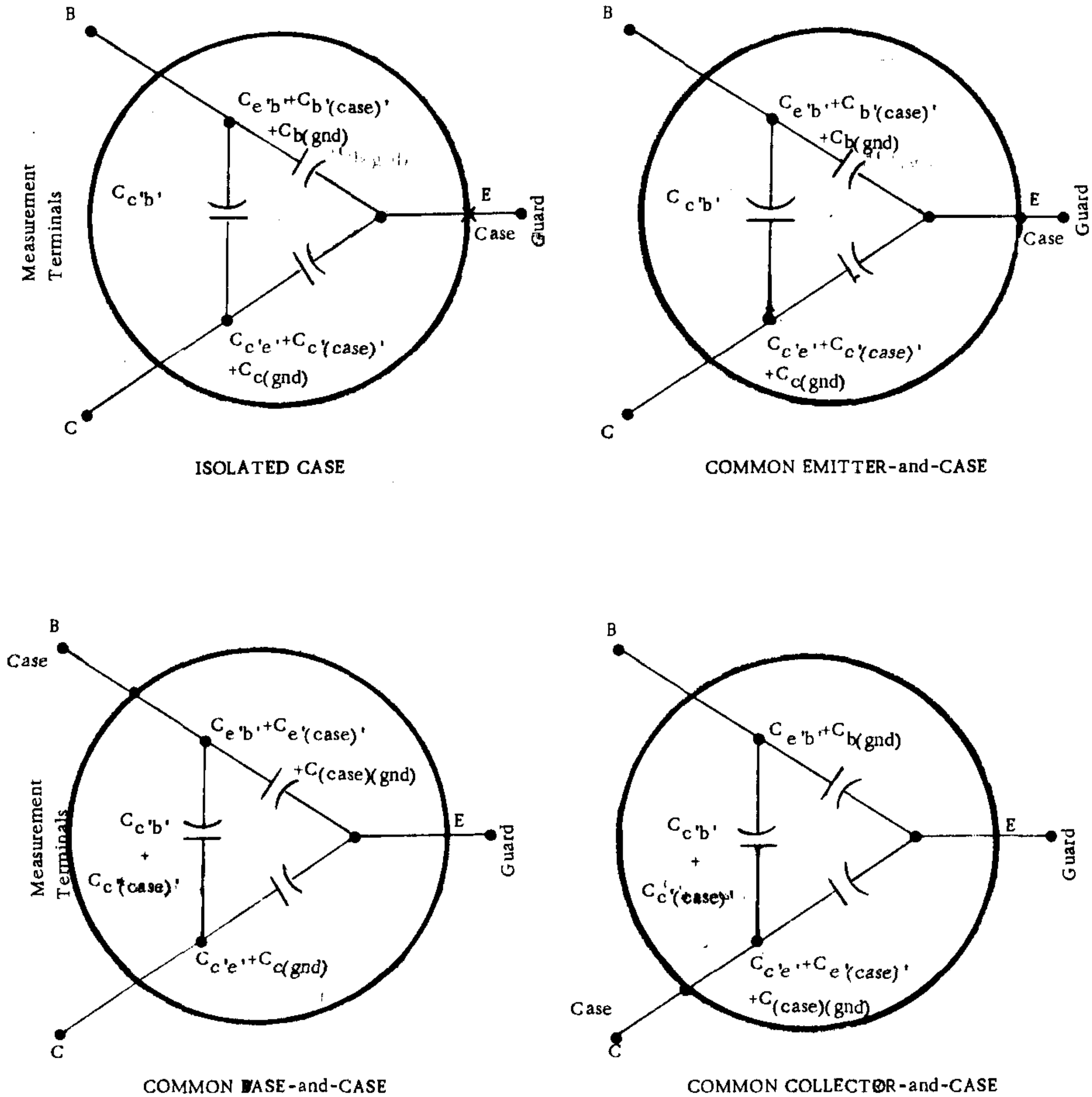


FIGURE 3 MEASUREMENT OF C_{cb}

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

TERMINAL-TO-TERMINAL TEST CONNECTIONS

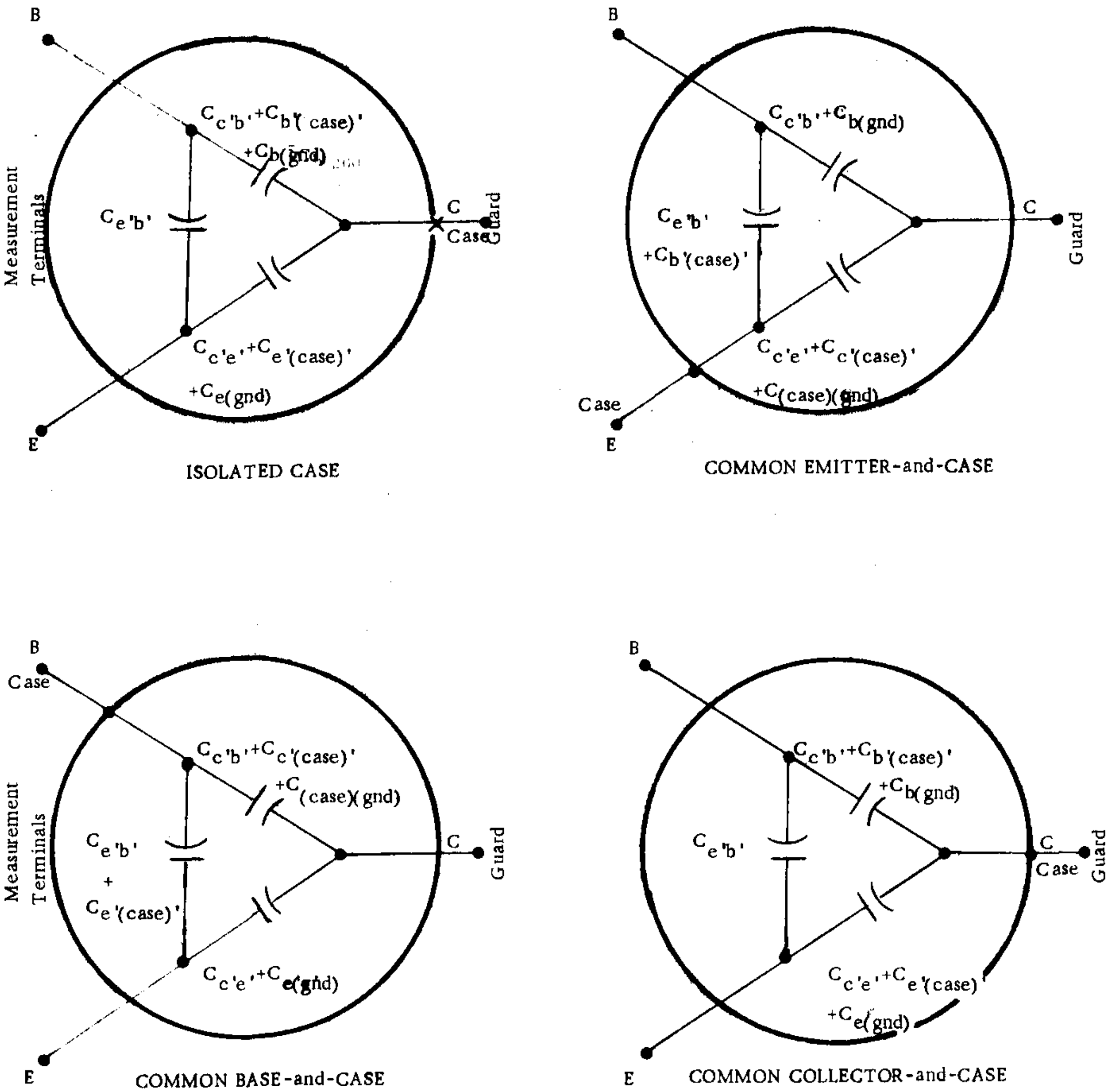
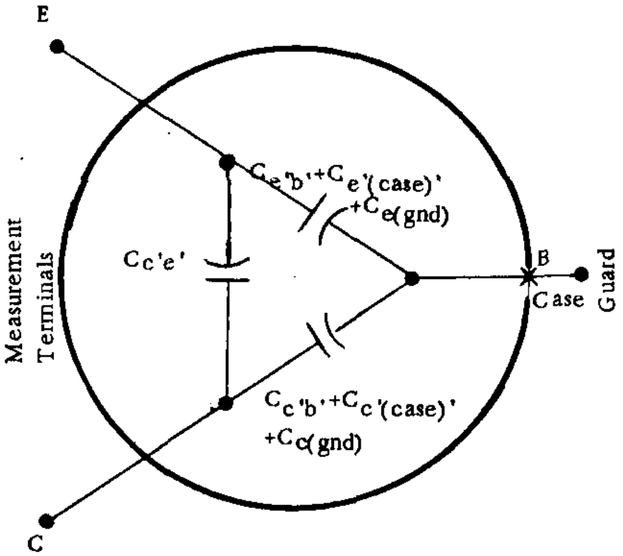


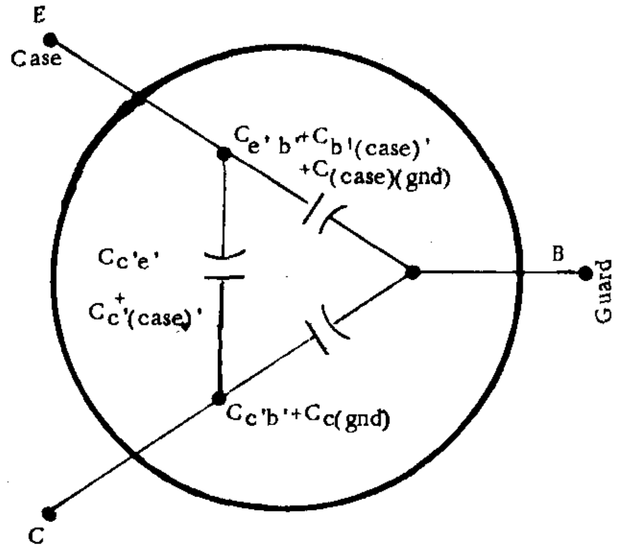
FIGURE 4 MEASUREMENT OF C_{eb}

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

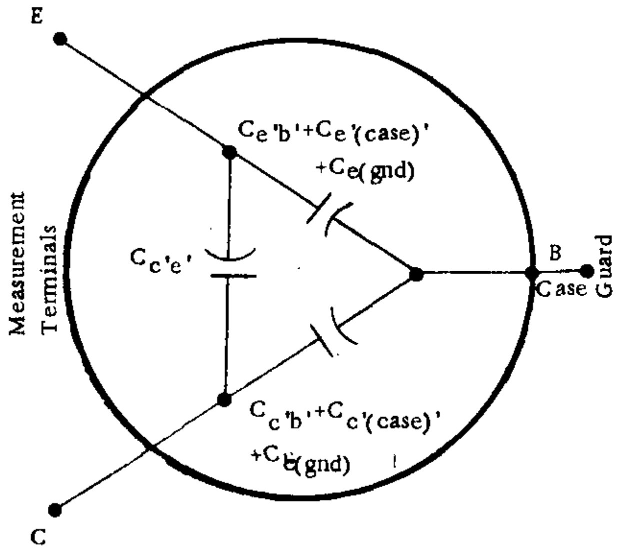
TERMINAL-TO-TERMINAL TEST CONNECTIONS



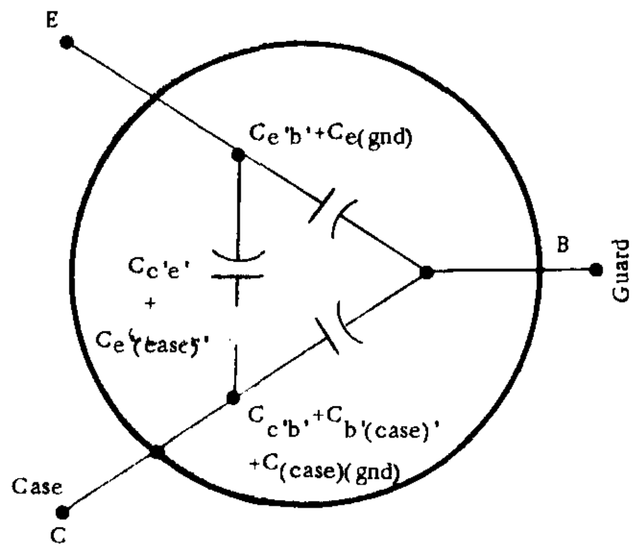
ISOLATED CASE



COMMON EMITTER-and-CASE



COMMON BASE-and-CASE

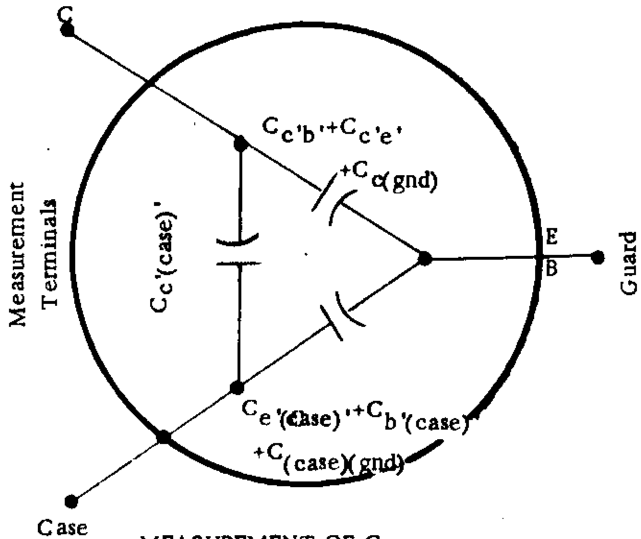


COMMON COLLECTOR-and-CASE

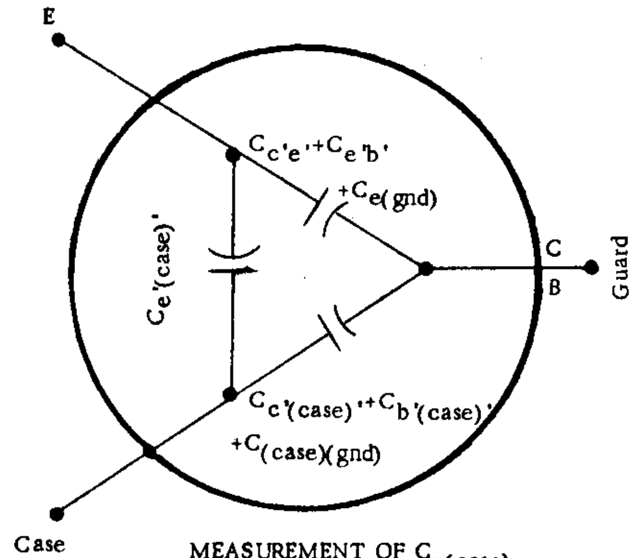
FIGURE 5. MEASUREMENT OF C_{ce}

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

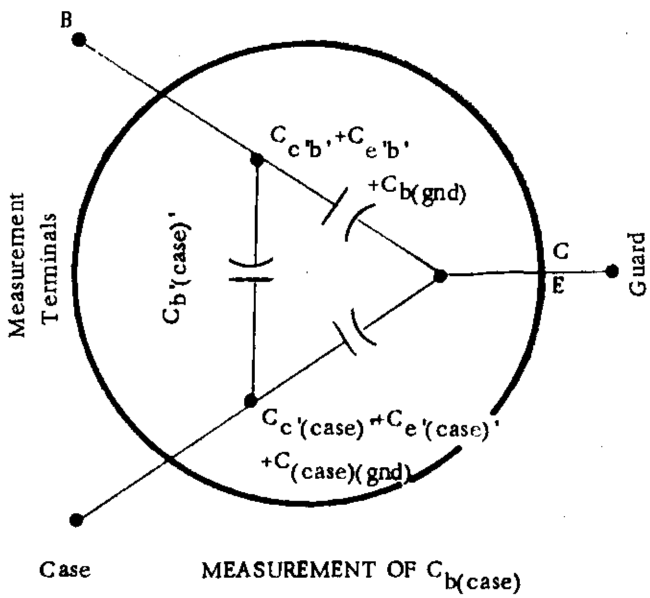
ELECTRODE-TO-CASE TEST CONNECTIONS
ISOLATED CASE CONDITION



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 A.C. potential of the guard terminal.

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