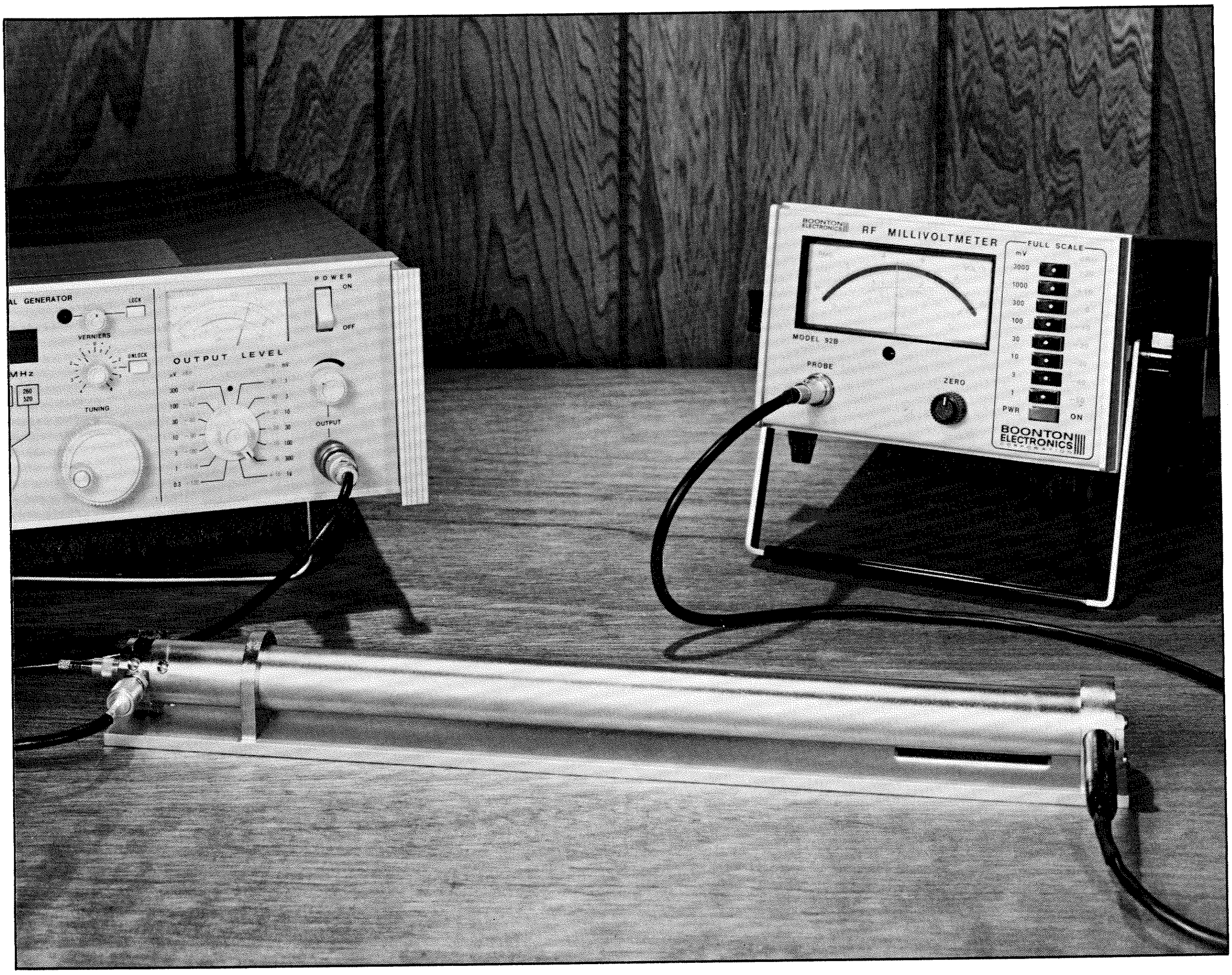
BOONTON

Model 34A Resonant Coaxial-Line

ISSUE #2

A Complete System for Measuring the Q-Factors of Unleaded or Leaded Components at High Frequencies



PURPOSE

The Boonton Model 34A Resonant Coaxial-Line, when coupled to a Model 102D Signal Generator and a Model 92B RF Millivoltmeter, provides an accurate system for measuring the Q-factor and effective capacitance of capacitors with excellent repeatability at high frequencies.

The Model 34A is especially well suited for the measurement of unleaded monolithic chip capacitors. Leaded capacitors may also be measured, with or without the influence of the resistance and inductance of the leads.

THEORY

A resonant, coaxial transmission-line, short-circuited at one end and open-circuited at the other, whose fundamental resonant frequency and Q-factor are known, is perturbed with a test component connected either in series at the short-circuited end of the line, or in shunt at the open-circuited end of the line.

The resulting Q-factor of the system applied in the proper equation, yields the effective series resistance (esr) and/or the Q-factor of the test element.

COMPONENT CONNECTION

Unleaded chip capacitors are connected in series with the line between the center conductor and the shorting plunger affixed to the plate at the end of the line.

Because of the convenience offered by a solid center conductor for series connections of unleaded capacitors, the Model 34A does not provide a slotted center conductor for leaded capacitors. If series measurements of leaded capacitors is required, order the Model 34A-01 which will accommodate either leaded or unleaded series connected capacitors.

Leaded components can also be connected at the open-circuited end of the line between the center conductor and the outer wall, using clamping means provided. For this connection the effect of the resistance and inductance of the leads is evidenced in the measured parameters. The Model 34-3A Radial Lead Swallower for shunt mode measurements is available for the convenient insertion of capacitors having radial leads with lengths of one inch, or less. Lead spacing of 0.030 to 0.8 inch can be accommodated.

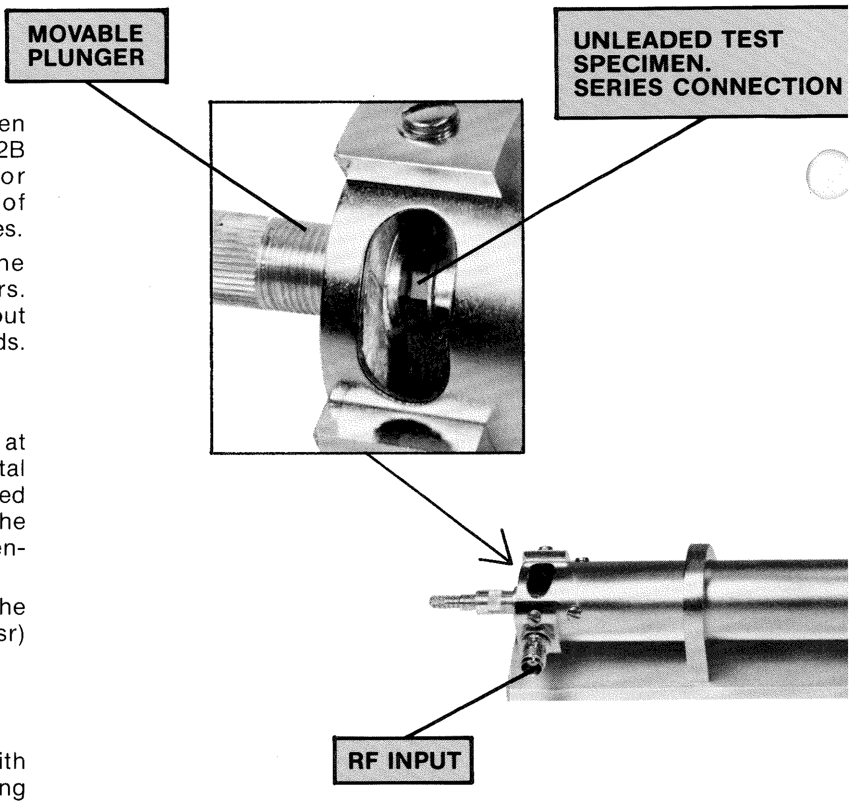
HIGHER VALUE CAPACITORS

The Model 34A can also be used to measure the esr of capacitors that fall into the category of blocking or by-pass capacitors. Capacitors of this type can be measured for effective series resistance by either a series or shunt mode measurement, depending upon the physical configuration of the capacitor.

Those with cubic construction may be placed in series with the line in the same manner as ordinary monolithic chip capacitors. The frequency of measurement will be in the order of 130 MHz, 390 MHz, 650 MHz, or higher, and the capacitor at any of these frequencies will be inductive. This, however, does not affect the program for esr.

Capacitors with radial leads or DIP construction can be measured in the shunt mode. In this case it is necessary to use a Model 34-3B Radial Lead Swallower which has a built-in series capacitor to permit operation at 100 MHz, 300 MHz, and 550 MHz.

Special fixturing is possible for other configured components provided short connections can be made. Measurements should yield Q-factors that reflect the properties of the test specimen rather than those of the fixture.



OTHER METHODS

Attempts at measuring high Q-factors of capacitors at high frequencies with admittance or impedance bridge techniques have been notably unsuccessful, principally because of imperfect bridge components and the extreme resolution needed to separate the loss from the major parameter when the Q-factor is several hundred or more.

Q-Meters have been used to measure the loss of capacitors having modest Q-factors of 500 or less. For higher Q-factors the uncertainty of the indirect measurement is sufficiently large to make the effort questionable. In some instances the measured Q-factor may even be negative.

It has also been suggested that S-parameters be used to determine the loss of capacitors at high frequencies. Unfortunately, the resolving power of present state network analyzers is inadequate for this purpose, and calculations based upon swept measurements of S_{11} and S_{21} produce a randomness of positive and negative numbers bearing no relationship to the actual Q-factor of the test capacitor.

ADVANTAGES OF THE 34A

The Model 34A Resonant Coaxial-Line offers advantages for the measurement of Q-factors of capacitors at high frequencies: there are no adjustable elements to alter circuit conditions in an unprescribed manner; the only variable is frequency which can be measured with an accuracy of 1 ppm or better; the loss of the line, as a function of frequency, is predictable; the Q-factor of the line is sufficiently high to support accurate measurements of low-loss capacitors; and the facility with which the center conductor can be parted, permits the insertion of components with little degradation of initial conditions.

REPEATABILITY OF MEASUREMENTS

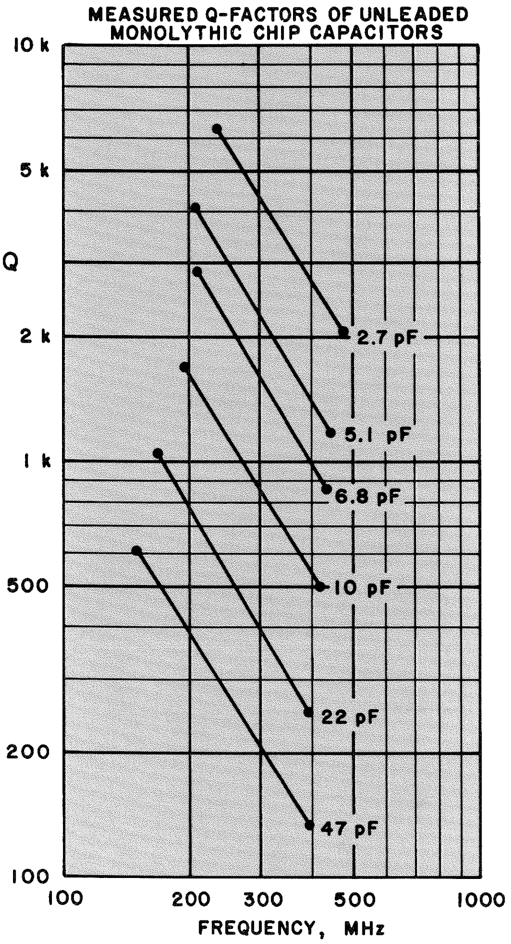
Excellent repeatablity is obtained using the 34A. Measurements of Q-factors of over 1000 may be repeated

MEASURED PARAMETERS

The evaluation of each component requires only the measurement of two frequencies, one on each side of the resonant response at a predetermined ratio of resonant to off-resonant voltage. When these two frequencies are entered in a programmed calculator, in which the coaxial line parameters of f_0, and Q_0 have been stored, the values of f_1 (the measuring frequency), esr, C, and the Q-factor of the test component are obtained.

EXAMPLE DATA

The graph below demonstrates the results of Q-factor measurements made at two frequencies for each of six capacitors using the series mode of operation.



ELECTRICAL SPECIFICATIONS

Capacitance Range[1]: 0 to >1000 pF

Series mode: 1.0 pF to >1000 pF
Shunt mode: 0 to 200 pF
Maximum value of capacitance shown is not an absolute limit, but for the shunt mode the influence of lead resistance and inductance becomes immoderate as capacitance and frequency increase. No limit for capacitance when measuring esr, only.

Frequency Range[1]:

Series mode: 130-250 MHz, 390-500 MHz, 650-750 MHz[2]
910-1000 MHz[2], 1170-1250 MHz[2]
Shunt mode: 40-130 MHz, 280-390 MHz, 540-650 MHz[2]

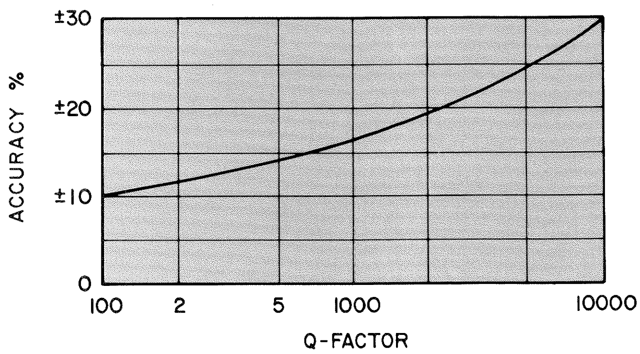
[1]Capacitance and frequency are interdependent.

[2]Use Boonton 102-1A Frequency Doubler for frequencies above 520 MHz. Also use Boonton 34-1A RF Probe and 34-2A cut-off attenuator above 700 MHz.

Test Level:

Series mode: Approximately 3 mA, or less.
Shunt mode: Approximately 0.2 volt, or less.

Accuracy: Certification for high frequency Q-factors of capacitors is not presently available from the National Bureau of Standards. Analysis of the sources of error for the 34A system of measurement indicates that the measurement accuracy for Q-factors is generally within $\pm (5 + Q^{0.35})\%$



MECHANICAL SPECIFICATIONS

Overall length: 24.2 inches (61.5 cm)
Width: 2 inches (5.1 cm)
Height: 2 inches (5.1 cm)
Maximum component body length for series measurements: 0.3 inch (7.6 mm)
Maximum component lead length that can be swallowed for a series measurement: 1 inch (2.54 cm) each lead (34A-01)
Spacing of contacting clamps for shunt measurements: 0.6 inch (1.52 cm)
Minimum component lead length for a shunt measurement: Approximately 0.7 inch (1.78 cm) without 34-3A or 34-3B.

ACCESSORIES

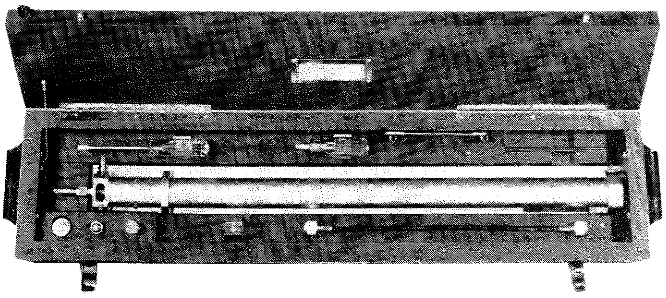
Supplied:

Storage case
1 ft. TNC/N coaxial lead
Tweezers
5/64" Allen wrench
Screwdriver
1/2" wrench
Spare input connector
34-2A Cut-off Attenuator

Model 34-2A Cut-off Attenuator

Optional:

34-1A High Z RF Probe
34-3A Radial Lead Swallowers (shunt measurement only)
34-3B Radial Lead Swallowers with built-in series capacitor (shunt measurement only)
34-4A Piston Capacitor Adapter, 15/64 inch x 64 threads/inch
34-4B Piston Capacitor Adapter, 0.120 inch x 80 threads/inch
102-1A Frequency Doubler.



Model 34A in storage case (furnished)

FM/AM Signal Generator

Model 102D

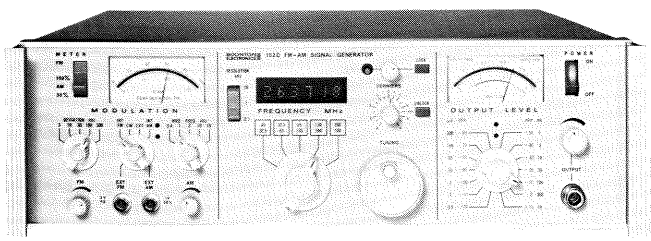
450 kHz to 520 MHz

The 102D FM/Am Signal Generator is a well shielded, low noise source from 0.45 to 520 MHz.

It has the smoothness of tuning necessary to take advantage of its excellent stability and frequency resolution. In addition, it has the high output level needed to drive the 34A and a vernier RF output control that allows easy detector reference level setting. The higher frequencies at which the 34A line operates can be derived using the accessory frequency doubler (also functions at X4).

Some of the main features are an excellent residual FM specification, 100 Hz resolution on a 6 digit frequency display, individual metering of modulation and RF output, true peak monitoring of AM level and FM deviation, 0-300 kHz internal FM deviation on all bands and external FM deviations as wide as 2 MHz p-p even at the lowest carrier frequency.

The output frequency of the Model 102D can be phase locked to a very stable internal reference oscillator by means of a built-in locking circuit. A unique feature is that the frequency counter is run by an identical but separate oscillator. This allows display of the true output frequency even when the vernier is used to tune between lock points.



SPECIFICATIONS

RF OUTPUT

Power Level: –130 dBm to + 13 dBm.
Attenuator: 13 steps, 10 dB/step, plus variable 13 dB.
Leveling: ±0.5 dB.
Impedance: 50 Ω; VSWR < 1.5:1

FREQUENCY

Range: 0.45 to 520 mHz, 5 bands *
Stability (locked): Bands 2-5, <0.2 ppm/hr after 1 hour warmup
<0.05 ppm/hr after 4 hour warmup
Band 1 <100 Hz/hr after 1 hour warmup

**102-1A Frequency Doubler provides higher frequency outputs to beyond 1.5 GHz.*

Accuracy (locked or unlocked): ±(resolution + 1 ppm), 15°C to 35°C

FREQUENCY MODULATION

Bandwidth: 50 Hz to 200 kHz locked, DC to 200 kHz unlocked.
0 kHz)
Deviation: 0 to 300 kHz in five ranges.
Accuracy: ±10% fs.

AMPLITUDE MODULATION

Percent: 0 to 100.
Calibrated Ranges: 30% , 100% fs.
Bandwidth: DC to 20 kHz.

MODULATION OSCILLATOR

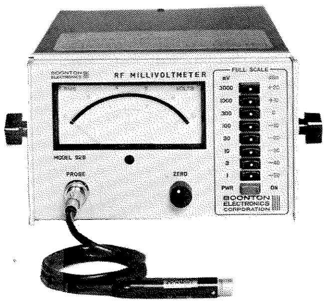
Frequencies: 400 Hz, 1, 3, 10, 19 kHz, ext.
Accuracy: ±3%

RF Millivoltmeter

Model 92B

This rf millivoltmeter offers the best choice for sensitive, wide-band, accurate rf voltage measurements.

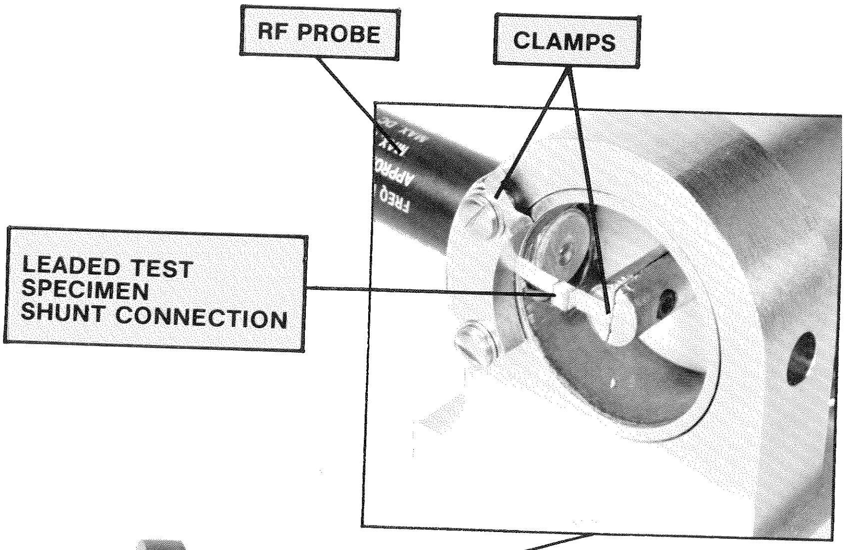
It is well suited as a detector for use with the Model 34A Coaxial Resonant Line. At frequencies greater than 700 to 800 MHz the optional 34-1A High Impedance RF Probe should be used instead of the Model 91-12F supplied.

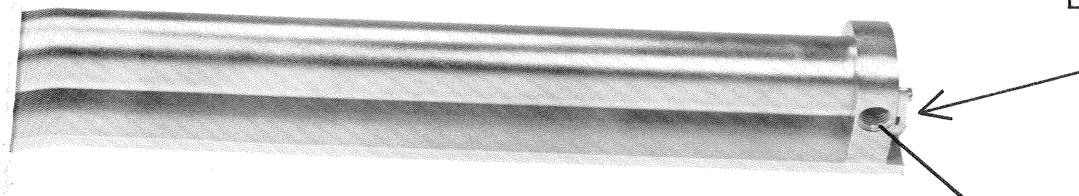


SPECIFICATIONS

Voltage Range: 200 μV to 3 V (300 V up to 700 MHz with divider). Useful indications down to 100 μV.
Frequency Range: 10 kHz to 1.2 GHz. * *
Basic Accuracy: ±(1% rdg + 1% fs).
Indicator: 4½" taut-band meter; scales 0-3, 0-10 and dBm.
Remote Control: All functions and ranges commanded by TTL inputs.
DC Output: 10 V fs.
Accessories Furnished:
91-12F RF Probe, 91-8B 50 Ω BNC Adapter, 91-13B Probe Tip.

***34-1A High-Z Probe when used with 92B gives accurate relative measurements to beyond 1.5 GHz.*





34A RESONANT COAXIAL-LINE

within a few percent. An important requirement is that a signal generator with superior frequency stability and resolution (such as our Model 102D) be used.

ACCURACY

Analysis of error souces for the 34A Q measurement system shows that absolute accuracies of ± 10% at Q = 100 to ± 30% at Q = 10,000 can be supported. Bearing in mind the NBS certification is not presently available, this has to be considered as "state-of-the-art".

MEASUREMENT SYSTEM

To take full advantage of the range of the 34A Resonant Coaxial line, it is recommended that the complete set of equipment and accessories be ordered.

The 102D Signal Generator, 92B RF Millivoltmeter, 102-1A Frequency Doubler, and 34-1A High Z Probe, are compatible and will perform satisfactorily in the system.

In addition to the requirements of good stability and resolution in the signal source, the measurement system also requires the high output power of the Boonton Model 102D Signal Generator and the sensitivity of the Boonton Model 92B RF Millivoltmeter. This allows loose coupling into and out of the coaxial line so as not to alter appreciably the inherent properties of the line.

FREQUENCY

The measuring frequencies are a function of the length of the coaxial line and the effective capacitance of the test specimen. The line length of the Model 34A was selected to permit capacitors to be measured in frequency bands for which there is general demand. At frequencies above 600 MHz radiation loss can be observed which increases with frequency and adversely affects the Q-factor of the line. Also, at frequencies above 700 or 800 MHz, the input resistance of the Boonton Model 91-12F RF Probe influences the loss of the resonant line. For measurements above these frequencies a Model 34-1A RF Probe, with a high input impedance, and a Model 34-2A Cut-Off Attenuator, which prevents radiation, must be used.

The following table shows related ranges of capacitance and frequency for both shunt and series modes of measurement.

SHUNT RANGE (pF)	FREQUENCY RANGE (MHz)		SERIES RANGE (pF)	
200 to 0	25 to 130			
		130 to 250	> 1000 to 1.0	(1/4) λ
100 to 0	265 to 390			
		390 to 500	> 1000 to 1.0	(3/4)λ
30 to 0	530 to 650			
		650 to 750	> 1000 to 1.0	(5/4)λ
		910 to 1000	> 1000 to 1.0	(7/4)λ
		1170 to 1250	> 1000 to 1.0	(9/4)λ