JEDEC STANDARD

Standard for the Measurement of CRE

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(Previously known as RS-340 and/or EIA-340)

NOVEMBER 1967 (Reaffirmed: April 1981, April 1999, March 2009)

JEDEC SOLID STATE TECHNOLOGY ASSOCIATION

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EIA STANDARD

for

The Measurement of $|C_{re}|$

ELECTRONIC INDUSTRIES ASSOCIATION
STANDARD RS-340

Formulated by

JEDEC Semiconductor Device Council

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STANDARD FOR THE MEASUREMENT OF $|C_{re}|$

(From Standards Proposal No. 917 formulated under the cognizance of JEDEC Committee JS-8 on Consumer Product Devices.)

1. INTRODUCTION

1.1 This standard offers an easily-measured parameter which is one of the significant characteristics in determining the stability of a transistor intended for small-signal operation. The measurement technique allows rapid testing. Its close correlation to AC stability will help to establish the interchangeability of a device.

1.2 The symbol used for this common-emitter short-circuit feedback parameter is $|C_{re}|$. The magnitude bars are included for three reasons:

(a) They reflect the true nature of the parameter in that it is an admittance magnitude rather than a susceptance.

(b) They eliminate the need for a minus sign. This prevents the confusion prevalent when the maxima of a minus quantity are to be considered.

(c) They reduce the possibility of mistaking the parameter for the imaginary portion of a reverse transfer matrix parameter (C_{res} for the Y-parameter or C_{reo} for the Z-parameter).

1.3 The parameter is expressed as a capacitance rather than an immitance because the latter is frequency dependent. It is desirable to allow easy correlation of the parameter with different measurement frequencies. $|C_{re}|$ as defined and measured very closely resembles C_{res} (the short circuit Y-parameter) which is the reason for the subscript "re".

1.4 It fits directly into the usual stability equations. A typical example is the equation for stability for a narrow-band amplifier with single-tuned interstages.

$$S = \frac{2}{1 + \cos(\psi_{re} + \psi_{fe})} \; \frac{(G_s + G_{ie})\,(G_{oe} + G_L)}{\omega\,|C_{re}|\,|Y_{fe}|}$$

All of the terms in this equation except for $|C_{re}|$ are either swamped by circuit constants or are relatively constant.

1.5 $|C_{re}|$ is easily measured on relatively inexpensive equipment. It is a "plug-in-and-read" type of measurement. Because it is not a bridge measurement no adjustments or balancing are required.

1.6 $|C_{re}|$ is a measurement on an active, full-biased, transistor. In this it differs from C_{cb} which is defined for zero emitter bias current.

1.7 It is a three-terminal admittance measurement. Thus it doesn't fall heir to the numerous difficulties and inaccuracies of the two-terminal measurement, C_{ob}.

1.8 The low frequencies used enable the measurements to be more easily reproduced. Correlation is improved. It is granted that the measurement of feedback at the actual operating frequency is the more efficacious method for determining stability performance; but the intent of $|C_{re}|$ is to provide a suitable means for judging transistor interchangeability over the widest possible range of transistor types, applications, and frequencies.

2. DEFINITION

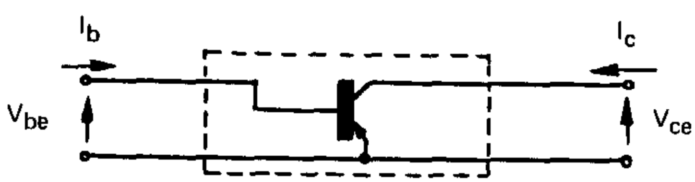
2.1 $|C_{re}|$ is a three-terminal admittance measurement. It is defined as the magnitude of the small-signal short-circuit reverse-transfer admittance, $|Y_{re}|$, of a fully-biased transistor connected in the common-emitter configuration, divided by the angular velocity, ω.

$$|C_{re}| = \left|\frac{Y_{re}}{\omega}\right|$$

ω is equal to $2\pi f$ where f is the frequency of measurement.

$|C_{re}|$ is derived from the Y-parameters although it is not itself a Y-parameter by rigorous definition.

2.2 The definition of Y_{re} is formally derived through the matrix-defining set of simultaneous equations for the two-port network representation of a common-emitter-configured transistor.



$$\begin{cases} I_b = Y_{ie} V_{be} + Y_{re} V_{ce} \\ I_c = Y_{fe} V_{be} + Y_{oe} V_{ce} \end{cases}$$

The definition of Y_{re} is mathematically expressed as:

$$Y_{re} = \frac{I_b}{V_{ce}} \Bigg|_{V_{be} = \text{zero}}$$

2.3 Insert this definition of Y_{re} into the definition of $|C_{re}|$

$$|C_{re}| = \frac{1}{\omega} \frac{|I_b|}{|V_{ce}|} \Bigg|_{V_{be} = \text{zero}}$$

3. DISCUSSION

3.1 For more of an understanding of what $|C_{re}|$ is physically, Y_{re} can be broken down into its rectilinear components. (The subscript, s, refers to the fact that the Y-parameters are short-circuit parameters.)

$$Y_{re} = g_{res} + j\omega C_{res}$$

The frequency of measurement should be chosen within the range where the magnitude of ωC_{res} is at least ten times greater than the magnitude of g_{res}. Then Y_{re} can be considered to be purely capacitive. That is:

$$C_{res} = \frac{|Y_{re}|}{\omega}$$

For most practical purposes, $|C_{re}|$ can be taken to be equal to $|C_{res}|$ in this frequency range.

3.2 C_{res} is normally expressed in minus picofarads. The minus sign for capacitive feedback is the result of the conventional polarity assignments of voltage and current for a two-port network. Refer to the diagram in Section 2.2. It does not mean that the feedback is inductive. $|C_{re}|$, on the other hand, does not have this polarity confusion because it is defined in terms of a magnitude and therefore is always positive.

3.3 $|C_{re}|$ can be related to the hybrid -π equivalent circuit as well as to the matrix equivalency. If the physical capacitance between the base and collector leads with the semi-conductor chip removed and the case grounded (three-terminal measurement) is known, it can be substracted from the measured value of $|C_{re}|$ and the difference will be a very close approximation of C_c in the hybrid -π network.

4. MEASUREMENT

4.1 Method

4.1.1 The method of measurement of $|C_{re}|$ must implement its formal mathematical definition. It is necessary to use that form of the definition which is expressed in physical rather than abstract qualities. From Section 2.3:

$$|C_{re}| = \frac{1}{\omega} \frac{|I_b|}{|V_{ce}|} \Bigg|_{V_{be} = \text{zero}}$$

4.1.2 The transistor under test is connected in the common-emitter configuration with the required bias conditions. See Figure 1. A fixed sinusoidal voltage of the desired frequency is applied across the collector-emitter terminals. A suitably small current-sampling resistor is used to provide a short between the base-emitter terminals. The voltage across this current-sampling resistor is directly proportional to $|C_{re}|$.

4.2 Frequency

The frequency of measurement shall be chosen such that the magnitude of $\omega\ C_{res}$ is at least ten times greater than the magnitude of g_{res}.

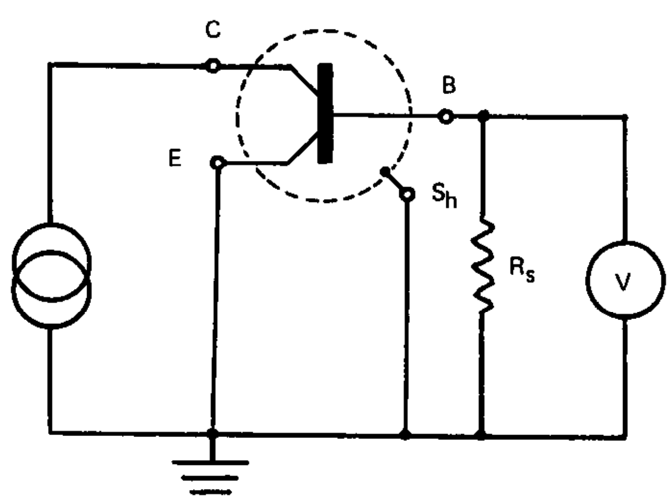


FIGURE 1

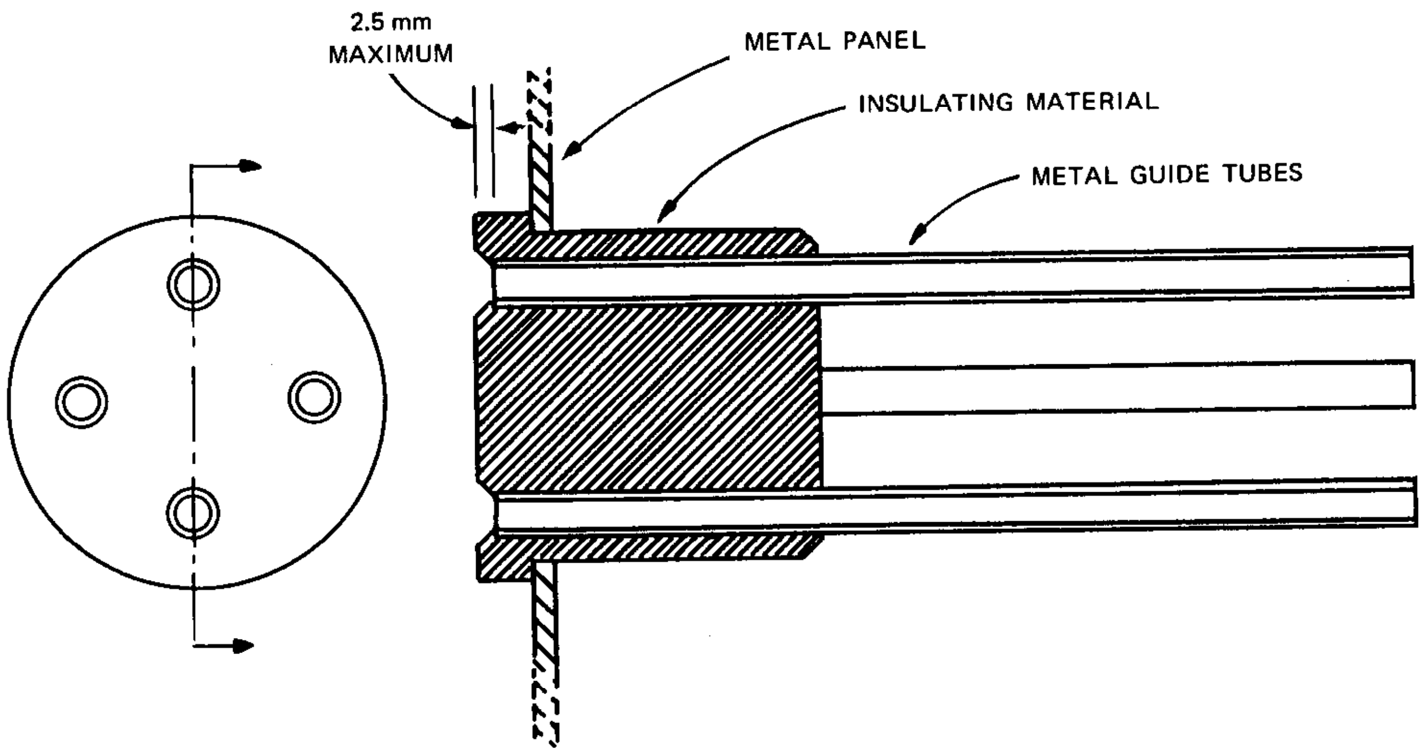
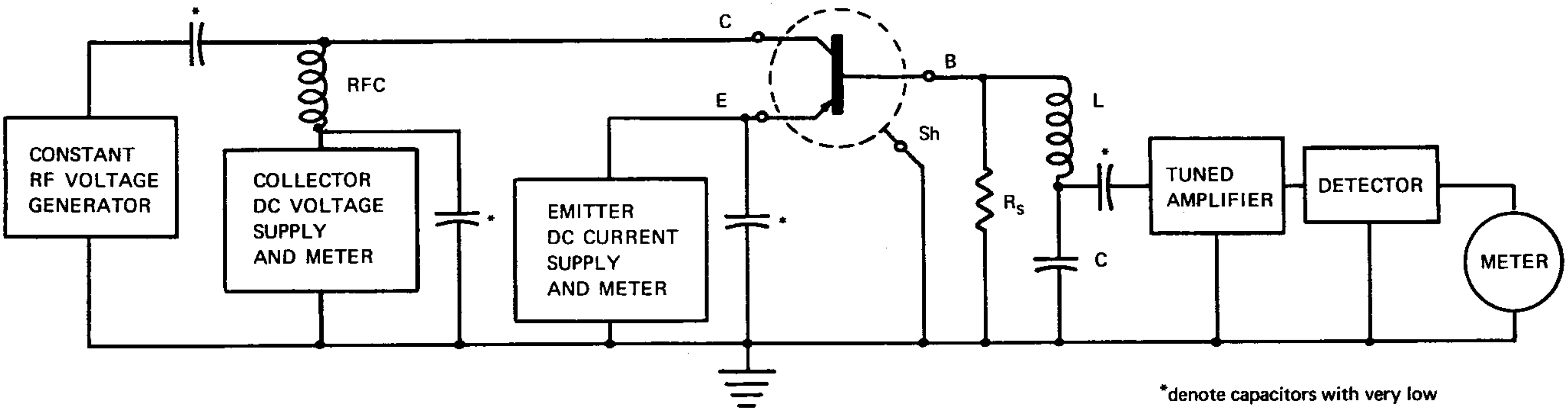


FIGURE 2

4.3 Test Socket

4.3.1 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 2. The spacing of the guide tubes shall conform close 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 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 two and one-half millimeters from the top surface. 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.



*denote capacitors with very low impedance at the measurement frequency

FIGURE 3

4.3.2 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 currents through the shielding to the socket terminals. The wires connecting the constant RF voltage generator and the metering circuitry to the socket should be shielded.

4.3.3 Cancellation of the residual $|C_{re}|$ meter reading (that exists when there is no transistor in the test socket) can be accomplished by using one or more of the following techniques:

4.3.3.1 The $|C_{re}|$ of the test socket itself can be largely eliminated by installing a piece of sheet metal (used as an electrostatic shield) between the base and the collector guide tubes and soldering it to the shield guide tube (which is grounded). This electrostatic shield should extend as near as practical to the top of the test socket (the header plane) and should extend sufficiently far in the other three directions to appreciably reduce the direct capacitance between the base and the collector guide tubes.

4.3.3.2 A dc bias can be applied to the detector to cancel the residual $|C_{re}|$ meter reading.

4.3.3.3 The mechanical zero adjustment of the panel meter can be used to "zero out" the residual reading. This technique will not work where the residual $|C_{re}|$ meter reading is larger than the capability of the mechanical zero or where the panel meter is used for more than one range.

4.4 Socket Connections

4.4.1 *Emitter*

The emitter shall be AC grounded. See Figure 3.

4.4.2 *Base*

The base shall be shorted to ground through a current sampling resistor, R_s.

4.4.3 *Collector*

The collector shall be fed with a constant RF voltage of the required measurement frequency. This voltage shall be low enough that doubling it will not change the $|C_{re}|$ reading by more than one-half of the required overall accuracy of measurement. This insures that the transistor will be tested under small-signal conditions.

4.4.4 *Shield*

The disposition of the shield lead (if any) shall reflect the transistor's intended use. The shield lead will almost always be grounded. A three-lead transistor having a floating case shall not have its case grounded (through a ground clamp) during the $|C_{re}|$ measurement unless it is intended to be used that way.

4.5 METER CIRCUITRY

4.5.1 *Current-Sampling Resistor*

The value of the current-sampling resistor, R_S, shall be low enough that doubling it will not increase the $|C_{re}|$ reading by more than one-half of the required overall accuracy of measurement. This condition can be met by satisfying the following inequality.

$$R_S \doteq \frac{(\beta + 1)\; r_e + r_{bb'}}{\frac{200}{p}}$$

where R_S = current-sampling resistor

$\beta = |h_{fe}|$ at the frequency of measurement

$r_e = \frac{kT}{qI_E} = \frac{25.7\ \text{mV}}{I_E}$ at 25^oC

$r_{bb'}$ = base-spreading resistance

p = overall measurement accuracy in percent

The value of $|C_{re}|$ is directly proportional to the magnitude of the sampling voltage, V_{rs}, across the current-sampling resistor, R_S.

$$|C_{re}| = \frac{|V_{rs}|}{\omega\, R_S\, |V_{ce}|}$$

This equation will yield the sensitivity requirement for the remainder of the metering circuitry.

4.5.2 *Tuned Amplifier*

A typical $|C_{re}|$ test will have a sampling voltage of a few microvolts per picofarad. It is necessary to use an amplifier to amplify this one or two microvolt signal to the level necessary to drive a detector and panel meter. A tuned rather than a wide-band amplifier is used to insure that any harmonics generated due to the nonlinearity of the transistor's base-collector junction will not affect the $|C_{re}|$ reading. A series L-C circuit connected across the current-sampling resistor, with the tuned amplifier being driven from the L-C junction will provide Q-multiplication of the sampling voltage. This L-C circuit must be tuned with a dc short between the base and collector socket terminals. This dc short should be mounted on a transistor header. The test transistor's bias supplies must be turned off while the dc short is plugged into the test socket.

4.5.3 *Panel Meter*

The panel meter shall be calibrated in terms of capacitance (picofarads). If the amplitude response of the tuned amplifier and detector circuitry isn't linear it will be necessary to provide an empirically derived scale for the meter.

4.6 Noise

The noise of the $|C_{re}|$ test set shall be low enough that the residual $|C_{re}|$ meter reading with an empty test socket and the constant RF voltage generator disconnected will be no more than five percent of full scale on any range.

4.7 Calibration

4.7.1 *Standard Capacitor*

A standard capacitor must be provided for the initial and subsequent periodic calibration of each scale of the $|C_{re}|$ test set. It is to be inserted into the base and collector guide tubes. The capacitance values chosen as standards shall lie in the range of one-half scale to full scale. The capacitor shall be capable of being pushed firmly down against the socket so that there will be negligible variations in the $|C_{re}|$ readings due to mechanical positioning. The capacitor shall be of a type that will not change its value more than a total of ten percent of the required overall accuracy of measurement due to the following:

1. Variation of environmental conditions within the specified range.

2. Difference between the $|C_{re}|$ test set's frequency of measurement and the calibration frequency.

3. Difference between the admittance magnitude and the capacitance due to the presence of excessive shunt conductance.

4.7.2 *Standard Calibration*

The standard capacitors shall be calibrated with a three-terminal capacitance meter having an accuracy of no worse than twenty percent of the required overall accuracy of measurement. The capacitance meter shall operate at a frequency no less than one-fifth or more than five times the $|C_{re}|$ test set's frequency of measurement. The adapter jig used to connect the standard capacitors to the input connectors of the capacitance meter shall conform to the requirements of Section 4.3 and shall use a test socket identical to that used on the $|C_{re}|$ test set. The metal cover of the adapter jig shall be connected to the capacitance meter's ground (or guard) terminal.

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