M-140 Multifunction Calibrator

Model M-140 is a bus compatible multifunction calibrator for precise generation of electric units. It is mainly designed for calibration by manufacturers of electronic instrumentation. It also finds its application at laboratories, design and service departments as well as at institutions that have to frequently calibrate their equipment in accordance with their internal quality certification system.

Compared with standard calibrators, the model M-140 represents a new concept of multifunctional calibrators, which generate not only the standard electric parameters but also parameters for temperature and energy applications. Apart from this, the calibrator generates non-harmonic signals for the testing of equipment with non-zero distortion input signals. The signals can be generated with variable frequency, amplitude and pulse-width ratio. The simulation of DIN thermocouples and RTD sensors is provided. M-140 is a high accuracy and high stability instrument with easy operation, which can be used for the calibration of multimeters, analog instruments, panelmeters, clamp ammeters, hand calibrators, wattmeters, electrometers, oscilloscopes, thermometers, dataloggers, X-Y recorders, etc. A built-in multimeter function can be utilised for simultaneous testing/calibration of transmitters, regulators and other controllers without the need of using supporting equipment.

Parameters

The calibrator´s main function is the generation of DC- and AC- voltage between 0 μV and 1000 V and DC- and AC- currents from 0μA to 20 A. By using an optional current coil currents from 50 μA to 1000A can be calibrated. The frequency range is programmable from 20Hz to 50 kHz. The best accuracy for DC voltage is 0.0035%, for AC voltage 0.03%, for DC current 0.013% and for AC current 0.055%.

A non-harmonic periodical signal with a defined crest factor can be generated and used for the calibration of multimeters, considering accuracy during measurements of distorted AC signals.

Resistors and capacitors can be simulated between 0 Ω and 50 Ω (accuracy of 0.03%) and 1 nF to 50 μF (accuracy of 0.5%). The resistors can be used for AC signals up to 1 kHz.

Model M-140 generates square wave signals with a programmable pulsewidth. The amplitude is programmable from 1mV to 10V within a frequency range of 0 to 10 kHz.
Another frequency output of up to 20MHz square wave with very fast edges is available and can be used for calibration of frequency characteristics of multimeters, oscilloscopes and time bases of instruments.

Wattmeters and electrometers for measuring DC or AC power can be calibrated up to 240V and 10A with a phase setting from -1 to +1 with a resolution of 1% within a frequency range of 20Hz to 400Hz. The voltage output can be loaded with 30mA and permits a calibration of classic analogue wattmeters.

The calibrator can simulate RTD thermometers and DIN thermocouples R, S, B, J, K, T, E and N. The cold junction can be set with the keyboard directly as temperature. The accuracy of the RTD thermometers is 0.04ºC to 0.5ºC. The accuracy of thermocouples is 0.4ºC to 4.3ºC.

Built-in Multimeter

Multimeter with inputs for 0-20mA and 0-10V has an accuracy of 0.01 % and is suitable for measuring standardised process signals from transmitters which are under test or calibration.

Calibrator - Tester

M-140 can be programmed as a calibrator-tester with up to 10 steps of selected testing procedure. The end of the test sequence is terminated with a display record output of a type PASS/FAIL. The output relay allows to control additional equipment.

Easy to use

There are additional functions available, which simplify the use of the instrument, such as programming the relative error band, displaying the actual uncertainty of the generated signal, calibration procedures, etc.

The large-scale LCD display shows the menu steps, the generated parameters as well as other additional information. Some of the keys are directly assigned to frequently used functions. Output ports GPIB – IEEE488 and RS232 are standard and permit to operate the calibrator in automatic testing set-ups.

Specification

Uncertainties include long-term stability, temperature coefficient, linearity, load and line regulation and the traceability of factory and National calibration standards. Specified accuracy is valid after one hour warm up in temperature range $23 \pm 2 \ ^{\circ}$C. Specified accuracy is one year accuracy.

Calibrator

Voltage

Summary range DCV:	0 μV - 1000 V
Summary range ACV:	1 mV – 1000 V
Internal ranges:	20 mV, 200 mV, 2 V, 20 V, 240 V, 1000 V
Frequency range:	20 Hz to 50 kHz below 20 V
	20 Hz to 10 kHz below 200 V
	20 Hz to 1000 Hz below 1000 V
Frequency uncertainty:	0.005 %

DCV uncertainty

range	*% value + % range*	*max. current mA*
0 μV - 20 mV	0.03 + 0.0 + 10 μV	5
20 mV - 200 mV	0.01 + 0.0 + 15 μV	5
200 mV - 2 V	0.003 + 0.0008	30
2 V - 20 V	0.003 + 0.0005	30
20 V – 240 V	0.003 + 0.0005	30
240 V - 1000 V	0.005 + 0.005	2

[2] value of the range for uncertainty calculation is 200 V

ACV uncertainty

range	*% value + % range*	*max. current mA*	*% value + % range*	*max. current mA*
	20 Hz - 10 kHz	*20 Hz - 10 kHz*	*10 kHz - 50 kHz*	*10 kHz - 50 kHz*
1 mV - 20 mV	0.2 + 0.05 + 20 μV	5	0.20 + 0.10 + 20 μV	5
20 mV - 200 mV	0.1 + 0.03+ 20 μV	5	0.15 + 0.05 + 20 μV	5
200 mV - 2 V	0.025 + 0.005	30	0.05 + 0.01	10
2 V - 20 V	0.025 + 0.005	30	0.05 + 0.03	10
20 V – 240 V [2]	0.025 + 0.010	30	- -	
240 V – 1000 V	0.03 + 0.02 [1]	2	- -	

[1] valid for f < 1000 Hz
[2] value of the range for uncertainty calculation is 200 V, in the range 200 to 240 V is frequency limited to 1 kHz.

range	*% value+ % range*	*max. current mA*
	50 kHz - 100 kHz	*50 kHz - 100 kHz*
1 mV - 20 mV	1.0 + 0.10 + 20 μV	3
20 mV - 200 mV	0.3 + 0.05 + 20 μV	3
200 mV - 2 V	0.2 + 0.05	5
2 V - 20 V	0.2 + 0.05	5
20 V – 240 V	- -	
240 V – 1000 V	- -	

Auxiliary parameters

range	*20mV*	*200mV*	*2V*	*20V*	*200V*	*1000V*
THD[2] [3]	0,05% + 200 uV	0,05% + 300 uV	0,05%	0,05%	0,05%	0,2%
output impedance	< 10 mΩ	< 10 mΩ	< 10 mΩ	< 10 mΩ	< 100 mΩ	< 100 mΩ
maximal capacitance load	500 pF	500 pF	500 pF	500 pF	300 pF	150 pF

[2] parameter includes non-linear distortion and non-harmonic noise
[3] valid for frequencies to 10 kHz

Function Shape

Voltage range:	1 mV to 200 V
Wave form:	square, positive, negative, symmetrical, ramp A, ramp B, triangle truncated sin with THD 13,45 %
Peak value uncertainty:	0.3 % + 50 uV
Displayed values:	peak, effective

Minimum frequency for squarewave signals is 0.1 Hz, for all others 20 Hz.

Current

Summary range DCI:	0 - 20 A (with adapter 130-50 to 500 A)
Summary range ACI:	1 μA - 20 A (with adapter 130-50 to 500 A)
Internal ranges:	200 μA, 2 mA, 20 mA, 200 mA, 2 A, 20 A
Frequency range:	20 Hz to 5 kHz bellow 200 mA
	20 Hz to 1000 Hz bellow 20 A
Frequency uncertainty:	0.005 %

DCI uncertainty

range	% value + % range	max. voltage V
0 μA - 200 μA	0.05 + 0.0 + 20 nA	3
200 μA - 2 mA	0.02 + 0.005	3
2 mA - 20 mA	0.01 + 0.003	3
20 mA - 200 mA	0.01 + 0.003	3
200 mA - 2 A	0.015 + 0.005	3
2 A - 20 A	0.02 + 0.010	1.5

ACI uncertainty

range	% value + % range	max voltage Vef	% value + % range	max voltage Vef
	20 Hz - 1 kHz		**1 kHz – 5 kHz**	
1 μA - 200 μA	0.15 + 0.0 + 20 nA	3	0.30 + 0.10 + 20 nA	3
200 μA - 2 mA	0.07 + 0.01	3	0.20 + 0.05	3
2 mA - 20 mA	0.05 + 0.005	3	0.20 + 0.05	3
20 mA – 200 mA	0.05 + 0.005	3	0.20 + 0.05	3
200 mA – 2 A	0.05 + 0.005	3	- -	- -
2 A - 20 A	0.10 + 0.03	1.5	- -	- -

range	% value + % range	max voltage Vef
	5 kHz – 10 kHz	
1 μA - 200 μA	- -	- -
200 μA - 2 mA	0.50 + 0.07	2
2 mA - 20 mA	0.50 + 0.07	2
20 mA - 200 mA	0.50 + 0.07	2
200 mA - 2 A	- -	- -
2 A - 20 A	- -	- -

Note: When option 140-50 Current Coil is used, add uncertainty 0.3% of the set current to the value specified in above table. Output current is multiplied by factor 50.

Auxiliary parameters

range	200 uA	2 mA	20 mA	200 mA	2 A	10 A
maximal inductive load	400 uH	400 uH	400 uH	400 uH	200 uH	100 uH
THD[1]	0,2%	0,2%	0,2%	0,2%	0,2%	0,3%

[1] parameter includes non-linear distortion and non-harmonic noise

Function Shape

Current range:	100 uA to 2 A
Wave forms:	square, positive, negative, symmetrical, ramp A, ramp B, triangle truncated sin with THD 13,45 %
Peak value uncertainty:	0.3 % + 500 nA
Displayed values:	peak, effective

Minimum frequency for squarewave signals is 0.1 Hz, for all others 20 Hz.

Resistance

 Summary range: 0 Ω to 50 MΩ

Resistance uncertainty

resistance range	uncertainty of value [%]	current range
0 Ω - 100 Ω	0.03 + 10 mΩ	1 mA - 40 mA
100 Ω - 400 Ω	0.015	400 µA - 20 mA
400 Ω - 2 kΩ	0.015	100 µA - 4 mA
2kΩ - 10 kΩ	0.015	20 µA - 1 mA
10 kΩ - 40 kΩ	0.015	4 µA - 200 µA
40 kΩ - 200 kΩ	0.015	1 µA - 40 µA
200kΩ -1 MΩ	0.05	0.2 µA - 10 µA
1 MΩ - 4 MΩ	0.1	40 nA – 2 µA
4 MΩ - 20MΩ	0.2	10 nA – 500 nA
20 MΩ - 50MΩ	0.5	4 nA – 150 nA

Note: Maximal allowed voltage on output terminals is 8 V_{pp}. Uncertainty is valid for four-terminal connection with use of Option 70 or Option 140-41 Cable adapters. For two-wire connection from the terminals Hi-Lo na the front panel add to the specified uncertainty next +10 mOhm.

Capacitance

 Summary range: 0.9 nF to 50 µF

Capacitance uncertainty

range	uncertainty of value [%]	max. frequency
900 pF - 2.5 nF	0.5 + 15 pF	1000 Hz
2.5 nF - 10 nF	0.5 + 5 pF	1000 Hz
10 nF - 50 nF	0.5	1000 Hz
50 nF – 250 nF	0.5	1000 Hz
250 nF - 1 µF	0.5	500 Hz
1 µF – 2.5 µF	1	300 Hz
2.5 µF - 5 µF	1	300 Hz
5 µF – 10 µF	1.5	300 Hz
10 µF - 50 µF	2.0	300 Hz

Note: Maximal allowed voltage on output terminals is 8 V_{pp}.

AC and DC power/energy

 Summary voltage range: 0.2 V to 240 V
 Current capability of voltage output: depends on the voltage range
 Summary current range: 2 mA to 10 A
 Maximal voltage on current output: depends on the current range
 Power range: 0.0004 to 2.4 kVA
 Time period range: 1.1 s to 1999 s
 Frequency range: DC, 40 Hz to 400 Hz

DCV uncertainty
See table of DCV uncertainty.

DCI uncertainty

range	% value + % range	max. voltage [V]
2 mA - 20 mA	0.05 + 0.010	3
20 mA - 200 mA	0.05 + 0.005	3
200 mA - 2 A	0.05 + 0.005	3
2 A – 10 A	0.05 + 0.010	1.5

DC POWER uncertainty
Uncertainty of DC power can be calculated from the following formula:

$$d P = \sqrt{(dU^2 + dI^2 + 0.01^2)} \ [\%]$$

where   dP is uncertainty of output power   [%]
                 dU is uncertainty of set voltage   [%]
                 dI is uncertainty of set current   [%]

DC ENERGY uncertainty
Depends on voltage, current, time values. The best uncertainty is 0.016 %.

ACV uncertainty
See table of ACV uncertainty.

ACI uncertainty

range	% value + % range	max. voltage [V]
2 mA – 20 mA	0.05 + 0.010	3
20 mA – 200 mA	0.05 + 0.005	3
200 mA - 2 A	0.05 + 0.005	3
2 A – 10 A	0.05 + 0.010	1.5

PHASE uncertainty

frequency range [Hz]	phase uncertainty dφ [°]
40 – 200	0.15
200 – 400	0.25

AC POWER uncertainty
Uncertainty of AC power can be calculated from the following formula:

for active power $dP = \sqrt{(dU^2 + dI^2 + dPF^2 + 0.03^2)}$ [%]
for reactive power $dP = \sqrt{(dU^2 + dI^2 + dPF^{*2} + 0.03^2)}$ [%]
for apparent power $dP = \sqrt{(dU^2 + dI^2 + 0.03^2)}$ [%]

where   dP is uncertainty of power   [%]
                 dU is uncertainty of set voltage   [%]
                 dI is uncertainty of set current   [%]
                 dPF is uncertainty of power factor (cosφ)   [%]

                 For calculation of dPF is valid following formula:

$$dPF = (1 - \cos(\varphi+d\varphi)/\cos\varphi) * 100 \quad [\%]$$

                         where   φ   is set phase shift between voltage and current outputs
                                       dφ   is uncertainty of set phase shift in table above

                 dPF* is uncertainty of of sinφ [%]

                 For dPF* is valid following formula:

$$dPF^* = (1 - \sin(\varphi+d\varphi)/\sin\varphi) * 100 \quad [\%]$$

Example:
Set parameters: U = 100 V, I = 10 A, cos φ = 0.5, f = 50 Hz, displayed value of active power in W
Output voltage uncertainty: dU = 0.025 % value + 0.010 % range = 0.045 %
Output current uncertainty: dI = 0.10 % value + 0.03 % range = 0.7 %
Uncertainty due the set phase shift: PF 0.5 corresponds phase shift 60 °
                                         dPF = (1 – cos (60+0.15)/cos 60) * 100 = (1 – 0.4977/0.5) * 100 = 0.45 %
Output power uncertainty: $dP = \sqrt{(0.045^2 + 0.7^2 + 0.45^2 + 0.03^2)} = 0.95\ \%$

POWER FACTOR (PF)
range: -1.0 to +1.0
PF uncertainty can be calculated for any set value of output voltage, current and PF from following formula:

$$dPF = (1 - \cos(\varphi + d\varphi)/\cos\varphi) * 100 \quad [\%]$$

where φ is set phase shift between voltage and current
                  $d\varphi$ is uncertainty of set phase shift form the above table

AC ENERGY uncertainty
It depends on set value of voltage, current, time and PF. The best uncertainty is 0.07% for apparent energy.

Frequency
Summary range: 0.1 Hz to 20 MHz
Frequency uncertainty: 0.005 %
Output: BNC connector located on the front panel
Modes: - PWM square wave output with calibrated duty cycle ratio, frequency and amplitude
                                         - HF square wave output with calibrated frequency and amplitude

Mode PWM
 Frequency range: 0.1 Hz to 100 kHz
 Voltage range: 1 mV to 10 V
 Duty cycle ratio range: 0.01 to 0.99
 Wave form: square, symmetrical– positive – negative
 Duty cycle ratio uncertainty: 0.05 %
 Signal noise (20 Hz – 1 MHz): < 2 mV from 0.1Hz to 10 kHz
                                          < 10 mV from 10kHz to 100 kHz

Amplitude uncertainty (average top/bottom square signal level)

range	% value + V	% value + mV
	0.1 Hz to 10 kHz	*10kHz to 100 kHz*
1.00000 mV – 20.00000 mV	0.2 + 0.02 mV	0.2 + 0.1 mV
20.0001 mV – 200.0000 mV	0.1 + 0.02 mV	0.1 + 0.1 mV
0.200001 mV – 2.000000 V	0.1 + 0.02 mV	0.1 + 0.1 mV
2.00001 V – 10.00000 V	0.1 + 0.02 mV	0.1 + 0.1 mV

Mode HF
Frequency range: 0.1 Hz to 20 MHz
Output impedance: 50 Ω
Wave form: square symmetrical, duty cycle ratio 1:1
Amplitude: 4 V $_{pk-pk}$
Output amplitude range: 0, -10, -20, -30 dB   +/- 1 dB
Amplitude uncertainty: 10 %
Rise/fall time: < 3 ns

Temperature sensors simulation

Temperature scale: ITS 90, PTS 68
Types of sensors: RTD, TC

A. RTD (resistance) sensors

Types: Pt 1.385, Pt 1.392, Ni
Range of R0 setting: 20 Ω to 2 kΩ
Temperature range: -200 to +850 °C
Temperature uncertainty: 0.04 °C to 0.5 °C (see table bellow)

Ranges and uncertainties of RTD sensor simulation

type	range –200 – 250 °C	range 250 – 850 °C
Pt100	0.1 °C	0.3 °C
Pt200	0.1 °C	0.2 °C
Pt1000	0.2 °C	0.4 °C
Ni100	0.07 °C [*1]	- -

[*1] *Valid in range –60 to +180 °C.*

Uncertainties in the table are maximal uncertainties of RTD sensor simulation. Actual uncertainty for each set value of simulated temperature is determined by uncertainty of relevant resistance. Actual temperature uncertainty is displayed on the calibrator display. Actual uncertainties are always lower than those in above table.

B. TC sensors:

Types: K, N, R, S, B, J, T, E
Temperature range: -250 to +1820 °C according to the type
Temperature uncertainty: 0.4 to 4.3 °C (see table bellow)

Ranges and uncertainties of TC sensor simulation (with function AUTOCAL ON)

R	range [°C]	-50 - 0	0 - 400	400 – 1000	1000 – 1767
	uncertainty [°C]	3.2	2.1	1.4	1.7
S	range [°C]	-50 - 0	0 - 250	250 – 1400	1400 – 1767
	uncertainty [°C]	2.7	2.1	1.7	2.0
B	range [°C]	400 – 800	800 - 1000	1000 – 1500	1500 – 1820
	uncertainty [°C]	2.8	1.8	1.6	1.8
J	range [°C]	-210 - -100	-100 - 150	150 – 700	700 – 1200
	uncertainty [°C]	0.9	0.5	0.6	0.7
T	range [°C]	-200 - -100	-100 - 0	0 – 100	100 – 400
	uncertainty [°C]	0.9	0.5	0.4	0.4
E	range [°C]	-250 - -100	-100 - 280	280 – 600	600 – 1000
	uncertainty [°C]	1.6	0.4	0.5	0.5
K	range [°C]	-200 - -100	-100 - 480	480 – 1000	1000 – 1372
	uncertainty [°C]	1.0	0.6	0.7	0.8
N	range [°C]	-200 - -100	-100 - 0	0 – 580	580 – 1300
	uncertainty [°C]	1.2	0.7	0.6	0.8

Uncertainties in the table are maximal uncertainties of TC sensor simulation. Actual uncertainty for each set value of simulated temperature is determined by uncertainty of relevant resistance. Actual temperature uncertainty is displayed on the calibrator display. Actual uncertainties are always lower than those in above table.

Built-in multimeter

Measuring functions: DC voltage
                                         DC current
                                         Resistance, Temperature
                                         Strain gauge sensors

Ranges and uncertainties

Function	total range	uncertainty (%)	resolution / range
DC voltage - DCV [1]	0 to +/-12 V	0.01 % + 300 µV	100µV / 10V
DC voltage - mVDC [1]	0 to +/-2 V	0.02 % + 7 µV	20mV / 100nV, 200mV / 1uV, 2V / 10uV
DC current [1]	0 to +/-25 mA	0.015 % + 300 nA	100 nA/20mA
Frequency	1 Hz to 15 kHz	0.005	10 µHz – 0.1 Hz
Resistance [2]	0 to 2.5 kΩ	0.02% + 10 mΩ	20Ω / 1mΩ, 200Ω / 1mΩ, 2kΩ / 10mΩ
Temperature - Pt sensor	-200 to +850 ºC [3]	0.1 ºC	0.1 ºC
Temperature – TC sensor	-250 to +1820 ºC	see Table	0.01 ºC
Strain gauge sensors [4]	depends on sensor	0.05 % + 10 µV + uncertainty of sensor	

[1] Uncertainties are valid after performing ZERO correction in set mode

[2] Measuring current 1 mA

[3] For Pt 1000 sensor maximum temperature is 350 ºC

[4] Supply voltage: 2 to 10 V DC, non-symmetrical
    Max. current: 40 mA
    Input resistance: min. 100 MΩ
    Sensitivity: setable in range 0.5 mV to 100 mV /V
    Displayed unit: user´s defined

Ranges and uncertainties of temperature measuring with TC sensor

R	range [ºC]	-50 - 0	0 – 400	400 – 1000	1000 – 1770
	uncertainty [ºC]	2.5	1.5	1.0	1.2
S	range [ºC]	-50 - 0	0 – 250	250 – 1400	1400 – 1770
	uncertainty [ºC]	2.0	1.6	1.1	1.3
B	range [ºC]	400 - 800	800 – 1000	1000 – 1500	1500 – 1820
	uncertainty [ºC]	2.0	1.3	1.2	1.1
J	range [ºC]	-210 - -100	-100 – 150	150 – 700	700 – 1200
	uncertainty [ºC]	0.7	0.4	0.4	0.6
T	range [ºC]	-200 - -100	-100 - 0	0 – 100	100 – 400
	uncertainty [ºC]	0.8	0.5	0.4	0.4
E	range [ºC]	-250 - -100	-100 - 280	280 – 600	600 – 1000
	uncertainty [ºC]	1.1	0.4	0.4	0.5
K	range [ºC]	-200 - -100	-100 - 480	480 – 1000	1000 – 1372
	uncertainty [ºC]	0.8	0.4	0.6	0.8
N	range [ºC]	-200 - -100	-100 – 0	0 – 580	580 – 1300
	uncertainty [ºC]	0.9	0.5	0.5	0.8

Sorting function

Output GO/NG: 1 x make, 1 x break contacts, 50Vpp / 100mA
Triggering: external, internal, manual

General data

Warm up time:	1 hour		
Range of working temperatures:	$23 \pm 10\ ^{\text{o}}$C		
Reference temperature:	$23 \pm 2\ ^{\text{o}}$C		
Dimension:	450 x 480 x 150 mm		
Power line:	115 - 220/230 V – 50/60 Hz		
Power consumption:	45 VA without load		
	Max. 150 VA with full load		
Safety class:	I according ISO EN 61010		
Used fuses inside instrument:	F315mL250		2 pcs
	F1.6L250		2 pcs
Used resistors with fuse effect:	0.5R	MRS16T 1%	1 pc
	1R	MRS16T 1%	18 pcs

Accessories

Basic accessories (included in delivery)

• Power line cord		1 pc
• User´s manual		1 pc
• Test report		1 pc
• Spare fuse		1 pc
• Test cable 1000V/20A, 1m		2 pc
• Option 40	Cable adapter Canon 25 / 2 x BANANA, 1 m	1 pc
• Option 60	Cable adapter Canon 25 / 4 x BANANA, 1 m	1 pc
• Option 70	Adapter for four-terminal resistance sourcing	1 pc

Options (extra ordered)

- 140-50   Current coil 50 turn
- 140-01   Cable adapter for calibration of multimeters
- 140-02   Set of cables (Opt.10 2 pcs, Opt.11 2 pcs, Opt.20 1 pc, Opt.30 1pc, Opt.140-01 1pc, Opt. 140-41 1pc)
- 140-41   Cable adapter for simultaneous calibration/measuring
- Option 10   Output cable 20A/1000V (black)
- Option 11   Output cable 20A/1000V (red)
- Option 20   Output cable BNC/BNC
- Option 30   Output cable BNC/BANANA
- Option 40   Output cable D-SUB25/ 2xBANANA, 1 m
- Option 60   Output cable D-SUB25/ 4xBANANA, 1 m
- Option 70   Adapter for four-wire resistance sourcing
- Cable GPIB   IEEE488/IEEE488, 2m
- Cable RS   Cable RS-232 for connecting to PC
- WinQbase   Application SW, inventory of meters
- CALIBER   Program module for automatic calibration of meters

Manufacturer

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