MODELS 494B 494C

SQUARE-WAVE VOLTAGE CALIBRATOR

The Models 494B and 494C Square-Wave Voltage Calibrators are square-wave generators designed specifically for precise calibration of oscilloscopes, and are also equally useful for precise calibration of RMS-indication, mean-indication, peak-indication, or peak-to-peak-indication type vacuum tube voltmeters.

Equipped with direct-reading peak-to-peak voltmeter and precision voltage divider circuit, these equipment deliver accurate square-waves up to 100 volts p-p at frequency of 60 or 1000 cps, and also can deliver DC output which voltage is equal to peak-to-peak voltage of square-wave.

Model 494C is identical to Model 494B except it utilizes precision wire-wound resistors in its voltage divider circuit, and enables the calibration at the highest accuracy.

SPECIFICATIONS

Power Requirement	100 volts, 50 to 60 cps, approx. 40 VA (1).
Size - Cabinet	170 W x 230 H x 251 D mm
Maximum	176 W x 245 H x 298 D mm
Weight	Approx. 6.5 kgs

Items Supplied with Equipment
- 1 - Type 47 Plug (Japan Telephone & Telgraph Corp Specification)
- 1 - KIK-941B Terminal Adaptor
- 1 - Inclining Angle
- 1 - Operation Manual
- 1 - Test Data

<u>Square-Wave Output</u>

Polarity	Square-wave rising toward plus from zero volt.
Range	18 ranges 0.1 - 0.2/0.5/1/2/5/10/20/50/100 mV p-p 0.1 - 0.2/0.5/1/2/5/10/20/50/100 V p-p
Accuracy	Model 494B -- Within 3% Model 494C -- Within 2% Model 494B - Using external meter - Within 1.5% (2) Model 494C - Using external meter - Within 0.3% (2)
Repitition Frequency	60 cps ±10% and 1000 cps ±10%
Sag	Less than 0.5%
Overshoot	Less than 1%

Rise-Up Time	Model 494B -- Less than 2 microseconds Model 494C -- Less than 10 microseconds
Symmetry	Adjustable to 1:1
Output Impedance	0 to 2.6 kiloohms, varies as to range position.

DC Output

Polarity	Plus
Range	Same as square-wave output
Accuracy	Same as square-wave output
Output Impedance	0 to 2.6 kiloohms, varies as to range position.

Stability

Line Stability	For ±10% change in line voltage -- Within ±1%

Note (1) When output is DC 100 volts.
(2) Precision external meter having full scale current of 200 uA and internal resistance of less than 1 kiloohm, or precision voltmeter with shunt resistor of 500 ohms is used. Accuracy does not include the error of the meter.

FUNCTIONS OF CONTROLS AND TERMINALS

POWER ON OFF OUTPUT VOLTS	Combined power switch and output voltage control. Turning this knob clockwise from OFF position, the power is applied and the equipment attains operating condition after about 20 seconds of warm-up. Turning further this knob clockwise, the output voltage increases, and its control range is from 35% to 105% of the meter indication.
VOLTS RANGE	A dual knob for selection of voltage range. External black colored knob is for selection of 9 ranges from 0.2 to 100. Internal red colored knob is for selection of voltage units, mV or V. For example, when external knob is placed 50 and internal knob is placed at MV, and if meter indication is 47 on scale of 50, output voltage is 47 mV p-p or 47 mV DC.
Output Voltmeter	A moving-coil type DC voltmeter to indicate output voltage, and is calibrated in 3 scales: 0 - 20, 0 - 50, and 0 - 100.
OUTPUT	UHF-type receptacle. Accepts UHF-type plug and also M-type plug and banana plug. GND terminal is connected to the chassis of the equipment.

+DC ↕ SQUARE	A toggle switch. With this switch placed in +DC position, DC voltage appears at OUTPUT, and placed in SQUARE position, square-wave appears at OUTPUT. Output voltage is not affected by the position of this switch.
SYMMETRY	A control to adjust the symmetry of the square-wave.
1000 C/S ↕ 60 C/S	A toggle switch to change the repitition frequency of square-wave. 1000 cps output is usually used for voltage calibration, and 60 cps output is used in measurement of sag.

PRINCIPLE OF OPERATION

Following schematic is to illustrate the basic circuit of this equipment when this equipment is working as square wave generator. V1 is a free-running multivibrator, and each section of tube is repeating on and off conditions reciprocally. Then, a waveform develops at plate of V1A as shown in the figure.

This waveform is supplied to grid of V2A, and V2A is working as a switch to turn on the current for a half period of the cycle and to turn off for other half period of the cycle. Resultant square-wave appears at the cathode of V2A. If characteristics of V2A are the same as that of V2B, peak-to-peak value of the square-wave should be equal to the cathode voltage of V2B, which is supplied to DC voltmeter. Loading effect of DC voltmeter can be neglected since output impedance of V2B is so high as compared to input impedance of voltmeter. (150 ohms as compared to 500 kiloohms which causes only 0.03% drop.) Using a high-mu triode with each unit having equal characteristics to the other as V2, connecting high accuracy resistors in places of R21 and R22, peak-to-peak value of square-wave is successfully observed at the cathode of V2B. In addition plate supply voltage is regulated employing series-type voltage regulator circuit for stable operation.

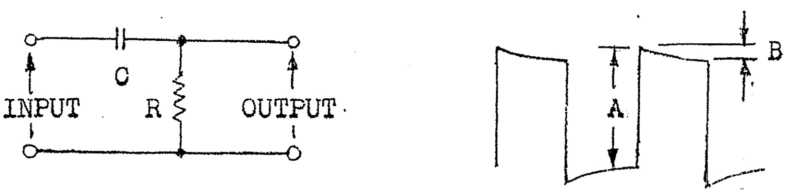
APPLICATION - ADJUSTMENT OF OSCILLOSCOPES

Calibration of Oscilloscope

Using this equipment as square-wave generator, oscilloscope can be calibrated in volts p-p/cm or volts p-p/div.

Measurement of Sag

When a square-wave signal is applied to a resistance-capacitance network as shown below, output is deformed. This is caused by leading low frequency phase shift.



Sag = B/A

Following table gives the relation between sang and time constant of this resistance-capacitance network (time constant - R in megohms x C in microfarads).

Sag (%)	At 60 cps	At 1000 cps
1	0.8301	0.04975
2	0.4125	0.02475
3	0.2736	0.01642
4	0.2041	0.01225
5	0.1624	0.00975
6	0.1347	0.00808
7	0.1148	0.00689
8	0.0999	0.00600
9	0.0884	0.00530
10	0.0791	0.00475

Adjustment of Input Attenuator

In input attenuator circuit of oscilloscope, capacitance divider network is provided in parallel to resistance divider network to compensate the frequency response at the high end. Typical example of circuit is shown in the figure below. In this circuit, if C1 is too high, sag results due to in adequate attenuation of high frequency component and resultant leading phase shift of low frequency component. If C1 is too low, fuzz results due to excessive attenuation of high frequency component and resultant lagging phase shift of low frequency component.

Low capacitance probe can also be adjusted in accordance to this same principle.

<u>Short Circuit of Output</u>

When range selector knob is placed in 100 volts position, and if output is short circuited, V2 and R217 may be damaged; and in 50 or 20 volts ranges, V2, R1, or R2 may be spoiled. When range selector knob is set in ranges below 10 volts, however, the circuit may hot be damaged even if output is short circuited.

<u>Output Voltmeter</u>

Output voltmeter is provided with a mirror to minimize reading error caused by parallax. When much higher accuracy is required, a precision meter can be connected externally as decribed in the following paragraph.

As described in the foregoing paragraph, when equipment is used as square-wave generator, meter indication might include an error resulting from difference of characteristics between each unit of V2 and difference of resistance values of R21 and R22. Therefore, in reading peak-to-peak voltage of output square-wave, it is preferred that SQUARE ↔ +DC switch is turned to +DC position so that cathode voltage of V2B is read which is equal to peak-to-peak voltage of output square-wave.

<u>Use of External Meter</u>

A meter can be connected externally using type 47 plug supplied with the equipment for much accurate control of output voltage. Plus side of the meter is connected to the center conductor of the plug and minus side is connected the the external conductor of the plug.

It is recommended to use a precision moving-coil type ammeter capable to measure between 80 and 200 uA with internal resistance of 500 ohms. If internal resistance differs from 500 ohms, error results accordingly. (If 1000 ohm meter is used, an error of -0.1% is caused.)

It is also recommended to use a DC potential meter or a digital voltmeter. A precision 500-ohm resistor is connected to the plug, and voltage across this resistor is measured. (A current of 200 uA causes voltage drop of 0.1 volt)

Output Impedance

Output Impedance when supplying +DC output is shown in column ON in the following table. When supplying square-wave, and V2B is in conducting condition, output impedance is also same as shown in column ON, and when V2B is in cutoff condition, output impedance is as shown in column OFF. Output impedance is almost purely resistive.

Voltage drop due to loading effect relates only to output impedance in ON column, and its rate is approximately equal to the ratio of output impedance to loead impedance. The column 1MΩ Load shows percentage of voltage drop when 1 megohm resistor is connected as load. Output impedance when range switch is put in MV position is approximately 200 ohms.

Range	Output Impedance (KΩ)		1 MΩ Load
	ON	OFF	(%)
100 V	0.25	9.03	
50 V	2.57	4.93	0.26
20 V	1.70	2.08	0.17
10 V	1.01	1.10	0.10
5 V	0.58	0.60	0.06
2 V	0.30	0.30	0.03
1 V	0.20	0.20	
0.5 V	0.15	0.15	
0.2 V	0.12	0.12	

APPLICATION - CALIBRATION OF VACUUM TUBE VOLTMETERS

AC vacuum tube voltmeters can be calssified as to their type indications into following four categories:

1. To indicate RMS value of voltage
2. To indicate mean value of voltage (Kikusui Model 161A)
3. To indicate peak value of rectified voltage (Kikusui Model 111A)
4. To indicate peak-to-peak value of voltage (Kikusui Model 107A)

Calibration on these vacuum tube voltmeters are generally made applying known value of sine-wave and calibrating in RMS value. Since square-wave voltage can easily be converted into RMS, mean, or peak value, this equipment can be used in calibration of any type of meter in any indication. However, it should be noted that the acutal vacuum tube voltmeter does not perform exactly in accordance to the theory, and its indication may deviate from ideal RMS or peak value. Consequently, the calibration made using square-wave may not always coincide with the calibration made using sine-wave.

Adjustment of Symmetry

In calibration of RMS indication type or mean indication type vacuum tube voltmeters, symmetrical square-wave is used (that is, duty cycle is 50%). Provided peak-to-peak value is the same, RMS value or mean value of square-wave is the maximum when duty cycle is equal to 50%. Therefore, symmetry control is adjusted so as to obtain maximum indication on RMS indication or mean indication vacuum tube voltmeters.

Conversion of Voltages

VTVM Indication	Scale	Adjustment of Symmetry	Indication of VTVM / Output of 494B (p-p)
RMS	RMS	Required	1/2 or 0.5/1
Mean	RMS	Required	1/1.8 or 0.555/1
Mean	Mean	Required	1/2 or 0.5/1
Peak	RMS	Not required	1/2.83 or 0.354/1
Peak	Peak	Not required	1/2 or 0.5/1
Peak-to-peak	RMS	Not required	1/2.83 or 0.354/1
Peak-to-peak	Peak-to-peak	"	1/1 or 1/1

Examples

Following table gives examples of calibrations made using square-wave output of this equipment on three types of Kikusui vacuum tube voltmeters.

At 1000 cps		Model 161A Mean Indication		Model 111A Peak Indication		Model 107A P-P Indication	
V T V M							
Range	Indication	Square Wave p-p	Converted RMS Value	Square Wave p-p	Converted RMS Value	Square Wave p-p	Converted RMS Value
50	50	90.6	50.3				
50	40	72.7	40.3				
50	30	54.5	30.2	84.6	29.9	84.0	29.7
50	20	36.3	20.15	56.5	20.0	56.0	19.8
50	10	18.2	10.1	28.8	10.0	27.7	9.8
15	15			42.4	15.0	41.8	14.8
15	12			34.0	12.0	33.4	11.8
15	9			25.3	8.94	24.9	8.8
15	6			16.8	5.95	16.5	5.8
15	3			8.01	2.83	8.0	2.86
5	5			14.0	4.93	13.7	4.85
5	4			11.1	3.92	10.9	3.85
5	3			8.01	2.89	8.0	2.86
5	2			5.40	1.91	5.3	1.88
5	1			2.61	0.92	2.57	0.91
1.5	1.5			4.00	1.42	3.96	1.40
1.5	1.2			3.17	1.12	3.11	1.10
1.5	0.9			2.33	0.82	2.29	0.81
1.5	0.6			1.50	0.53	1.49	0.53
1.5	0.3			0.70	0.25	0.68	0.24

ADJUSTMENT

Check on R21 and R22

Values of R21 and R22 are checked. Difference should not exceed 1% on Model 494B or 0.5% in Model 494C.

Regulated Power Supply

Turning SQUARE ↔ +DC switch in SQUARE position and VOLTS RANGE switch in 100 mV position, and further, adjusting output voltage so that meter pointer indicates 100, voltages at various points of the circuit and their variations as to variation of line voltage by ±10% are checked.

Eb1 -- 250 -10 volts. Ripple less than 0.2 volts p-p. Variation as to line voltage change approximately 3 volts.

Eb2 -- R216 and R217 are adjusted so that variation of Eb2 covers from 30 to 105 volts as OUTPUT VOLTS is turned between its ends. Ripple less than 20 millivolts p-p. Variation as to line voltage change approximately 0.2 volt. Variation when SQUARE ↔ +DC switch is turned should be lessthan 0.1 volt.

V6 -- Voltage across voltage reference tube V6 (85A2) should be 85 ±3 volts. Variation as to line voltage change approximately 0.3 volt.

Output Meter

Adjustment of meter circuit is made using a standard ammeter capable to measure 80 to 200 uA DC and a standard voltmeter capable to measure 40 to 100 volts DC. SQUARE ↔ +DC switch is turned to +DC position.

Adjustment of Current Sensitivity -- Standard ammeter is connected to the jack, and turning OUTPUT VOLTS, current is adjusted exactly to 200 uA. Then, a resistor connected in series to R26 is selected so that the meter pointer indicates its full scale.

Adjustment of Voltage Sensitivity -- Standard voltmeter is connected between pin #3 of V2A and GND terminal, and voltage is exactly to 100 volts turning OUTPUT VOLTS. Then, a resistor connected in series to R24 is selected so that the meter pointer indicatesits full scale.

Check on Scale -- Reducing current or voltage between 40 and 100% of full scale, correspondence between standard ammeter or voltmeter and panel meter is checked.

Selection of V2

Preparing a batch of well aged 6BQ7A, a tube is selected which shows minimum voltage difference when SQUARE ↔ +DC switch is turned to either side.

Check on R1 through R11

Values of R1 through R11 are checked. Relative deviation should be less than 1% in Model 494B and less than 0.2% in Model 494C.