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Chapter 1
Safety

Introduction

To ensure the correct and safe operation of this instrument, it is essential that you follow generally accepted safety procedures in addition to the safety precautions specified in this manual.

Caution and Warning Statements

Caution

Shows where incorrect procedures can cause damage to, or destruction of equipment or other property.

Warning

Shows a potential danger that requires correct procedures or practices to prevent personal injury.

Symbols

⚠ Indicates that the operator should consult the manual.

One such symbol is printed on Fluke 163 and Fluke 164, near the input connectors, and one on the AC/DC Power Adapter. This symbol on the instrument should encourage the user to use the correct procedure for common instrument ground and maximum input voltages as described below.

The symbol on the AC/DC Power Adapter indicates that only the PM9080 AC/DC Power Adapter is allowed for Fluke 163 and Fluke 164.

⏊ This symbol is printed on MultiFunction Counters with 1.3GHz inputs (T and H models). It indicates that the signal ground of the connectors are internally connected to the other connectors with the same symbol, and to parts that are easily accessible for the user. The accessible part is the Input-C BNC-connector.

Warning

The metallic C-input BNC will carry the same voltage as the common connector of input A, B, the ext. ref. Input, and the output connector. Applying signals with a common potential of more than 30Vrms (42Vpk or 60Vdc) above ground potential will make the instrument dangerous.

The reason for using a non-safety designed BNC-connector on the HF-input is that safety designed BNC's are made of plastic and does not function on the high frequencies of the 1.3GHz input.

This symbol is printed on MultiFunction Counters without 1.3GHz inputs. It indicates that the signal ground (common) of the connectors are internally connected to other connectors that carry the same symbol. However, the terminals are protected against access. The common instrument ground can be raised 300Vrms above the ground potential, providing safety designed probes are used.

Warning

Never raise the common more than 30Vrms above the ground potential if any non-safety designed — probe or BNC cable — is connected to the MultiFunction Counter.

Connections

Fluke 163 and 164 are double insulated and battery operated. The instrument is therefore floating with respect to ground potential. Before connecting probes to the instrument you must be aware of that the grounds of all BNC-connectors on the instrument are interconnected inside the instrument. This means that connecting the signal ground of one probe or test lead to 42VDC (30Vrms) or more above ground potential will make the signal ground of other probes and measuring leads dangerous.

Warning

To avoid electrical shock, remove any test leads that are not currently in use. Use safety designed probes without exposed metal connectors. Use probes and test leads within ratings and inspect before use.

Caution

Never apply signals with higher amplitude than 100Vrms to Input-A or Input-B, or 12Vrms to the other inputs for safety reasons.

If In Doubt About Safety

Whenever you suspect that it is unsafe to use the instrument, you must make it inoperative by doing the following:

- Disconnecting the line cord
- Clearly marking the instrument to prevent its further operation
- Informing your local Fluke Service Center.

For example, the instrument is likely to be unsafe if it is visibly damaged.

Chapter 2
Characteristics

Introduction

Specifications apply after 30 minutes warm-up time
For timer / counter functions, the minimal frequency specified is valid with manual trigger setting. When using AUTO TRIGGER or AC-coupled inputs, the minimal frequency is 20 Hz.

Presentation Modes

Waveform:	Displays recurrent signals and trigger settings. Eliminates the need for a separate oscilloscope to verify the input signal and correct triggering. Displays additionally one selected timer/counter read-out with up to 10 digits resolution plus the input signal's Vp-p value.
Values:	Up to 10 simultaneous readings of frequency, time and voltages like on a Counter, DVM and Phasemeter.
Statistics (163):	Mean, Maximum, Minimum plus Peak-to-Peak and Standard Deviation of a selected number of samples; sample size: 2 to 10^6.

Timer / Counter Functions

Frequency

Range:	
Input A & B:	1µHz to 160 MHz
Input C:	70 MHz to 1300 MHz (models 164H / 164T only)
Resolution:	9 digits/s measuring time, max. 10 digits resolution

Burst Frequency, Burst Repetition Rate (163)

Synchronization timing:	
Manual:	Manually set timing parameter
Automatic:	AUTO SET sets suitable timing parameters for bursts with a duration of 50 µs to 100 ms, min. 3 cycles on Input A or B and min. 192 cycles on Input C.
Burst duration:	
Input A & B:	0.5 µs to 1.5 s, min. 2 cycles in burst
Input C:	50 µs to 1.5 s, min. 128 cycles in burst.
Burst ON/OFF ratio:	< 1:1
Burst Frequency Range:	
Input A & B:	1 Hz to 70 MHz
Input C:	70 MHz to 1300 MHz (models 164H / 164T only)
Resolution:	9 digits/s burst measuring time, max. 10 digits resolution
Burst repetition rate:	
Input A & B:	Up to 1 MHz
Input C:	Up to 20 kHz

Resolution:	9 digits/s measuring time, max. 10 digits resolution

Note

If an external control signal (burst synchronization) is available, Input C Burst frequency can be measured in bursts with a duration from 0.5 μs and min. 128 cycles using normal Frequency measurement with External Arming.

Period

Range:	
Input A & B:	6 ns to 10^6s (averaged, to 160 MHz) 20 ns to 10^7s (single, to 50 MHz)
Input C:	770 ps to 14 ns (70 MHz to 1.3 GHz) (models 164H / 164T only)
Modes:	Single cycle (Input A, B) or Multiple cycles averaged (Input A, B, C)
Resolution:	
Single:	1 ns
Averaged:	9 digits/s measuring time, max. 10 digits resolution

Frequency Ratio f_1/f_2

Range:	10^{-9} to 10^9
Frequency Range:	
Input A & B:	1 μHz to 160 MHz
Input C:	70 MHz to 1300 MHz (models 164H / 164T only)
Measurement Modes:	f_A / f_B, f_B / f_A, f_C / f_A and f_C / f_B

RPM

Range (Input A or B):	10^{-5} RPM to 10^9 RPM (with 1 pulse/revolution)
Transducer scaling factor:	1 to 10^6 pulses/revolution

Time Interval

Range:	0 ns to 10^7 s
Measurement Modes:	Input A to B, Input B to A, (separate) Input A to A, Input B to B (common)
Frequency Range:	up to 50 MHz
Pulse Width:	≥6 ns at set trigger level
Resolution:	1 ns

Positive/Negative Pulse Width

Range (Input A or B):	6 ns to 10^7 s
Frequency Range:	up to 50 MHz
Resolution:	1 ns

Rise/Fall Time

Range (Input A or B):	6 ns to 10^7 s
Frequency Range:	up to 50 MHz
Pulse Width:	≥ 6 ns at set trigger level
Resolution:	1 ns

Duty Cycle

Range:	0.000 1 to 99.999 9%
Frequency Range:	10 mHz to 50 MHz
Pulse Width:	≥ 6 ns at set trigger level
Resolution:	0.000 1% or $(Frequency / 1GHz \times 100)\,\%$ whichever is greatest

Phase

Range:	-180.00° to +360.00°
Measurement Modes:	Input A to B or Input B to A
Frequency Range:	10 mHz to 50 MHz
Resolution:	0.01° or $(Frequency / 1GHz \times 360)\,°$ whichever is greatest

Totalize with manual control and / or set measuring time

Range:	0 to 10^{14} counts
Measurement modes:	Counts simultaneously pulses on inputs A and B
Pulse-count displayed:	Counts on input A, B, A-B or A+B
Start/Stop:	- With Run/Hold key - Totalize during the set time 200 ns to 15 s
Frequency Range:	0 Hz to 100 MHz
Pulse Width:	≥ 5 ns at set trigger level

Totalize with external control signal

Range:	0 to 10^{14} counts
Measurement modes:	Counts pulses on Input A (or B), starts and stops counting via external control signal on input B (or A)
Start/Stop:	- By two consecutive pulses - Totalize during presence of gating signal
Frequency Range:	0 Hz to 100 MHz
Pulse Width:	≥ 5 ns at set trigger level

Measuring Time and Synchronization

Measuring Time

Multiple cycles:	200 ns to 15 s with 100 ns resolution. Used for averaging of Frequency, Burst Frequency, Burst Repetition Rate, RPM, Period and Ratio measurements.
Single cycle:	Equal to the time duration to be measured. Used for Single Period A & B, Time Interval, Pulse Width and Rise-/Fall times.
Display time:	Measuring time or 200 ms whichever is greater.
HOLD / RUN:	HOLD freezes last result. RESTART starts new measurement.

Additional Trigger Control (163)

Normally, measurements are immediately started/stopped by the first input event, that meets the trigger conditions. Arming, Arming Delay and Hold-Off are additional trigger control features that enable the counter to measure on a specific point in a stream of pulses on input A (or B), by ignoring triggering during a set delay time and/or as long as an additional trigger condition on input B (or A) has not been fulfilled.

Arming ON:	Start triggering on input A is enabled directly after an external arming signal has triggered the arming input B. Applies to Frequency, Period or Pulse Width measurements.
Start Arming Delay:	After arming, an additional delay is inserted before the instrument can be start-triggered for a new measurement. Range: 200 ns to 5s Resolution: 100 ns
Trigger Hold-Off:	Stop triggering is inhibited during the set trigger Hold-Off time. Applies to Time Interval, Pulse Width, and Rise/Fall Time measurements. Range: 200 ns to 5s Resolution: 100 ns

Voltage Functions

Inputs:	A or B
Voltage range selection:	Manually in three steps or automatically via Auto Set key.
Over-ranging indicator:	Screen indicator "Clipped" indicates over-ranging.
Uncertainty:	Uncertainties specified apply from 10% to 100% of full range - and from 18 °C to 28 °C, after 30 minutes warm-up time. Add (specified uncertainty) x 0.1/ °C at < 18 °C or > 28 °C. Confidence level corresponds to 2σ for a normal Gaussian distribution (>95%).

Peak Voltage (V max, V min, V p-p)

Voltage Range:	500 mV, 5.00 V, 50.0 V
Frequency Range:	20 Hz to 50 MHz
Resolution	1, 10, 100 mV

Uncertainty:	
20 Hz to 2 kHz:	2% + 0.2% of range
2 kHz to 5 MHz	4% + 0.2% of range
5 MHz to 20 MHz	10% + 1% of range
20 MHz to 50 MHz	25% + 1% of range

DC Voltage (DC or DC-component from AC-signal)

Range:	500 mV, 5.00 V, 50.0 V
Resolution:	1, 10, 100 mV
Uncertainty:	2% + 0.2% of range

AC or AC+DC True-RMS Voltage

Range:	300 mV, 3.00 V, 30.0 V
Peak voltage limits:	±500 mV, ±5 V, ±50 V
Resolution	1 mV, 10 mV, 100 mV
Uncertainty (sinewaves):	
20 Hz to 50 Hz:	2% + 0.2% of range (DC +AC), 4% + 0.2% of range (AC)
50 Hz to 2 kHz:	2% + 0.2% of range
2 kHz to 5 MHz:	4% + 0.2% of range (4% + 2% of range in 300 mV range)
5 MHz to 10 MHz:	10% + 1% of range (10% + 2% of range in 300 mV range)
RMS-principle:	The rms-value is calculated from input signal volt-vs-time samples. Specified uncertainty applies only when triggering is correct, resulting in a correctly displayed waveform.
Crest Factor:	Any crest factor tolerated for signals within Vp limits. The instrument is calibrated to the rms value of a sinewave input. For non-sinusoidal input signals, with crest factors up to 3.0, add 2% + 2% of range (typically).

Multiple Parameter Display

Automatic waveform characterization with simultaneous display of all parameters, relevant for selected signal type:

Signal type Parameters displayed simultaneously

SINE and similarcontinuous symm. signals:

Frequency, Period, Vmax, Vmin, Vp-p

PULSE and similar cont. asymm. signals:

Frequency, Period, Positive Pulse Width, Negative Pulse Width, Rise Time, Fall Time, Duty Cycle, Vmax, Vmin, Vp-p.

BURST and similar — Burst Frequency, Burst Repetition Rate, Vmax, Vmin, Vp-p. (163)

Waveform Display Function

Displays the waveform of recurrent input signals. Eliminates for most signals the need for a separate oscilloscope to verify the input signal and correct triggering. Uses the same inputs A & B as for Timer/Counter and Voltage measure functions. For viewing complex signal patterns, dynamically changing signals or low amplitude signals, a fully featured oscilloscope can be expected to give a better signal representation..

Vertical Sampling(Voltage sequential)**:**

	Suitable for recurrent signals of 200 Hz to 50 MHz. The waveform is captured by measuring Time vs. Voltage samples. Measured time intervals start at one unique start trigger point and stop at consecutive stop trigger points at different trigger levels, scanned over the entire signal.
Bandwidth / rise time:	50 MHz / 3.5ns. Note. Vertical sampling technique causes a different relationship between bandwidth and rise-time, compared to traditional oscilloscopes. The -3dB loss in amplitude is like on a 50 MHz oscilloscope, while the pulse response is 3.5 ns rise time i.e. like on a 100 MHz oscilloscope.
Effective sampling rate:	3 Gsa/s, ≤ 20 ns/div. 1 GSa/s, > 20 ns/div.
Glitch detect:	≥6 ns repetitive pulses. Always active independently from time-base setting.
Horizontal Sampling:	Suitable for recurrent signals of 1 Hz to 2 kHz. (Time sequential)
Frequency Range:	1 Hz to 2 kHz
Sampling Rate:	Up to 40 kS/s
AUTO Sampling:	Automatic selection between Vertical- and Horizontal Sampling. Selection is based on detected input signal frequency and pulse width.

Vertical deflection

Display Modes:	One input (A or B), or two input (A *and* B). Fixed selection depending on selected measure function.
Frequency response:	1 Hz to 50 MHz (-3dB in Vp-p display)
AC coupled:	20 Hz to 50 MHz (-3dB in Vp-p display)
Coupling:	AC/DC
Rise time:	3.5 ns (vertical sampling mode)
Display Voltage Range:	100 mV to 50 V
Sensitivity:	20 mV/div. to 10V/div. AUTO- and manual scaling
Accuracy:	2% + 25 mV
Number of divisions:	8
Pixels/division:	21

Horizontal deflection

Time Coefficients:	5 ns/div. to 0.2 s/div. in a 1-2-5-sequence, auto-scaling (2 cycles of signal) or manually set
Accuracy:	1 ns + 1 pixel (vertical sampling) 25 µs + 1 pixel (horizontal sampling)
Number of divisions:	8 divisions with post trigger data 2 divisions with pre trigger data (vertical sampling mode only)
Pixels/division:	21
Max. display length:	5 input signal cycles

Waveform (Scope) Triggering

Sources:	Input A or B, AUTO selected, depending on set measuring function
Trigger sensitivity:	60 mVp-p to 10 MHz 90 mVp-p to 50 MHz 120 mVp-p to 75 MHz
Trigger Point:	AUTO SET or manually set trigger level and slope
Pre-trigger:	2 divisions, max. 1 cycle (vertical sampling mode only)

Display

Trace:	Dot or dot-joined line
Grid graticule:	Dotted or full line

Input A & B

Coupling:	DC or AC
Frequency Range:	0 Hz to 160 MHz (DC-coupled) 20 Hz to 160 MHz (AC-coupled) Frequency limits for MEASURE FUNCTIONS and WAVEFORM display are separately specified (see Timer/Counter, Voltage and Waveform Functions).
Trigger Level Range:	± 500 mV, ± 5.00 V or ±50.0 V
Resolution:	1, 10 or 100 mV
Uncertainty:	± 1% + resolution
Setting:	AUTO, Manual
Read-out:	Digital read-out, or with trigger lines on WAVEFORM display.

Trigger sensitivity, manual trigger setting:

± 0.5 V / ± 5 V range:	20 mVrms sine (up to 50 MHz) 40 mVrms sine (50 MHz to 160 MHz)
± 50 V range:	200 mVrms sine (up to 50 MHz) 400 mVrms sine (50 MHz to 160 MHz)

AUTO Trigger:

Level:	Automatically set at 50% of input signal's Vp-p value, or at 10% and 90% of Vp-p for Rise/Fall Time measurements
Trigger hysteresis:	In Frequency and Period Average modes, hysteresis is automatically set to approx. 33% of input signal's Vp-p value to provide optimal noise immunity. For all other functions, the hysteresis is equal to the specified trigger sensitivity (manual setting) up to 120 MHz. Above 120 MHz the trigger hysteresis increases to 100 mV (0.5V/5V range), and to 1V (50V range) at 160 MHz.
Min. Frequency:	20 Hz.
Impedance:	1 MΩ//15 pF
Low Pass Filter:	≤ 100 kHz
Digital Low-Pass Filter:	≤ 1 Hz to 3 MHz
Maximum input voltage:	
No instrument damage:	240 Vrms up to 1 kHz, decreasing linearly to 6 Vrms at 10 MHz.
Safe for user:	100 Vrms (model 163/164 only), 30 Vrms (models 164H/164T).
Floating voltage:	All inputs: 300 Vrms to ground, (model 163/164 only), 30 Vrms (models 164H/164T).

Input C (Models 164H / 164T only)

Frequency Range:	70 MHz to 1.3 GHz
Prescaler Factor:	64
Operating Input Voltage:	
70 to 900 MHz:	10 mVrms to 12 Vrms
0.9 to 1.1 GHz:	15 mVrms to 12 Vrms
1.1 to 1.3 GHz:	40 mVrms to 12 Vrms
Impedance:	50 Ω nominal, AC coupled, VSWR <2:1
Maximum Voltage Without Damage:	12 Vrms, PIN-diode protected

Ext. Reference Input

Frequency:	10 MHz
Voltage Range:	500 mVrms to 12 Vrms
Impedance:	Approx. 500 Ω, AC coupled

Test signals output

Reference frequency:	10 MHz square-wave
Probe Compensation:	2 kHz square-wave
Gate Monitor:	Gate open: low, gate closed: high
Test Signal Source:	Square-waves, selectable: 1 Hz, 50 Hz, 100 Hz, 1 kHz, 10 kHz, 100 kHz, 1 MHz and 5 MHz Low- and high-duty cycle pulses: 1 kHz/0.2 µs and 1 kHz / 999.8 µs.

Output levels:	Fixed TTL: low ≤0.4 V, high ≥1.8 V into 50 Ω:

RS232 Data in/output (163)

Connector:	Isolated optical connector, for use with optional optical-to-RS232 adapter PM9080/001
Input:	Full programmability via LEARN data strings and RECALL of up to 10 complete instrument settings. Full description available on PM9080 software diskette.
Output:	Measurement data, bitmap screen dump etc., see also Flukeview™

FlukeView™ (163)

SW 160/011	Optional FlukeView™; MultiFunction Counter software for Windows®
Documenting:	Transfers waveforms and measurement data from MultiFunction Counter to a PC with the optional optical-to-RS232 adapter PM9080/001. Print out complete screens directly or store graphical data in a popular file format to import into word processor or spreadsheet programs.
Archiving:	Waveform storage and retrieval with text annotations like measurement conditions and instrument set up.
Analysis:	Log and graph readings to monitor and analyze signal variations and related events, reveal relationships and conditions that could otherwise remain hidden.

Auxiliary Functions

Statistics (163)

Statistical functions:	Maximum-, Minimum- Mean- values, plus Standard Deviation and Peak-peak Deviation (= Max-Min). Not available in Totalize functions.
Error reduction:	Random uncertainties for instance from noise and jitter can normally be reduced by $\sqrt{N}$, by averaging a number of measurement readings.
N (Sample Size):	2 to 1 000 000

Mathematics (163)

Mathematics:	Displayed value = K x measurement + L, where K and L are selectable constants
Constants K and L range:	0 and $\pm(10^{-20}$ to $10^{20})$, 12 digits resolution

INFO

A built in context sensitive help function gives guidance for all manual settings.

Tutorial

A built in tutorial description of the MultiFunction Counter

SAVE / RECALL

No. of instrument set-ups:	10
No. of screen images:	1 (WAVEFORM, VALUES or STATISTICS).

General

Quality and maintenance

Quality assurance:	ISO 9001 Quality System
Warranty:	3 years parts and labor
MTBF	40 000 hours
Calibration:	Closed Case Calibration, recommended interval: 12 months

Display

Type:	Super Twisted Liquid Crystal
Size:	84 x 84 mm, 4.7" diagonal
Resolution:	240x240 pixels
Backlight:	Cold Cathode Fluorescent (CCFL) tube.
Brightness:	3 user selectable levels: max. 50 cd/m^2
Contrast ratio:	User adjustable, max. 1:15 (typical at 20°C)

Environmental Data

Temperature:	
Operating:	0°C to 50°C
Storage:	-20°C to 70°C
Humidity:	
Operating:	<90% RH non-condensing, 20°C to 30°C, <70% RH non-condensing, 30°C to 50°C,
Storage:	<95% RH
Altitude:	
Operating:	3000 m (10 000 ft)
Storage:	12000 m (40 000 ft)
Vibration:	Up to 3G at 55 Hz, per MIL-T-28800E, Class 3
Shock:	Half-sine shock pulse 30G, per MIL-T-28800E, Class 3
Safety:	EN 61010-1:1993, Cat. II
EMC:	Emission: EN 55011 ISM Group 1, Class A.
	Susceptibility: EN 50082-2

Safety

Safe Operation:	100 Vrms to 10 kHz (models 163/164 only), 30 Vrms (models 164H/164T).
Floating voltage:	All inputs: 300 Vrms to ground, (model 163/164 only), 30 Vrms (models 164H/164T).
Compliance:	EN 61010-1:1993, Cat. II CE
	CSA CAN / CSA - C22.2 No.1010.1 - 92
AC/DC adapter:	UL: UL1310 Class 2
	C22.2 No. 223

Power Supply

Line voltage:	Via PM 9651 AC/DC adapter: 90 to 130 Vrms or 190 to 255 Vrms, 45 Hz to 440 Hz, 18 VA
Internal Ni-Cd Battery:	Type PM 9086, 4.8 V
Battery Operating Time:	Pulse output and external reference input switched off, lowest backlight brightness level and full battery capacity
Model 163, 164:	typical 2¼ hours
Model 164T:	typical 1¾ hours
Model 164H:	typical 1½ hours
Battery Charging Time:	3 h typical (instrument switched OFF) 30 h typical (instrument switched ON)
Alternate Battery:	4 alkaline C cells (not included)
External DC Supply:	10 V to 20 V DC, 10 W typical
Current at 12 Vdc:	0.8 A (operating) 0.5 A (non operating, charging only)
Input Connector:	5 mm power jack, DIN 45323

Mechanical Data

Height x Width x Length:	60 x 130 x 260 mm / 2.4 x 5.1 x 10.2 in., excl. holster 65 x 140 x 275 mm / 2.5 x 5.5 x 10.8 in., incl. holster
Weight:	1.5 kg /3.3 lb., excl. holster, 1.8 kg/4.0 lb., incl.holster
Transport weight:	3.4 kg / 7.5 lb.

Timer/Counter Measurement Uncertainty

Uncertainty examples

Uncertainty examples below are a simplified way to quickly obtain the magnitude of accuracy for commonly made measurements. The figures are overall figures, taking into account all instrument error-contributors, such as quantization error, trigger errors, timebase oscillator ageing, temperature drift and one year calibration interval.
Exact calculations of the measurement's uncertainties are described in the following section "Uncertainty Calculation Formulas" (random, systematic and total values), taking into account specific manual settings, ambient temperature and input signal characteristics as slew-rate and noise.

Frequency measurements on Sinewave signals

Table 1 shows the uncertainty for measurements on undistorted 1Vrms sinewave input signals, with instrument settings obtained through AUTO-SET and making use of the internal time-base reference at room temperature.

Table 1 Uncertainty for measurements sinewave input signals

Model	**163, 164**	**164T**	**164H**
Mode and input signal	Absolute uncertainty	Absolute uncertainty	Absolute uncertainty
Frequency & Period Average: (Period =1 ÷ Frequency) ≤ 100 Hz	1 mHz	1 mHz	1 mHz
1 kHz	5 mHz	1 mHz	1 mHz
10 kHz	50 mHz	10 mHz	1 mHz
100 kHz...1.3 GHz	$5x10^{-6}$ x Frequency	$1x10^{-6}$ x Frequency	$1x10^{-7}$ x Frequency
Phase: f: ≤100 kHz	0.1°	0.1°	0.1°
1 MHz	0.5°	0.5°	0.5°
10 MHz	5°	5°	5°
Frequency Ratio f_1 / f_2: f_2: 100 Hz	0.1	0.1	0.1
10 kHz	0.001	0.001	0.001
1 MHz	0.00001	0.00001	0.00001
100 MHz	0.0000001	0.0000001	0.0000001

Conditions that lead to a better accuracy (reduced uncertainty) are: steeper trigger transitions (for instance through higher input amplitude and higher input frequency), use of STATISTICS to average the result of a number of readings (not model 163), the use of a more accurate external time-base reference and a shorter calibration interval than 12 months. In LF Frequency measurements, the internal trigger uncertainty is the dominating error contributor, whereas for HF Frequency measurements the internal time-base uncertainty dominates.

Frequency measurements on PULSE signals

Table 2 shows the uncertainty for measurements on undistorted 1Vp-p pulse signals with 10 ns rise/fall times (except where otherwise noted for rise/fall-time measurements), with instrument settings obtained through AUTO-SET and making use of the internal time-base at room temperature.

Table 2 Uncertainty for measurements pulse input signals

Model	**163, 164**	**164T**	**164H**
Mode and input signal	Absolute uncertainty	Absolute uncertainty	Absolute uncertainty
Frequency & Period Average: (Period =1 ÷ Frequency) 20 Hz to 1.3 GHz	$5x10^{-6}$ x Frequency	$1x10^{-6}$ x Frequency	$1x10^{-7}$ x Frequency
Period Single: ≤ 1 µs	1 ns	1 ns	1 ns
1 ms	5 ns	1.5 ns	1 ns
1 s	5 µs	1 µs	100 ns
Time Interval, Pulse width: ≤ 1 µs	1.5 ns	1.5 ns	1.5 ns
1 ms	5 ns	2 ns	1.5 ns
1 s	5 µs	1 µs	100 ns
Rise/Fall time (@ **100 kHz):** ≤ 10 ns	2 ns	2 ns	2 ns
100 ns	5 ns	5 ns	5 ns
1 µs	50 ns	50 ns	50 ns
Duty Cycle: ≤ 100 Hz	0.0001 %	0.0001 %	0.0001 %
10 kHz	0.0015 %	0.0015 %	0.0015 %
1 MHz	0.15 %	0.15 %	0.15 %

Conditions that lead to a better accuracy (reduced uncertainty) are: steeper trigger transitions (for instance through shorter rise-/fall time and higher input amplitude), use of STATISTICS to average the result of a number of readings (not model 163), the use of a more accurate external time-base reference and a shorter calibration interval than 12 months. For short duration Time measurements, the 1ns resolution is the dominating error-contributor, whereas for long duration Time measurements, the internal time-base uncertainty dominates.

Uncertainty calculation formulas:

Time Interval Pulse Width Rise/Fall Time (s)

Uncertainty due to Random Effects (rms or standard deviation)

$$\sqrt{1\ ns^2 + Start\ Trigger\ Error^2 + Stop\ Trigger\ Error^2}$$

Uncertainty due to Systematic Effects (maximum values)

$$\pm Trigger\ Level\ Timing\ Error \pm 1\ ns \pm (Time\ Base\ Error \times Measurement\ Value)$$

LSD Displayed

$$500\ ps$$

Frequency, Period (Hz or s)

Uncertainty due to Random Effects (rms or standard deviation)

$$\frac{\sqrt{1\ ns^2 + 2 \times (Start\ Trigger\ Error)^2}}{Measuring\ Time} \times Frequency\ or\ Period$$

Uncertainty due to Systematic Effects (maximum values)

$$\pm Time\ Base\ Error \times Measurement\ Value \pm \frac{1\ ns}{Measuring\ time} \times Frequency\ or\ Period$$

LSD Displayed

$$\frac{500\ ps \times Freq.\ or\ Per.}{Measuring\ Time} = \text{(Rounded to nearest decade)}$$

Ratio f_1 / f_2

Uncertainty due to Random Effects (rms or standard deviation)

$$\frac{\sqrt{Prescaler\ Factor^2 + 2 \times (f_1\ \times\ Start\ Trigger\ Error f_2\ )^2}}{f_2\ \times\ Measuring\ Time}$$

LSD Displayed

$$\frac{Prescaler\ Factor}{Measuring\ Time \times f_2} = \text{(Rounded to nearest decade)}$$

Phase(degrees)

Uncertainty due to Random Effects (rms or standard deviation)

$$\sqrt{(1\ ns^2 + Start\ Trigger\ Error^2 + Stop\ Trigger\ Error^2)} \times Frequency \times 360°$$

Uncertainty due to Systematic Effects (maximum values)

$$\pm(Trigger\ Level\ Timing\ Error \times Freq. \times 360°) \pm (1\ ns \times Frequency \times 360°)$$

LSD Displayed

0.01°

Duty Cycle (%)

Uncertainty due to Random Effects (rms or standard deviation)

$$\sqrt{(1\ ns^2 + Start\ Trigger\ Error^2 + Stop\ Trigger\ Error^2)} \times Frequency \times 100\ \%$$

Uncertainty due to Systematic Effects (maximum values)

$$\pm(Trigger\ Level\ Timing\ Error \times Freq. \times 100\%) \pm (1\ ns \times Frequency \times 100\%)$$

LSD Displayed

0.0001%

Internal Time Base Stability

Table 3 Time Base Stability.

	Type	Standard	TCXO	High Stability Oven
	Model	**163, 164**	**164T**	**164H**
Aging Rate per:	24h			$<1.5 \times 10^{-9}$ (first year)
	Month	$<5 \times 10^{-7}$	$<1 \times 10^{-7}$	$<3 \times 10^{-8}$
	Year	$<5 \times 10^{-6}$	$<1 \times 10^{-6}$	$<1 \times 10^{-7}$ (after first year)
Temperature Stability: (referenced to +23°C)	0° to 50°	$<5 \times 10^{-6}$	$<1 \times 10^{-6}$	$<2 \times 10^{-7}$
	10° to 40°			$<1 \times 10^{-7}$ (after 15 min.)
	18° to 28°	$<2 \times 10^{-6}$ (after 15 min.)		$<5 \times 10^{-8}$ (after 15 min)
Factory adjustment uncertainty (+23°C):		10 MHz ± 50 Hz	10 MHz ± 10 Hz	10 MHz ± 1 Hz

Start/Stop Trigger Error due to Random Effects

Trigger error, caused by external and internal noise, results in too early or too late start- and stop- triggering. The rms trigger errors associated with each trigger point is:

$$Start\ /\ Stop\ Trigger\ Error\ =\ \frac{\sqrt{(Vnoise\text{ - }input)^2\ +\ (Vnoise\text{ - }signal)^2}}{Signal\ slew\ rate\ (V/s)\ at\ trigger\ point}$$

Vnoise-input: 0.5 mVrms noise of the input amplifier

Vnoise-signal: rms noise of the input signal over a 160 MHz bandwidth

Trigger Level Timing Error due to Systematic Effects

Trigger level timing error is the sum of two error sources:

1. The trigger level setting error due to deviation of the actual trigger point from the set (indicated) trigger level and
2. The width of the input amplifier hysteresis band (only in Pulse Width & Duty Cycle measurements)

The magnitude of both errors depend on the input signals slew rate:

$$Trigger\ Level\ Setting\ Error = \frac{2 \times trig.lev.\ resol. + 1\%\ of\ start\ trigger\ level}{Slew\ rate\ (V/s)\ at\ start\ trigger\ point} + \frac{2 \times trig.lev.\ resol. + 1\%\ of\ stop\ trigger\ level}{Slew\ rate\ (V/s)\ at\ stop\ trigger\ point}$$

$$\textit{Input Amplifier Hysteresis Error} = \frac{0.01}{\textit{Slew rate } (V/s) \textit{ at start trigger point}} - \frac{0.01}{\textit{Slew rate } (V/s) \textit{ at stop trigger point}}$$

Calculation of Measurement Uncertainty (2 σ)

The total uncertainty of a measurement is calculated as twice the combined standard uncertainty (two standard deviations or 2 σ) using the following formula:

$$\textit{Total Combined Standard Uncertainty} = 2x\sqrt{s^2 + \frac{S a_i^2}{3}}$$

where:

s = uncertainty due to random effects, calculated from the formula, specified for each measuring function.

a_i = uncertainty due to systematic effects, calculated for each contributing error, specified for each measuring function.

Ordering Information

Selection guide

Table 4 Features.

Models	163	164	164T	164H
160 MHz Frequency Counter 50 MHz Time and Vp-p meter 100 MHz PulseTotalizer V dc and 10 MHz true-RMS V ac meter	•	•	•	•
50 MHz Waveform presentation mode	•	•	•	•
Frequency in Burst and Burst Repetition Rate		•	•	•
1.3 GHz Frequency- and Period			•	•
Timebase stability / Accuracy	5×10^{-6}	5×10^{-6}	1×10^{-6}	5×10^{-7}
Statistics, including Jitter measurements		•	•	•
Mathematics,		•	•	•
Trigger Hold-Off, Arming and Arming Delay		•	•	•
Optional PC-support: RS232 adapter Optional FlukeView® for Windows®		•	•	•

Fluke 163 — 50MHz / 160 MHz MultiFunction Counter with Standard Time Base

Fluke 164 — 50MHz / 160 MHz MultiFunction Counter with Standard Time Base

Fluke 164T — 50 MHz / 1.3 GHz MultiFunction Counter with TCXO Time Base

Fluke 164H — 50 MHz / 1.3 GHz MultiFunction Counter with High Stability Oven Time Base

Included Accessories

Operators Manual

Calibration Certificate	
PM 9086	Ni-Cd Battery Pack
PM 9083	Protective Holster
PM 9651/00X	Line Voltage Adapter/Battery Charger X = 1 for Europe (230V) X = 3 for USA (115V) X = 4 for UK (240V) X = 6 for Japan (100V) X = 7 for Australia (240V) X = 8 for universal (115V or 230V)

Optional Accessories

Probes; safety designed for isolated measurements:

PM 8918/101	Probe 1:1, 1 MΩ, 12 MHz BW, (1.5m, 5 ft)
PM 8918/002	Probe Set (2 pcs) 10:1,10 MΩ, 100 MHz BW, (1.5m, 5 ft)
PM 8918/202	Probe Set (2 pcs) 10:1, 10 MΩ, 75 MHz BW, (2.5m, 8 ft)
80i-110s	Clamp-on AC/DC current probe, DC to 100 kHz, 100 mV/A (max. 10A) or 10 mV/A (max. 100 A)

Probes; optimized for HF-measurements; not safety designed:

PM 9020/001	Probe 10:1, 10 MΩ, 200 MHz BW, (1.5m, 5 ft). Recommended for pulse response testing on Input A and B.
PM 9639/011	Probe 10:1, 500Ω, 1.0 GHz (-3 dB), 2.3 GHz (-6 dB) BW, (1.5m, 5 ft). Recommended for frequency measurements on Input C.

50Ω BNC-BNC cables; safety designed for isolated measurements:

PM 9091/001	Cable set (3x1.5 m)
PM 9092/001	Cable set (3x0.5 m)

50Ω BNC-BNC regular cables; not safety designed:

PM 9588/01	50Ω BNC-BNC cable set (5x0.2 m, 4x0.4 m, 3x0.6 m, 3x2 m).

Other Accessories:

C 95	Soft carrying case
C 97B	Protective hard carrying case
PM 9080/001	RS-232C Optically isolated interface adapter
PM 9585/01	50Ω Feedthrough Termination, 1W
SW 160/011	FlukeView®; software for Windows®
PM 9086/011	Spare Ni-Cd Battery Pack

Manuals:

4822 872 20084	Users Manual, English
4822 872 20085	Users Manual, German
4822 872 20086	Users Manual, French
4822 872 20087	Quick Operating Guide
4822 872 25016	Service Manual

Chapter 3
Circuit Descriptions

Introduction

A basic MultiFunction Counter (Fluke 163 and Fluke 164) consists of three main units:

- Input PCA
- Display PCA
- Keyboard

"T"-models

In Fluke 164**T**, the following boards are added:

- A 1.3 GHz HF input
- A Temperature Compensated X-tal Oscillator (TCXO)

"H"-models

In Fluke 164**H**, the following boards are added:

- A 1.3 GHz HF input
- An Oven Controlled X-tal Oscillator (OCXO)

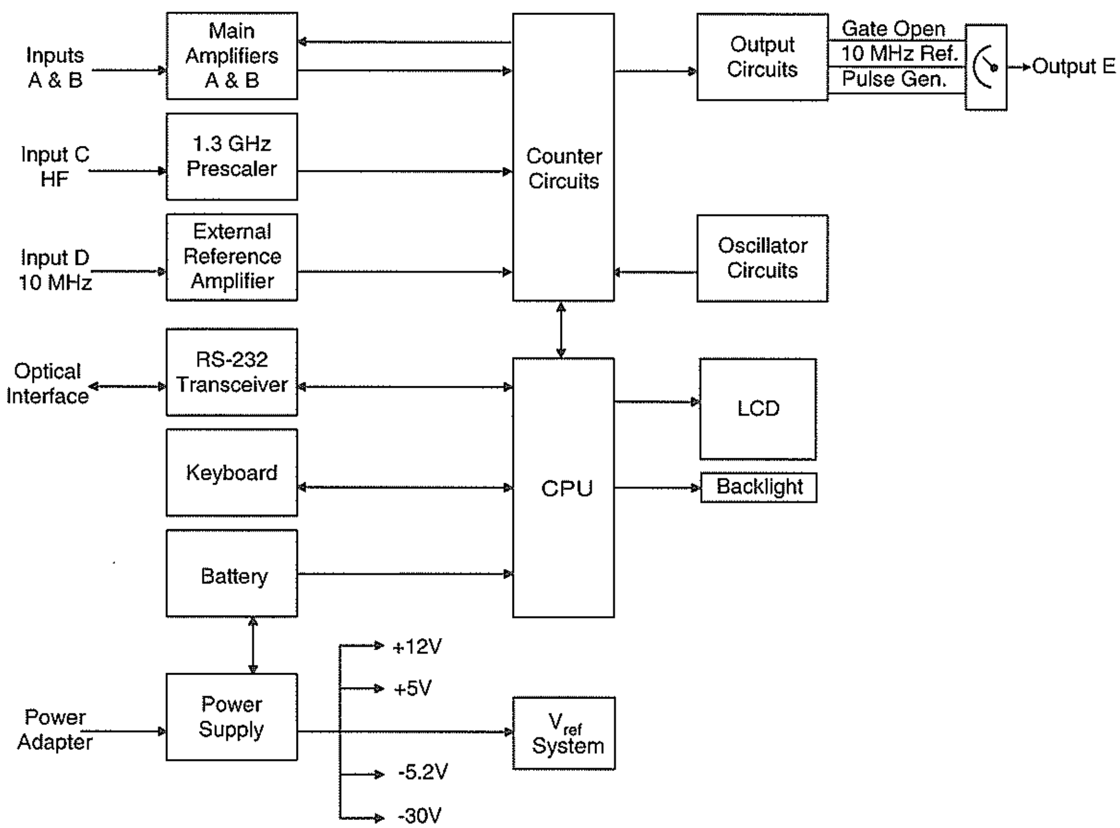


Figure 3-1. Block Diagram, Fluke 160 series

The following functions are placed on the input PCA:

- Input amplifiers and part of trigger level circuitry

- External frequency reference input
- Power supply
- Battery charging control
- Output driver

On the display PCA the following functions can be found:

- Microcomputer circuits
- Internal reference oscillator
- Counting circuitry
- LCD controller and drivers
- Basic trigger level generation
- Voltage reference and LF voltage measurement
- RS232 optical interface

Note

Simplified extracts from the schematic diagrams are used in this chapter. For complete information, see Chapter 9, Circuit Diagrams.

Hardware functional description

General Shielding and Grounding Principles

Noise generated in the digital circuitry has to be confined to the display PCA as far as it is possible. The sensitive input amplifiers, the signal comparators and the reference voltage system should be protected from interfering signals that may influence the measuring procedures and in the end the accuracy and reliability of the calculated results.

Several precautions have been taken in the MultiFunction Counters to achieve high noise immunity. Some of them, like filtering, are mentioned later in this chapter in the context where they belong.

Shielding by means of metal sheet is done where necessary to protect sensitive circuitry from radiated noise. EMC requirements are also met by proper shielding and grounding.

By separating the digital ground from the analog ground on the display PCA it is possible to keep the reference voltage system clean. In order to prevent ground noise in the digital circuitry from propagating to the input PCA, only the analog ground on the display PCA is directly connected to the ground plane on the input PCA. Noise created by inductive or resistive voltage drops due to current variations in the supply lines is isolated from the most sensitive parts in this way.

When measuring high frequency or low level signals it is most important to connect the probe ground terminal to the appropriate ground plane with as short a lead as possible. Otherwise distortion or noise may cause mistinterpretation of the measured signal.

Input PCA

Input amplifier

Channel A and Channel B are formed by two identical, matched 200 MHz amplifiers.

The following description refers to channel A but is also valid for channel B. See Figure 3-2

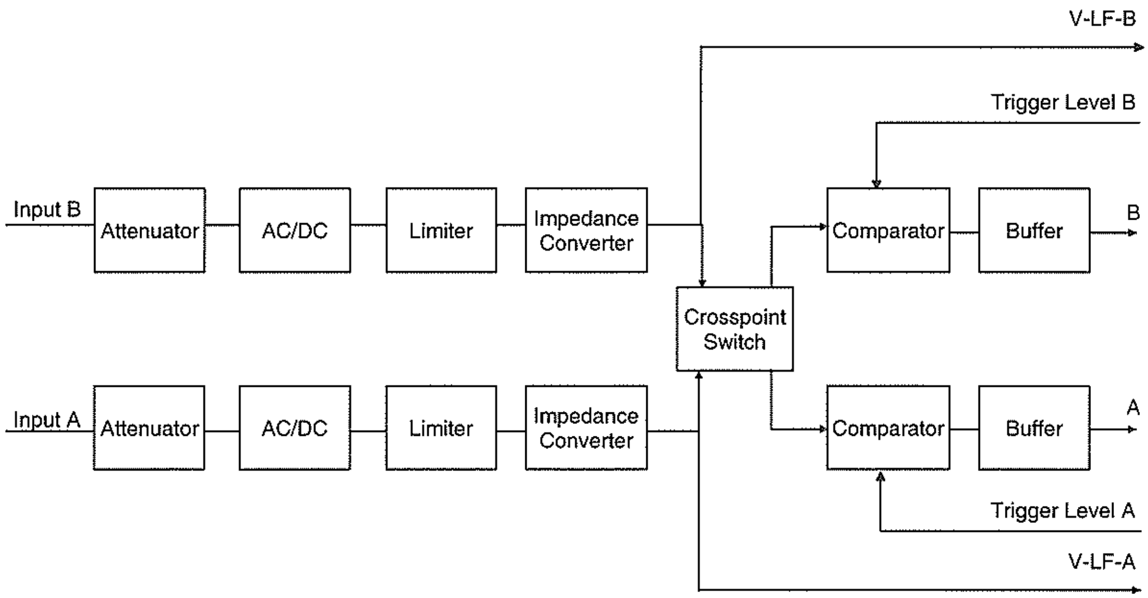


Figure 3-2. Input Amplifier Block Diagram

Four main stages make up the input amplifier: Attenuator and protection circuitry, impedance converter, comparator and buffer.

Attenuator and Protection Circuitry

The attenuator and protection circuitry contains:

- 1X/10X attenuator
- AC/DC coupling
- Voltage limiter

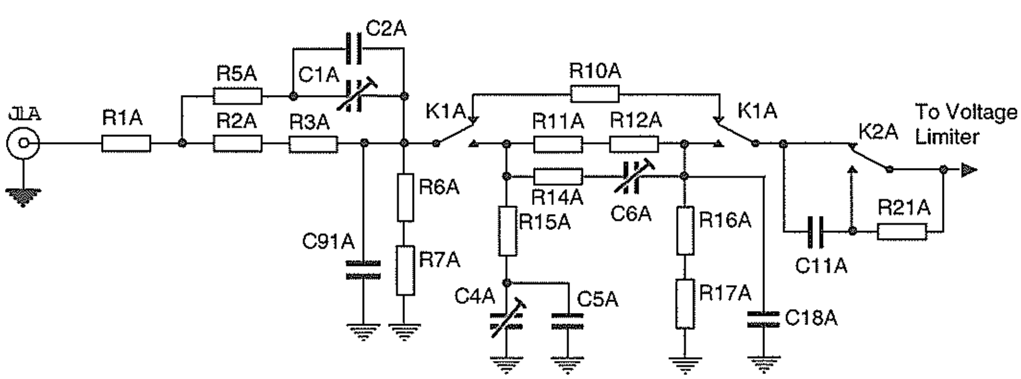


Figure 3-3. x1/x10 Attenuator and AC/DC Coupling

1X/10X Attenuator

See Figure 3-3. The 1X attenuator consists of a resistive low frequency divider, formed by R2A, R3A, R6A and R7A, which reduces the input signal by a factor of 2.4. The variable capacitor C1A in conjunction with C91A form the capacitive high frequency divider in parallel with the resistive divider.

The variable capacitor C1A is used to adjust the HF attenuation to the same value as the LF attenuation.

Resistors R11A, R12A, R16A and R17A form the resistive part of the 10X attenuator. The variable capacitor C6A and the resistor R14A together with C18A form the capacitive divider.

C4A sets the 10X input capacitance equal to the 1X input capacitance.

AC/DC coupling

See Figure 3-3. Relay K2A selects AC/DC coupling. In AC coupling relay K2A is open and the signal is fed through the AC capacitor C11A.

In DC coupling the relay K2A is closed and the AC capacitor C11A is short-circuited. To protect the relay contact the resistor R21A serves as current limiter.

Voltage limiter

A limiter that protects the impedance converter against overvoltage is placed between the AC/DC selector and the impedance converter. See Figure 3-4.

It consists of the diodes D3A and D4A. D3A clamps negative voltages and D4A clamps positive voltages. The clamp voltage is approximately ±2.3 V.

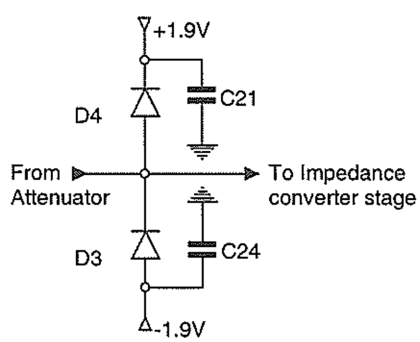


Figure 3-4. Voltage Limiter

Impedance Converter Stage

The analog signal from the input stage is fed to an amplifier stage where split-band technique is used to get a good response over a wide frequency range. See Figure 3-5.

This means that the high frequency contents of the signal are fed to a high input impedance AC-coupled dual gate MOSFET transistor stage. The low frequency contents from DC to about 5 kHz are handled in parallel by a high input impedance operational amplifier stage.

Both the FET (V1A) and the op amps (U1A) are used to convert high input impedance to low output impedance. The two signal paths are summed at the source of V1A by letting the LF signal control the current source V2A serving as part of the V1A source load impedance.

The FET drain is supplied with +12 V instead of +5 V via resistors R35A and 36A in order to optimize the HF characteristics within the whole input voltage dynamic range.

The resistor R20A sets the 1 MΩ input impedance and limits the low frequency signal before it is coupled to the inverting input of the op amp U1A:1. The resistors R30A and R31A at the output of U1A:2 center the output swing.

A driver stage (V4A and V7A) and an output stage (V5A and V6A) form an amplifier with high output drive capability. This amplifier is used to get a linear output swing of ±2 V with high slew rate.

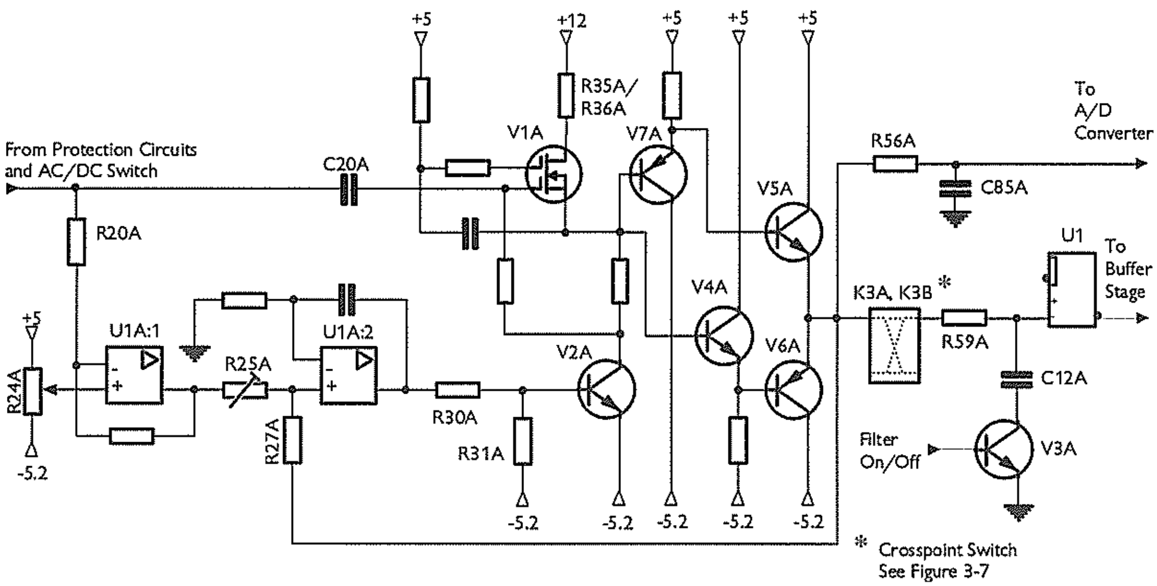


Figure 3-5. Impedance Converter

From the output of this second amplifier stage there is a feedback path to the non-inverting input of U1A:2 via R27A. Trimmer R25A sets the gain of the low frequency path equal to the gain of the high frequency path (about 0.9). Trimmer R24A is used to adjust the offset voltage of the complete input amplifier.

An A/D converter in the microcontroller is fed from the amplifier output via a lowpass filter consisting of R56A and C85A. This signal is used to measure the input voltage.

Another lowpass filter is connected to the amplifier output. It is a 100 kHz RC filter consisting of R59A and C12A. The microcontroller switches this filter on or off via transistor V3A. The filter output is connected to the input of the comparator stage (U1). The operator can control the filter state via the keyboard.

Comparator Stage

The comparator converts the analog signal from the impedance converter to a square wave. See Figure 3-6.

This circuit consists mainly of the high speed integrated comparator U1 and a separate trigger level circuit connected to the comparator at pin 12 via a lowpass filter consisting of resistor R53A and capacitor C41A.

The trigger level circuits, which are described separately, generate a DC level in the range from –2 V to +2V . This covers a dynamic range of ±5 V since the input signal is divided by a factor 2.4 before it reaches the comparator.

The comparator has a temperature compensated hysteresis that is set by the network made up by R3, D4, R4, R5 and R6.

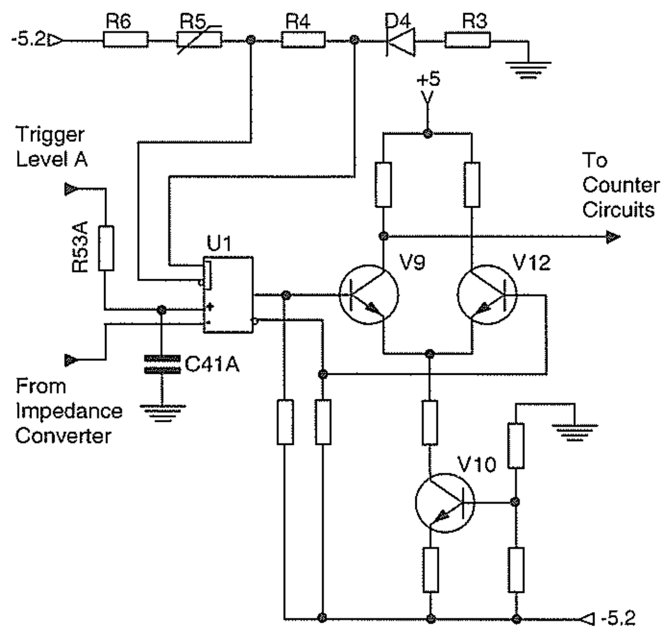


Figure 3-6. Comparator and Buffer

Buffer Stage

Before the signal can be handled by the ASIC U43, it has to be converted by the buffer stage. See Figure 3-6.

The negative ECL logic level (~–0.9 V to ~ –1.7 V) from U1 pins 19 and 20, is converted to positive CMOS logic level (0 V to 5 V).

The buffer is a differential amplifier consisting of the two transistors, V9 and V12 whose bases are fed differentially from the two comparator outputs. Transistor V10 sets the current in the stage.

Crosspoint Switch

The normal signal flow from amplifier A to comparator A (and from amplifier B to comparator B) can be altered by means of the crosspoint switch. See Figure 3-7. Full control is possible so the input channels can be swapped or one of the input channels can be fed to both comparators. Unused contacts are connected to ground to minimize crosstalk. The relays are controlled by the microcomputer.

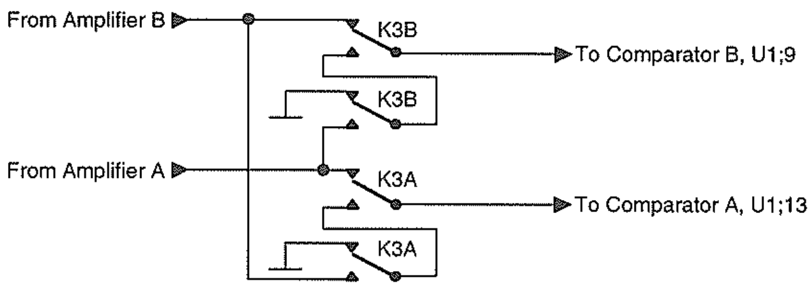


Figure 3-7. Crosspoint Switch

Trigger Level Circuits

See Figure 3-8. The description below refers to channel A but is equally valid for channel B provided the part numbers are substituted accordingly.

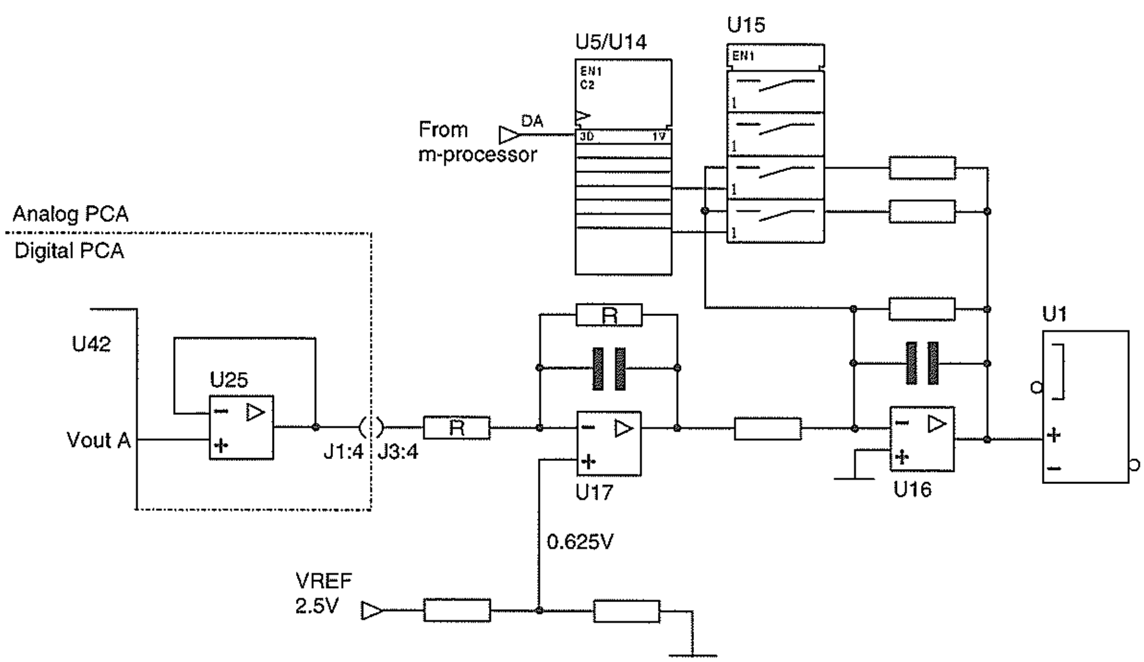


Figure 3-8. Trigger Level Circuits

The ASIC U42 has a built-in 10-bit DAC leaving an output voltage VoutA in the range 0 V<= VoutA <= +2.5 V and a resolution of 2.44 mV. The output impedance of the DAC is high and must be buffered by the op amp U25. Then the voltage is inverted and level shifted in U17 according to the formula VoutA" = -VoutA' + 1.25 resulting in a voltage range of ±1.25 V. This voltage is inverted and amplified in U16. The amplification factor can be set to three different values (-1.86, -0.73 or -0.186) by means of the analog switch U15 that selects either of two resistors or none at all in parallel with a fixed resistor in the feedback path of U16.

Let us assume that the amplification factor -1.86 is used. The ±1.25 V range at the output of U17 is converted to ±2.33 V at the comparator input. Considering the initial input attenuation of 2.4 the result is a trigger voltage range exceeding ±5 V seen from the channel A input BNC connector.

The other amplification factors are used for magnification around zero, i.e. the trigger voltage range is narrower but the resolution is higher. The trigger level system is calibrated by applying known voltages to the main input. The supply voltages to the trigger level circuits are filtered carefully to prevent noise originating in the digital circuitry from affecting the trigger level.

Reference Input Circuits

The external reference input is solely designed to accept signals having a frequency of 10 MHz and is therefore AC coupled by means of C78. R87, R88, R89 and D30 form an attenuator with symmetrical clipping to protect the input of the line receiver U20 which amplifies the signal and converts it to CMOS logic levels. See Figure 3-9.

The microcontroller activates the external reference input via U5 and the signal EXT.REF.ON. If the level is low V27 will conduct, enabling the amplifier by connecting the power supply pin of U20 to +5 V. R91 is a pull-up resistor that is necessary to make the output of U20 CMOS compatible. A smoothing filter consisting of R92 and C90 removes unnecessary HF contents from the signal before further distribution.

An external reference frequency can be used by the ASIC circuit U42 as an alternative for the built-in reference oscillator.

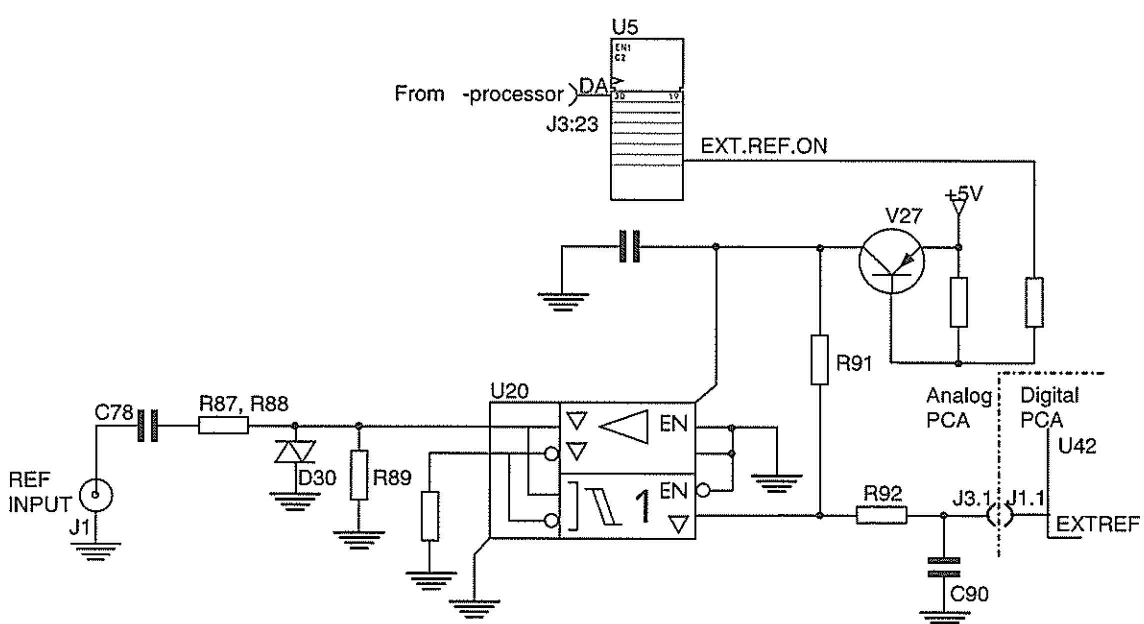


Figure 3-9. Reference Input Circuits

Power Supply

Note

See also chapter 9, Circuit Diagrams, Power supply for detailed information.

See Figure 3-10.

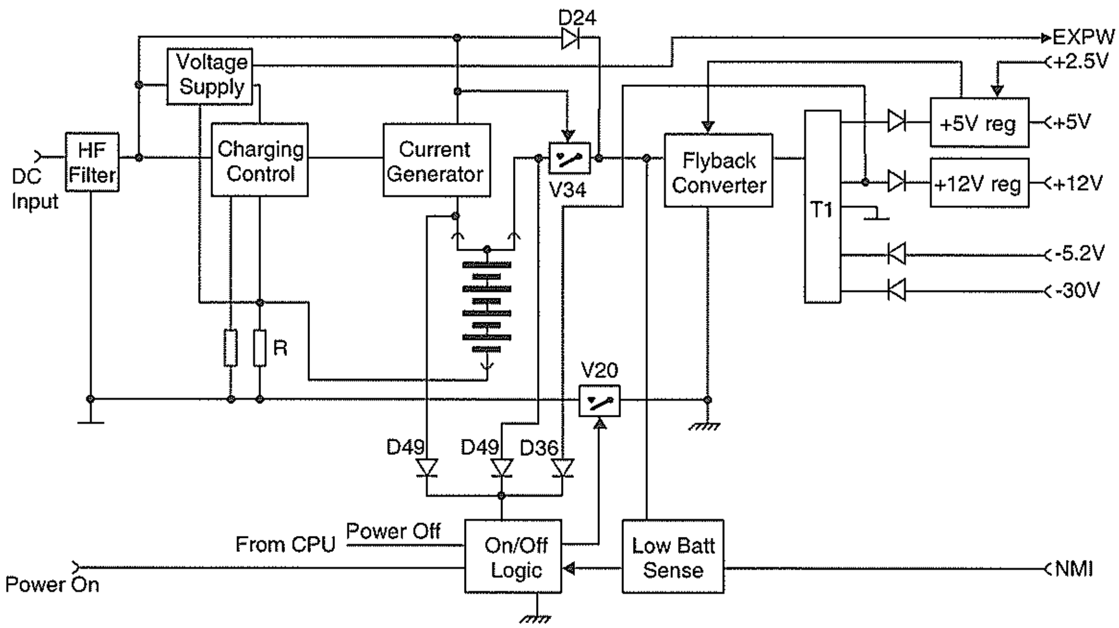


Figure 3-10. Power Supply Block Diagram

The power supply is designed to meet several requirements that are often interacting and sometimes counteracting. The main functions are:

- To supply the instrument with multiple voltages generated from either a single, normally rechargeable battery package or an external DC source, normally the AC/DC power adapter that was delivered with the instrument. However, alkaline cells shall also be accommodated.
- To charge the battery package if it is rechargeable. An intelligent control procedure insures that the battery is recharged as fast as possible without impairing its expected lifetime. In case the instrument is operating it has first priority and the battery will only be trickle charged.
- To warn the user when the battery has to be recharged.
- To switch off the power before the battery voltage is so low that measuring results may be affected by malfunction. Permanent damage to the battery package is also liable to occur if the discharge is too deep.

The power supply consists of the following blocks:

HF Filter

This filter prevents high frequency signals generated inside the instrument from reaching the power lines.

Voltage Supply

This block generates the supply voltage to the charging control block. By pulling the signal line marked EXPW low it also tells the microcontroller via U8 that the MFC is connected to an external DC source.

Charging Control

The charging control circuit outputs a pulse train to the current generator that is designed as a low-loss buck converter. The charging current goes via D2, V18, L15, the battery, and the resistors R82/83 and R149/150. When the switch transistor V18 is off the current will flow through the freewheeling diode D22 to L15. The voltage drop over the resistors is sensed by the charging control circuit U10 at pin IB, and the pulse width at PWM is adjusted accordingly. This pulse train is continuous until the battery is fully charged. Then the small voltage drop over the battery is sensed by U10 and the pulse train will be discontinuous in order to trickle charge the battery.

When the MFC is switched on the battery will always be trickle charged. V20 conducts during the "power-on state" of the MFC, grounding the V-BATT line. The base of V7 goes low and consequently V7 will short-circuit resistor R39. This condition is sensed by the NTC input of U10.

Current Generator

By feeding back the pulse train via capacitor C73 to transistor V18, its gate will assume a higher drive potential relative to the source than the DC supply alone can give, insuring low on-state resistance. In this way the overall efficiency will be high independent of operating conditions.

On/Off Logic

The On/Off logic controls the use of the battery. To insure a safe function under all circumstances these circuits are supplied from the current generator via D49:1, the battery via D49:2 and from +14V via D36.

When the On/Off key is pressed the POWER-ON signal goes low, and so does the base of V9, making it conduct. Consequently the MOSFET V20 also conducts connecting the V-BATT line to the power supply ground. The flyback converter will start.

Another press on the On/Off key will result in a high POWER-OFF signal from the microcontroller, making V28 and V10 conduct. V9 and V20 will be switched off. The flyback converter will stop.

Low Batt Sense

This block senses the battery voltage and informs the microcontroller via a "non maskable interrupt" (NMI) when the voltage is too low. This will occur when the voltage at pin 2 of the op amp U12 is lower than the reference voltage at pin 3. When the battery voltage drops even more the transistor V12 in the differential stage V12, V13 can not keep its conducting state anymore. V13 will take over making V11 short the emitter and base of V9. The flyback converter will stop and prevent the battery from being totally discharged.

Flyback Converter

To generate voltages with reverse polarity or voltages higher than the battery voltage, it is necessary to use a converter. The flyback converter is simple and reliable and fulfills the basic requirements: DC/AC conversion, transformation, rectification and regulation. The circuit chosen for this instrument is self-oscillating and generates a sawtooth current in the transformer T1.

When the MFC is switched on current will flow from V+BATT via the transformer T1, transistor V19, and the resistors R80/R81/R214/R215 to V-BATT. The voltage drop over the resistors will increase linearly due to the inductance in T1 and C58 is charged. The unijunction transistor V21 will start to conduct when its trigger level is reached and V19 will be switched off due to the low gate voltage. When C58 has been discharged V21 will be switched off again and one cycle has been completed.

The oscillation is maintained by positive feedback to the V19 gate from the secondary side of T1 via capacitor C75.

Switch Transformer T1

The transformer generates four voltages which are +14V, +5V, -5.2V and -30V after rectification and filtering.

+5V Regulation

The amplitude of the sawtooth current in T1 is set by the +5V control stage which has a very stable +2.5 V reference voltage generated by U46 on the display PCA. A higher current consumption will cause the DC level from the regulating circuit (V15 and V16) to decrease. This voltage change is fed to the gate of V21 via diode D19. The recharging of C58 will be delayed, indirectly increasing the current level in the transformer where V19 will switch off.

+12V Regulation

The +14V from T1 is regulated by the linear voltage regulator U3 and V14 to +12V.

External / Internal Power Sources

With an external DC source connected to the MFC the converter is supplied via diode D24. The battery is always trickle charged if the MFC is switched on in this state. If the MFC is switched off the battery will be charged normally.

When the internal battery is used as the sole power source the current to the converter goes via V34, a power MOSFET working as a diode with very low forward voltage. It is of paramount importance to keep voltage drops and power losses at a minimum in this operating state. The signal EXPW will be high informing the microcontroller that the MFC is supplied by the internal battery.

Output Driver Circuits

The pulse output can be used for three different purposes:

- 10 MHz Reference Output, either internal or external source.
- Gate Open Monitor Output signaling when the MFC is counting.
- Test Pulse Generator outputting square wave signals with frequencies selectable from a list of fixed values in the range 1 Hz - 5 MHz. Low and High Duty Cycle pulses with 1 kHz frequency are also available.

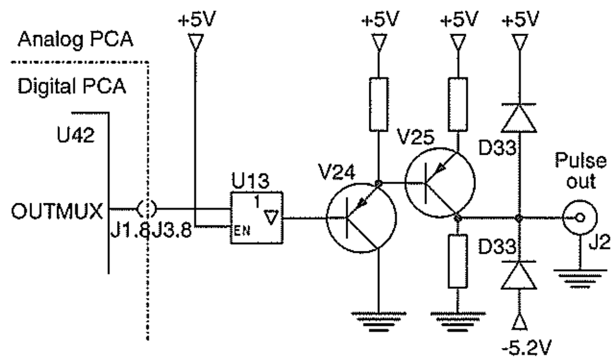


Figure 3-11. Output Driver Circuit

The ASIC circuit U42 generates these signals by means of the 10 MHz reference frequency and outputs them at the OUTMUX pin. They are buffered by U13 and amplified in V24 and V25. D33:1 and D33:2 protect the output from being damaged by external signals connected accidentally as long as the source impedance is not too low. The pulse output has 50 Ω source impedance and is designed to give fixed TTL levels into 50 Ω.

Display PCA

Reference Voltage System

Stable reference voltages are required in different places, both on the display PCA and the input PCA. See Figure 3-12. The main reference circuit is U46.

Its output is buffered/multiplied by a system of op amps arranged to avoid undesirable signal interaction and noise distribution.

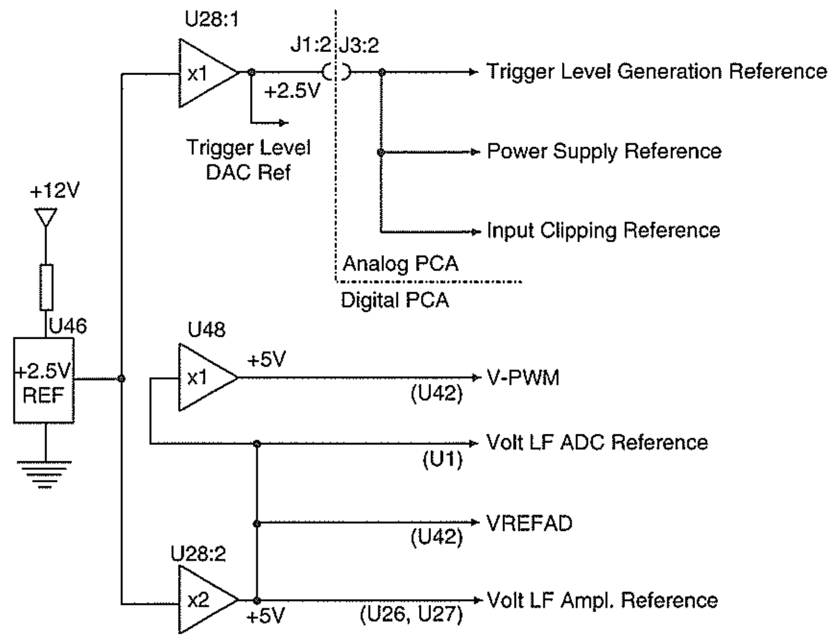


Figure 3-12. Reference Voltage System

Microcomputer Circuitry

Microcontroller

The microcomputer circuitry consists mainly of the microcontroller U1, an Intel 16-bit CHMOS 80C196NT, RAM's (U2, U3, U6, U7), and FLASH EPROM's (U4, U8). The microcontroller has built-in AD converters and works at 16MHz. The data and address lines AD0 to AD15 are shared by means of multiplexing. Therefore the addresses are stored in the latches U11 and U12. The ALE signal (Address Latch Enable) enables the latches.

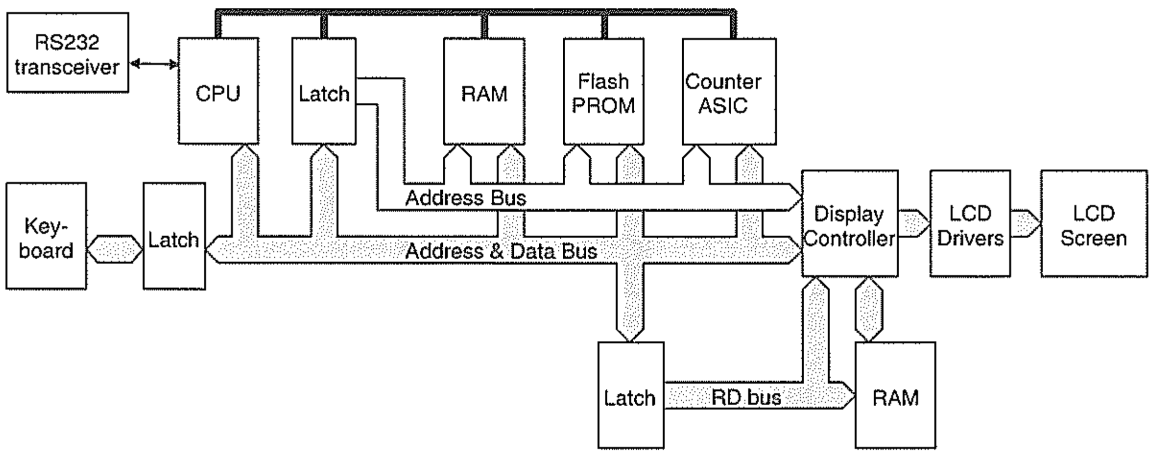


Figure 3-13. Microcomputer Circuitry

Flash EPROM

The main program is stored in U4 and/or U8 making it easy to update and customize the software in the MFC without having to disassemble the instrument. Front panel settings and last used setting, however, are stored in the LCD RAM which has battery backup.

Reset Circuit

A special reset circuit, the power supply supervisor U17, is included in the design. If the +5 V supply line becomes lower than 4.5 V, the reset output pin 5 goes low and the microcontroller will start over. The length of the reset pulse is set by C4; 2.2 μF gives a pulse of approximately 30 ms. U17 also controls the reset pulse during power-on so that the microcontroller will be initiated correctly.

Keyboard Scanning

The keyboard is arranged as a crosspoint switch with four horizontal and eight vertical lines. The keys are placed at the intersecting points. When a key is pressed down the lines crossing it will be connected making it possible to determine the key position in the same way as you can tell the position of a point in a coordinate system by two numbers.

Normally the keyboard is not scanned as long as no key has been depressed. The eight output lines of the latch U29 are low. They are connected to the vertical lines of the keyboard. The horizontal lines are connected to the NAND gate U22 and the latch U23. By activating an arbitrary key one of the inputs of U22 will go low. The output of U22 goes high generating an interrupt at pin P1.5 of U1.

The microcontroller program jumps to a special service routine that starts by latching the data at the input of U23. This information is employed to calculate which of the four rows the key is in. Then the output lines of U29 go high. A low level is latched to the vertical lines one by one. The data at the inputs of U23 is latched and monitored by the microcontroller once for each step in the scanning cycle until the vertical position is found. Now it is possible to decide which key was depressed and the program exits the interrupt routine to process the command from the operator.

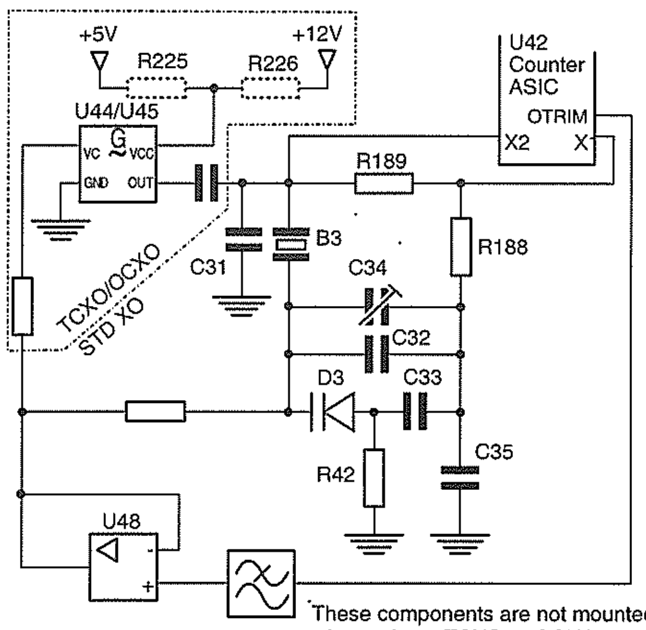
The Power-On/Off key is connected to the On/Off logic in the power supply. When the key is pressed the X0 and X1 lines on the keyboard (J2:13 and J2:14) are connected generating a low level on J1:7 as J2:13 is grounded via resistor R186. J1:7 is connected to J3:7 on the input PCA. The MFC is switched on according to the description of the power supply. However, if the MFC is already on, the Power-On/Off key is scanned in the normal way and will give an interrupt to the microcontroller that sends the Power-Off signal to the On/Off logic.

Oscillator Circuits

CPU Oscillator

The microcontroller U1 is clocked at 16 MHz. The crystal B1 is connected to the XTAL inputs of the microcontroller.

Reference Oscillators



*These components are not mounted when using a TCXO or OCXO.

Figure 3-14. Oscillator Circuits

A 10 MHz crystal oscillator is used as the reference for the measuring logic. See Figure 3-14. If a stable external 10 MHz reference is available it can be connected to the REF INPUT and selected via the USER OPTIONS menu.

There are several optional oscillators to choose from. The uncompensated standard oscillator is mounted in the 163 model and the 164 model without 1.3 GHz HF input. A TCXO or OCXO is mounted in the more advanced models.

The standard oscillator consists of the crystal B3, C31 -C35, R42, R188, and R189. C34 is used for manual coarse adjustment of the frequency and is only intended for compensation of manufacturing tolerances. Drift due to aging is taken care of by a software routine allowing 'closed case' calibration and adjustment.

If a TCXO or OCXO is mounted, the crystal B3 and the capacitors C31 and C34 are not mounted. The supply voltage for the TCXO is +5 V and for the OCXO +12 V, so only one of the jumper resistors R225 or R226 is mounted.

Fine tuning of all oscillators is made by means of the signal OTRIM from the ASIC U42. It is a pulse width modulated signal generated by a D/A converter block. The DC content is extracted in a multilink lowpass filter consisting of R213 - R215, C112 - C114 and the integrating buffer U48. Depending on oscillator type the DC voltage either controls the VC input of a TCXO/OCXO or the variable capacitance diode D3 of a standard XO.

Counter ASIC

The main part of the counting logic is integrated in a CMOS ASIC specially designed for the Fluke MultiFunction Counter series. There are also analog blocks included in the 100 pin QPF package.

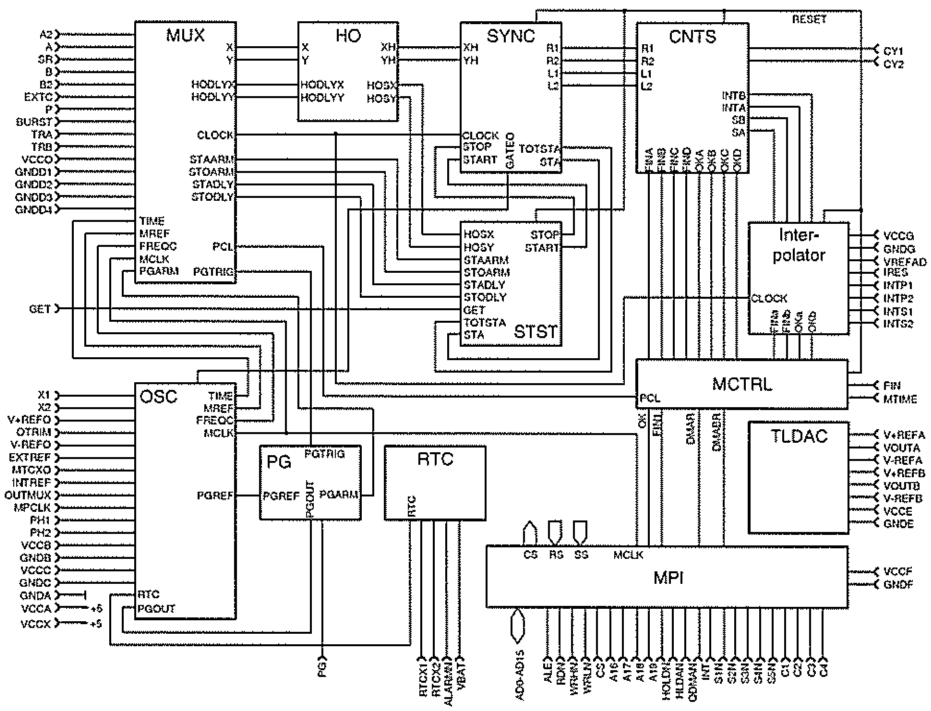


Figure 3-15. Counter ASIC

MUX

The MUX block is a switchboard for incoming and internal signals involved in the measuring process. Some signals are divided by 2 to make it possible to measure higher frequencies. The trigger slope is controlled by the MUX block as well. A trigger edge detector senses the presence or absence of comparator pulses and controls the trigger level DAC's in the TLDAC block. These functional units form an essential part of the Auto Trigger System.

OSC

The oscillator block generates, selects, and distributes the reference clock for the circuit. The active semiconductors of the standard oscillator are included in this block. The crystal is connected to pins X1 and X2. A TCXO or OCXO is connected to X2 only. An external reference clock is connected to EXTREF. The PWM signal generated at OTRIM controls the frequency of the reference oscillator after external integration.

PG

A built-in pulse generator having the 10 MHz clock as a reference can generate pulses with controllable duration and repetition rate at the OUTPUT connector. The level is fixed TTL.

RTC

A real time clock not used at present.

TLDAC

This block contains two 10-bit DAC's generating the trigger levels for the input comparators, VOUTA for channel A and VOUTB for channel B. An external reference voltage is connected to V+REFA and V+REFB.

HO

The Hold Off block can manipulate the internal measuring signal X in several ways. One operating mode simulates a low pass filter (normal hold off), another mode is used in burst measurements.

The following blocks (SYNC, STST, CNTS and MCTRL) form the actual measuring logic in the ASIC. Three types of measurements can be made in this MEAS block:

- Continuous measurements (frequency, ratio and period average). Not used at present.
- Controlled measurements (time interval, period single, pulse width, frequency, totalize gated, totalize start-stop, and ratio).
- Totalize manual

SYNC

The SYNC block synchronizes the actual measurement with certain internal or external events like measuring time and arming signals.

STST

The start and/or the stop of the measurements are controlled by this block. External events can be used to define the exact moments.

CNTS

Two 32-bit binary counters count external events or keep track of the time.

Interpolator

This block is not used at present.

MCTRL

The different events in the measurement cycle of the ASIC are timed by this block.

MPI

This is the microprocessor interface block. The bus width is 16 bits, AD0 to AD15. Interrupts to the microprocessor are generated at INT.

External Interpolator

The X-POLATOR unit is connected directly to the internal interpolator in the ASIC. It is used for increasing the time resolution beyond the limits set by the reference clock period of 100 ns. An error pulse is generated in the SYNC block. Its width is determined by the difference between an external event on an input channel and the next clock pulse. This pulse controls a current generator charging a capacitor. When the pulse has expired the voltage across the capacitor is A/D converted and the value is added to the result. There are two interpolators, one for the start event and one for the stop event. They are calibrated over the possible error pulse range to allow for any aberrations from the theoretical linear behavior.

Display Controller and LCD Driver Circuits

Display Controller

The display controller U13 reads screen data from the external RAM U15 and sends it to the LCD. It also sends line pulses, LINECL (17 kHz) and frame pulses, FRAME (70 Hz).

The screen data, for example cursor and grid information, is stored in the external RAM as bitmap data.

The trace data is stored as a value for every vertical line on the LCD. This data is converted to bitmap form and added to the cursor and grid information.

The display controller module also has the facilities to change the dot size of the trace displayed and to use dot joining.

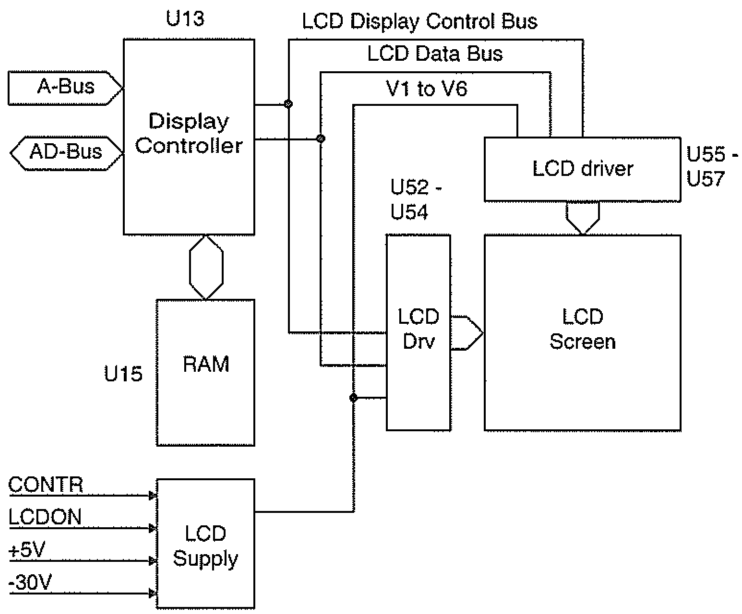


Figure 3-16. Display Controller and LCD Driver Circuits

LCD Screen

The LCD used in the MultiFunction Counter is controlled by six LCD driver IC's. These drivers get their data and control signals directly from the display controller U13.

The MFC uses a Super Twisted Nematic Liquid Crystal Display with a resolution of 240x240 pixels. The display is of the transmissive type and requires backlight, in this case a CCFL unit.

The picture on the LCD screen is written columnwise. It is divided horizontally in three row sections, each 80 pixels high, and vertically in three column sections, each 80 pixels wide.

LCD Drivers

The LCD is controlled by the display controller, U13 via six LCD drivers, the three row drivers U52 to U54, and the three column drivers U55 to U57.

The outputs of the drivers are connected directly to the LCD matrix. Every column driver serves 80 pixel columns of the LCD and every row driver serves 80 pixel rows. The staircase signals present at these outputs have six levels that are set by the voltages V1 to V6 coming from the LCD power supply.

The data from the display controller is sent via the driver bus to the column driver inputs LD0 to LD3.

Display Control Signals

The signals LINECL, DATACL, M1, and FRAME are used for controlling the LCD. Together with the data signals LD0 to LD3 these display control signals build the display picture.

- DATACL clocks the data LD0 to LD3 into the driver buffers.
- LINECL clocks one complete line into the LCD.
- M1 is not time related to the other display control signals and is used by the LCD drivers to convert all drive signals to AC signals suitable for the LCD. The reason for this DC/AC conversion is that the LCD drive signals must not have any net DC content to prevent electrolysis.
- FRAME synchronizes the row drivers.

LCD Supply

The pulse width modulated signal CONTR controls the contrast of the display. It is generated in the microcontroller and is integrated by R119 and C56 to a DC voltage that is a function of the duty cycle. This voltage is buffered by transistor V6 and is then connected to one end of the resistor ladder R100 - R104. The other end is connected to a temperature compensated negative voltage of nominally -20 V. Contrast variations due to the temperature characteristics of the LCD are handled by the PTC sensor R126. The two untapped voltages are filtered with pure RC links whereas the four tapped voltages are first buffered by the op amps U33 and U39 in order to equalize the source impedance. Together they form the LCD driver reference voltages V1 to V6.

If the signal LCDON from the microcontroller is high both ends of the resistor ladder get their respective supply voltages and the LCD system as well as the backlight converter will be activated. The unregulated -30 V is series regulated to -20 V by means of transistor V20. V5 limits the current in case of short circuit.

Backlight DC/AC Converter

The circuit configuration chosen for this block is a self-oscillating current driven Royer converter (V54, V55 and T1) controlled by the integrated circuit U5 that senses the current through the CCFL tube at the DIO input.

The desired light intensity is set by converting a pulse width modulated signal (B-LI) from the microprocessor into a current at the ICCFL input of U5. R326 and C179 integrate the pulses and R327 converts the averaged voltage to a current level suitable for this input ($<100\ \mu A$).

Three different intensity levels are selectable by toggling the dedicated button on the keyboard.

The currents at ICCFL and DIO are compared and the output at VSW is pulse width modulated by U5 and averaged by the choke L1 into a current that supplies the converter with just enough power to keep the CCFL current constant.

The transistors V53 and V56 form an overvoltage protection circuit that trips if, for instance, the CCFL tube gets disconnected. Then the high voltage converter will be transferred from current mode to voltage mode preventing damage due to flashovers or overstress.

The average voltage between the primary of the transformer T1 and the emitters of the switch transistors V54, V55 is monitored by the zener diode D42 and the base-emitter junction of V56. When the trip point is exceeded V56 starts to conduct and V53 saturates pulling the input CCFL on U5 low. The regulator loop switches from current to voltage control until the cause for mode change is removed.

RS232 Optical Interface

The asynchronous serial communication facilities in the microcontroller U1 are employed to operate the infrared receiver V19 and transmitter D28 of the MFC. For this purpose a stripped version of the RS232C protocol is used.

Only the TXD (transmit data) and RXD (receive data) lines from the RS232C standard are implemented. The IR transmitter D28 is driven directly from the TXD pin of the microcontroller.

The operational amplifier U32 powers the collector of the photo transistor V19. On receiving IR light V19 will drive V3 into saturation pulling the RXD line low. A low level is interpreted as a logic 1 by the microprocessor.

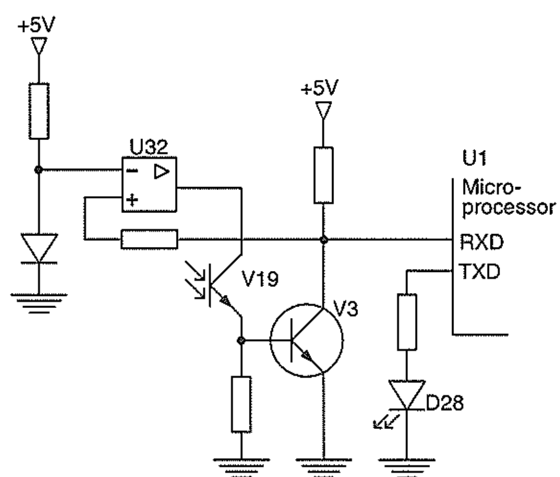


Figure 3-17. RS232 Optical Interface

Optional Units

1.3 GHz HF Input

The HF input is mounted on the input PCA. It is plugged into connector P4.

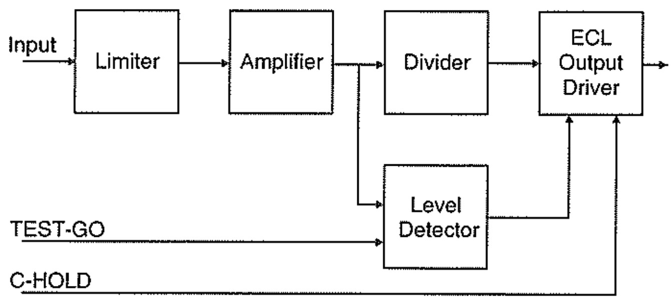


Figure 3-18. HF-input Block Diagram

The frequency range for the HF input is 70 MHz to 1.3 GHz. The frequency is divided by 64 to make it possible for the measuring logic on the display PCA to handle the signal. The input is AC coupled and the input impedance is 50 Ω. Five main blocks make up the HF input: Limiter, amplifier, divider, ECL output driver and level detector. See Figure 3-18.

Limiter

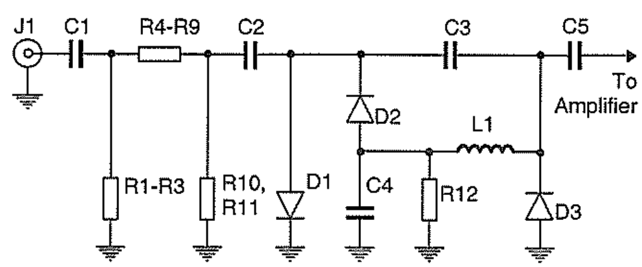


Figure 3-19. Limiter Circuits

The 6 dB attenuator (R1 to R11) keeps the VSWR low for all input levels, even if the PIN diodes D3 have low impedance, (see Figure 3-19). When the peak-to-peak level of the input signal is greater than the sum of the voltage drops of the Schottky diodes D1 and D2, the charging of capacitor C4 starts. The filtered DC voltage across C4 is a function of the signal amplitude at the amplifier input. It is used to control the impedance of the PIN diodes that shunt the signal to ground. The diodes start to conduct when the voltage is lower than approximately –0.65V. Increasing current through the diodes means lower impedance. The result is that the HF voltage over D3 is virtually constant when the input amplitude has crossed the threshold level. R12 discharges C4 when the input level decreases. L1 prevents capacitor C4 from short-circuiting the HF signal.

Amplifier

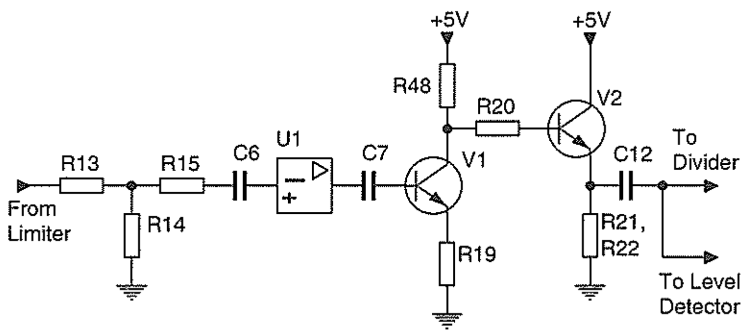


Figure 3-20. Amplifier Circuits

R13, R14, and R15 attenuate the HF signal 3 dB to prevent overloading of the amplifier circuit U1that amplifies the HF signal approximately 15 dB. V1 raises the amplitude in the frequency range 0.9 GHz to 1.4 GHz by 8 dB to compensate for the falling frequency response of U2. V2 is an impedance converter, (see Figure 3-20).

Divider

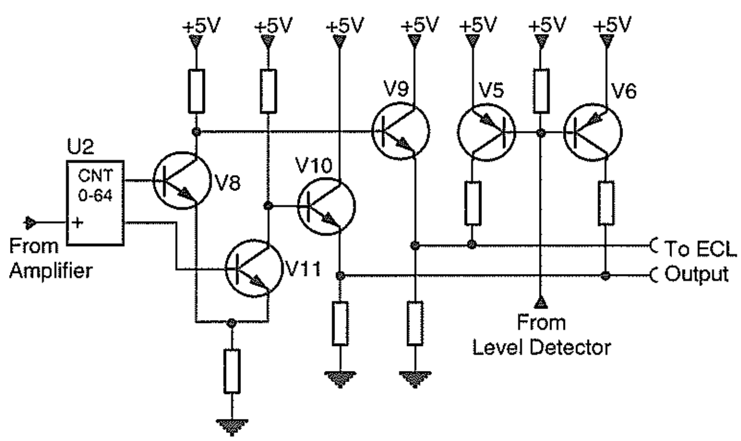


Figure 3-21. Divider and ECL-converter Circuits

The divider U2 divides the input frequency by 64. The output frequency is maximum 21 MHz. See Figure 3-21.

ECL output

See Figure 3-22. The transistors V8 and V11 form a differential amplifier that reduces the transition times of the differential signal at the outputs of U2. V9 and V10 convert the signal to positive ECL levels. The transistors V5 and V6 can disable the ECL output by setting the normally differential output levels high. This is done by means of the control signal from the level detector. Base currents applied to V5 and V6 make them conduct, lifting the emitters of V9 and V10 to a logic high level. The base-emitter junctions of these transistors will be reverse biased and the output signal will be blocked.

Level Detector

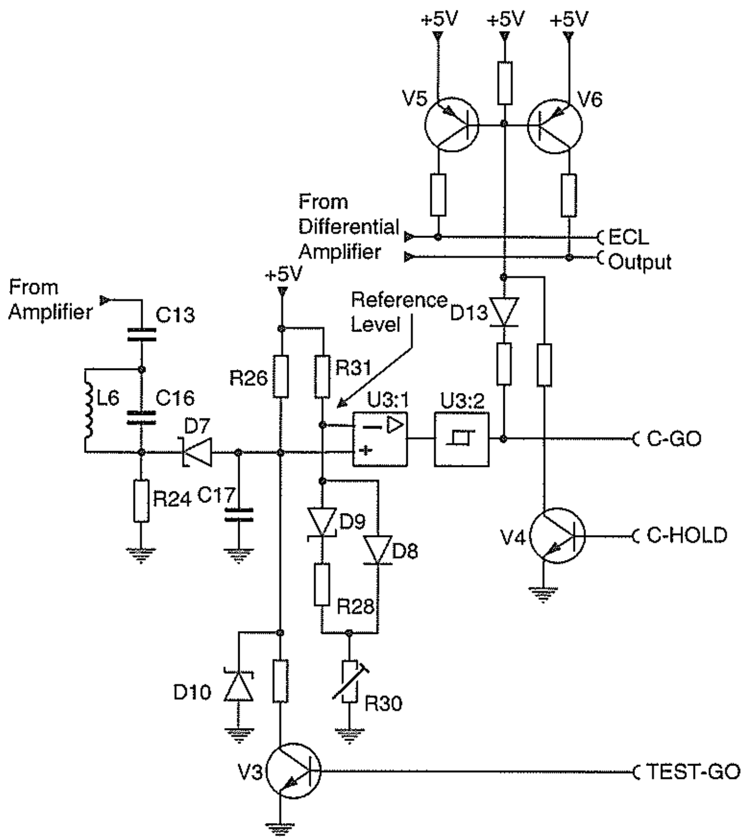


Figure 3-22. Level detector

C13, C16, and L6 form a filter that adapts the frequency response of the level detector diode D7 to the frequency response and input impedance characteristics of U2 so that the effective overall response seen from the input connector is as straight as possible. See Figure 3-22.

The detector voltage is filtered and fed to U3. Diode D10 prevents the input level from becoming too negative, a condition that might cause latch-up. The first stage in U3 amplifies the level approximately 15 times and the second stage is a Schmitt trigger. A low output level from the Schmitt trigger disables the ECL output via D13, V5 and V6. If the detected level on pin 3 of U3 is more negative than the reference level on pin 2, indicating the presence of an HF signal with sufficient amplitude, the Schmitt trigger output goes high, enabling the ECL output signal.

The reference level on U3 pin 2 is set by the trimmer R30. D8, D9, and R28 form a circuit that compensates for the temperature behavior of the detector diode D7. For testing purposes the level detector can be enabled by the signal TEST-GO independent of the input HF signal amplitude. The ECL output signal can be disabled by means of the signal C-HOLD, also independent of the input HF signal amplitude.

The +5V supply is switched off to increase the battery discharge time when the HF input is not in use. A transistor acting as a switch (V7) is inserted in the supply line. It is controlled by the signal C-OFF. These parts are not shown in Figure 3-22.

Chapter 4
Performance Verification

Introduction

The MultiFunction Counter should be calibrated and in operating condition when you receive it.

The following performance verification tests are provided to ensure that the MultiFunction Counter is in proper operating condition. If the instrument fails any of the tests, calibration adjustments (see chapter 5) and/or repair (see chapter 7) is necessary.

The Performance Verification Procedure consists of two parts

Operational Verification Procedure useful for:

- Incoming inspection
- Routine maintenance
- Check after instrument repair

Complete Performance Verification Procedure to verify the specifications listed in chapter 2.

If the instrument passes the Operational Verification and the Complete Performance Verification it is considered to be calibrated and can carry a calibration sticker.

All tests can be performed without opening the cover of the instrument.

Warning

Before turning on the instrument, ensure that it has been installed in accordance with the installation instructions outlined in Chapter 1 of the operators manual.

Required Test Equipment

Table A Test Equipment for Operational Verification.

Equipment Type	Required Characteristics	Recommended Model
50Ω Power Splitter		Fluke PM 9584
50Ω Feedthrough Termination (2 pcs)		Fluke PM 9585
50Ω Coaxial Cable (3 pcs)	BNC to BNC, 2 pcs of equal length	Fluke PM 9074
HF Signal Source	10 MHz, 0.5 Vrms	

Complete Performance Verification requires the following additional equipment:

Table B Test Equipment for Performance Verification.

Equipment Type	Required Characteristics	Recommended Model
Signal Generator	1 -1300 MHz	Gigatronics 6062A
Voltage Calibrator	DC/AC (f >= 500 kHz)	Fluke 5500A
Pulse Generator	Rise & Fall Time 2 ns	Fluke PM 5786
Reference Frequency Source	10 MHz ± 0.1 Hz, 0.5 Vrms	Fluke PM 6685R

Operational Verification

The operational verification is a quick way to check that the instrument operates properly without performing the complete performance verification. Because of the highly integrated design of the MultiFunction Counter, it is not always necessary to check all features separately.

Note

Power up the MultiFunction Counter and the test equipment at least 30 minutes before testing to let them reach normal operating temperature. Failure to do so may result in certain test steps not meeting the specifications.

Test 1, Self Test

Procedure

1. Press ⏻ to turn on the MultiFunction Counter.
2. Select Default Settings by: Pressing SAVE RECALL and choosing Recall Default Setup and then pressing SELECT.
3. Press USER OPTIONS.
4. Position the black cursor on Test&Adjust and press SELECT.
5. Check that **Select Self Test: All Self Tests** are displayed.
6. Position the black cursor on Run Self Tests and press SELECT.
7. Check that all tests are passed. If the test is not applicable, dashes (----) will show in stead of "Passed".
8. End the self test by pressing any key.

Test 2/3/4, Presentation Mode

These tests verify the operation of the PRESENTATION MODE.

Test setup

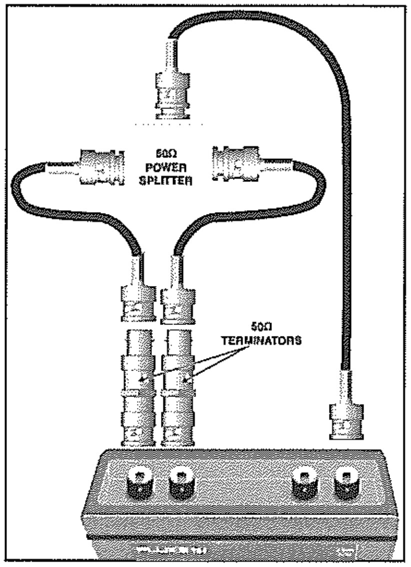


Figure 4-1. Test setup

Test 2, WAVEFORM Test Procedure

1. Select Default Settings by: Pressing [SAVE RECALL] and choosing [Recall Default Setup] and then pressing [SELECT].
2. Press [USER OPTIONS]; then choose [Output]; then press [SELECT].
3. Set OUTPUT as follows:
   Output: On
   Output Signal: 1 MHz, Square
4. Press [∿]; then verify that the 1 MHz, 0.9 Vp-p square wave is displayed.
5. Press [MEASURE FUNCTION] and choose [Frequency (Hz)], press [SELECT], select [Frequency Ratio] and press [SELECT].
6. Verify that the two 1 MHz, 0.9 Vp-p square wave traces are displayed.
7. Press [UNDO] to return to the one trace screen.

Test 3, VALUES Test Procedure

1. Press [1234].
2. Verify the following measured approximate values:
   Frequency A: 1.000 MHz
   Period Average A: 1.000 µs
   Vmax: 0.45V
   Vmin: -0.45V
   Vp-p: 0.90V

Test 4, STATISTICS Test Procedure (1&3)

1. Press [MAX MIN].
2. Verify the following measured approximate values:
   Mean: 1.000 MHz
   Standard Deviation: <5 mHz
   Maximum: 1.000 MHz
   Minimum: 1.000 MHz
   Max-Min: < 30 mHz

Test 5/6/7, Measure Function

These tests verify the operation of the MEASURE FUNCTION setup menu.

Test setup

As test setup in Figure 4-1. Test setup.

Test 5, Time Interval A to B Test Procedure

1. Select Default Settings by: Pressing [SAVE RECALL] and choosing [Recall Default Setup] and then pressing [SELECT].
2. Press [USER OPTIONS]; then choose Output; then press [SELECT].
3. Set Output as follows:
   Output: On
   Output Signal: 1 kHz, Square
4. Press [MEASURE FUNCTION]; then choose [Period&Time]; then press [SELECT].
5. Choose [Time Interval]; then press [SELECT].
6. Press [INPUT TRIGGER]; choose [Input A]; then press [SELECT].
7. Set Input A conditions to:
   Trigger Slope: Positive
   Auto Trigger: On
   Voltage Range: ±5.0V
   Coupling: DC
   100 kHz LP Filter: Off
8. Press [EXIT] to exit Input A settings.
9. Choose Input B; then press [SELECT].
10. Set input B conditions to:
    Trigger Slope: Negative
    Auto Trigger: On
    Voltage Range: ±5.0V
    Coupling: DC
    100 kHz LP Filter: Off
11. Press [EXIT] to exit input B settings.
12. Choose [Arming&Hold Off]; then press [SELECT].
13. Set Hold Off conditions to
    Trigger Hold Off: On
    Hold Off Time: 2.00 ms

14. Press [1.234].
15. Verify the following measured approximate values:
16. Time Interval A to B: 2.500 000 X ms ±3 ns

Vmax	Vmin	Vp-p
0.90V	0.00V	0.90V
0.90V	0.00V	0.90V

Test 6, Totalize, Gated by Time Test Procedure

1. Press [MEASURE FUNCTION]; then choose [Totalize (Counts)]; then press [SELECT].
2. Choose [Gated by Time]; then press [SELECT].
3. Use the INFORMATION MENU at the bottom of the display and set A trigger to MAN; then press [AUTO SET].
4. Verify the following measured value:
   Totalize A Timed: 100
5. Press [INPUT TRIGGER] , choose 'Measure Channel(s)' and press [SELECT]; then select B and press [SELECT].
6. Use the INFORMATION MENU at the bottom of the display and set B trigger to MAN; then press [AUTO SET].
7. Verify the following measured value:
   Totalize B Timed: 100

Test 7, Pulse Group Test Procedure

1. Press [MEASURE FUNCTION]; then choose [Pulse]; then press [SELECT].
2. Verify the following measured values:
3. Period A: 1.000 ms
4. Frequency A 1.000 kHz
5. Positive Pulse Width A 500.0 µs
6. Negative Pulse Width A 500.0 µs
7. Positive Duty Cycle A: 50.00%
8. Rise Time A: 15 ns
9. Fall Time A: 10 ns

Test 8, 10 MHz Reference Input

This test verifies the operation of the External Timebase Reference Input.

Test setup

As test setup in Figure 4-1. Test setup. Also connect an external 10 MHz, 0.5 Vrms signal to the MultiFunction Counter's REF INPUT.

Test Procedure

1. Select Default Settings by: Pressing [SAVE RECALL] and choosing [Recall Default Setup] and then pressing [SELECT].
2. Press [USER OPTIONS]; then choose **Timebase Reference: External.**
3. Choose [Output]; then press [SELECT].
4. Set OUTPUT as follows:
   Output: On
   Output Signal: 10 MHz, Reference.
5. Press [1234];

Verify that the display reads approximately 10.000 000 XX MHz and the Ext Ref on the INFORMATION MENU is lit.

Complete Performance Verification

The following tests are used to verify the performance of the 163/164 MultiFunction Counters. If an out-of-tolerance condition is found, the instrument can be re-adjusted using the procedure described in Chapter 5: Calibration Adjustment.

The Performance Test Records have reserved columns for recording the measured values.

Note

Power up the MultiFunction Counter and the test equipment at least 30 minutes before testing to let them reach normal operating temperature. Failure to do so may result in certain test steps not meeting the specifications.

Test 9. Internal Timebase Uncertainty

These tests check the internal time base specification.

Test Equipment

Reference Frequency Source.

Test Setup

Connect the Reference Frequency Source to the MultiFunction Counter's INPUT A.

Procedure

Set the MultiFunction Counter to the following:

1. Cycle ⏻ to preset MultiFunction Counter.
2. Select Default Settings by: Pressing [SAVE RECALL] and choosing [Recall Default Setup] and then pressing [SELECT].
3. Press [INPUT TRIGGER].
4. Choose Measuring Time 1s; then press [EXIT] twice.
5. Record the measured frequency in the appropriate place in the Test 9, Internal Timebase Uncertainty Record.

Test 10. Time Interval Uncertainty

These tests check the resolution and channel mismatch errors in Time Interval measurements:

Test Equipment

Pulse Generator.

Test Setup

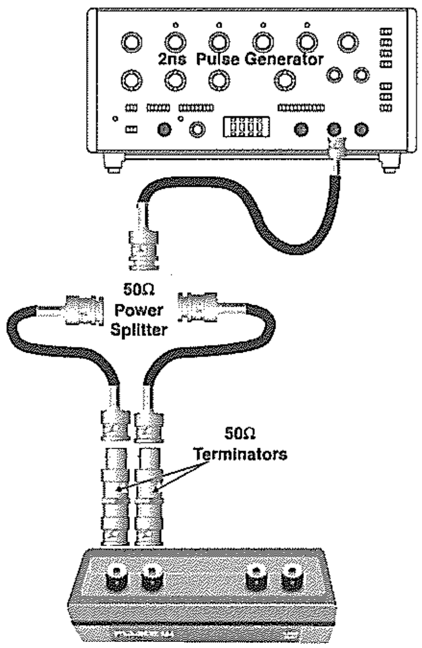


Figure 4-2. Test Setup for Time Interval Uncertainty

Set the Pulse Generator to the following:

- Period: 100 µs
- Width: Square wave signal
- Amplitude Levels: +2V and -2V
- Rise Time: 2 ns

Procedure

1. Cycle ⏻ to preset MultiFunction Counter.
2. Select Default Settings by: Pressing [SAVE RECALL] and choosing [Recall Default Setup] and then pressing [SELECT].
3. Press [MEASURE FUNCTION]; then choose Period & Time; then press [SELECT].
4. Choose Time Interval; then press [SELECT].
5. Press [INPUT TRIGGER]; then choose Input A; then press [SELECT].
6. Set input A conditions to:
   Trigger Slope: Positive

Auto Trigger: Off
Voltage Range: ±5.0V
Coupling: DC
LP Filter: Off

7. Press [EXIT] to exit input A settings.
8. Choose Input B; then press [SELECT].
9. Set input B conditions equal to input A conditions:
10. Press [EXIT] twice to exit input B settings.
11. Press [AUTO SET].
12. Verify that two square wave signals are displayed.
13. Press [MAX MIN] to measure Time Interval A to B.
14. Record the Mean and Standard Deviation values in the appropriate place in the Test 10, Time Interval Uncertainty Test Record.
15. Press [INPUT TRIGGER] select 'Measure Channel(s)' and press [SELECT] then choose A,A (A both Primary and Secondary Channel) and press [SELECT].
16. Record the Mean and Standard Deviation values in the appropriate place in the Test 10, Time Interval Uncertainty Test Record.

Repeat steps 15 and 16 to complete the Time Interval measurements: B to A and B to B (via A).

Test 11. Frequency Sensitivity

These tests check the sensitivity of the INPUTS A, B, and C in Frequency measurements.

Test Equipment

Signal generator.

Test Setup

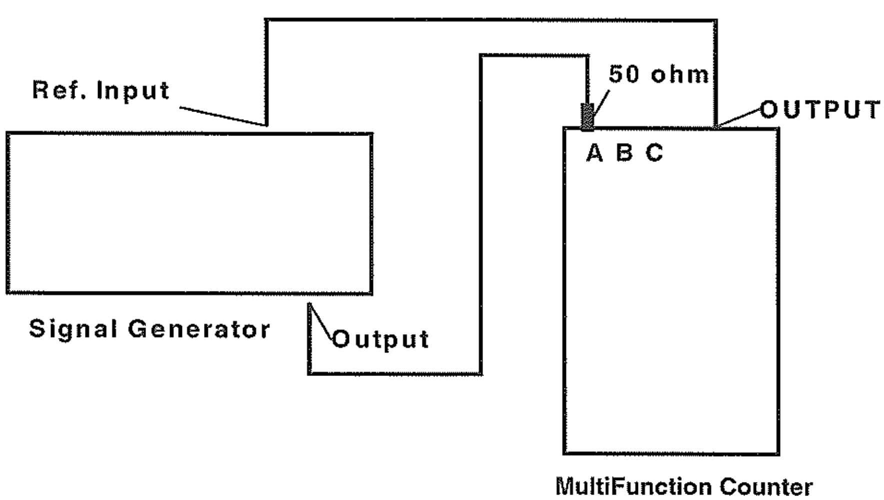


Figure 4-3. Test Setup for Sensitivity

Set the MultiFunction Counter to the following:

1. Cycle ⏻ to preset MultiFunction Counter.
2. Select Default Settings by: Pressing [SAVE RECALL] and choosing [Recall Default Setup] and then pressing [SELECT].
3. Press [USER OPTIONS]; then choose Output; then press [SELECT].
4. Set OUTPUT as follows:
5. Output: On
6. Output Signal: 10 MHz, Reference
7. Press [EXIT] twice to exit OUTPUT settings.

11-1. Procedure for Input A tests

1. Set the Signal Generator to output 1 MHz, -30 dBm sine wave signal.
2. Press [1234]: then press [AUTO SET] to measure frequency A.
3. In 1 dB steps, increase the power level until the MultiFunction Counter displays a stable reading of 1 MHz.
4. Record the power level in the appropriate place in the Test 11, Frequency Sensitivity Test Record.
5. Repeat steps 1, 3, and 4 for 50 MHz and 160 MHz.

11-2. Procedure for Input B tests

1. Connect the Signal Generator to Input B, via the 50Ω feedthrough termination, and set the Generator to output 1 MHz, -30 dBm sine wave signal.
2. Press [INPUT TRIGGER] select 'Measure Channel(s)' and press [SELECT] then choose Channel B and press [SELECT].
3. In 1 dB steps, increase the power level until the MultiFunction Counter displays a stable reading of 1 MHz.
4. Record the power level in the appropriate place in the Test 11, Frequency Sensitivity Test Record.
5. Repeat steps 1, 3, and 4 for 50 MHz and 160 MHz.

11-3 Procedure for Input C tests (163)

1. Connect the Signal Generator to Input C, without the 50Ω feedthrough termination, and set the Generator to output 70 MHz, -35 dBm sine wave signal.
2. Press [INPUT TRIGGER] select 'Measure Channel(s)' and press [SELECT] then choose Channel C and press [SELECT].
3. In 1 dB steps, increase the power level until the MultiFunction Counter displays a stable reading of 70 MHz.
4. Record the power level in the appropriate place in the Test 11, Frequency Sensitivity Test Record.
5. Repeat steps 1, 3, and 4 for 900 MHz, 1100 MHz, and 1300 MHz.

Test 12. Frequency Uncertainty

These tests check the frequency uncertainty specifications of the INPUTS A, B, and C.

Test Equipment

Signal generator.

Test Setup

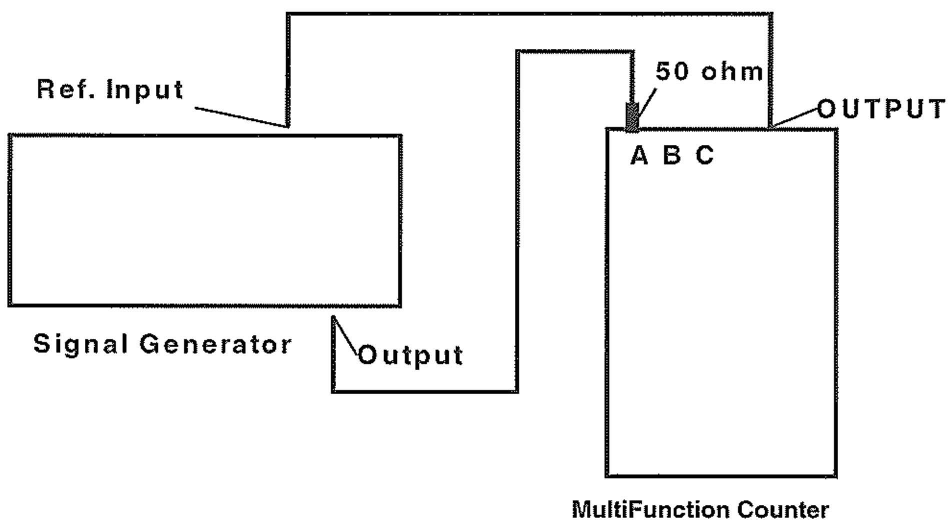


Figure 4-4. Test Setup for Frequency Uncertainty

Set the MultiFunction Counter to the following:

1. Cycle ⏻ to preset MultiFunction Counter.
2. Select Default Settings by: Pressing [SAVE RECALL] and choosing [Recall Default Setup] and then pressing [SELECT].
3. Press [USER OPTIONS]; then choose Output; then press [SELECT].
4. Set OUTPUT as follows:
5. Output: On
6. Output Signal: 10 MHz, Reference
7. Press [INPUT TRIGGER]; then choose Measuring time 1 ms.

Set the Signal Generator to the following:

- Output 100 MHz
- 0 dBm sine wave signal

12-1. Procedure for Input A tests

1. Press [MAX MIN] to measure frequency including statistics.
2. Record the Mean value and Standard Deviation in the appropriate place in the Test 12, Frequency Uncertainty Test Record.

12-2. Procedure for Input B tests

1. Connect the Signal Generator to Input B.
2. Press [INPUT TRIGGER] select 'Measure Channel(s)' and press [SELECT] then choose Channel B and press [SELECT].
3. Record the Mean value and Standard Deviation in the appropriate place in the Test 12, Frequency Uncertainty Test Record.

12-3. Procedure for Input C tests (163)

1. Connect the Signal Generator to Input C without the 50Ω feedthrough termination.
2. Press [INPUT TRIGGER] select 'Measure Channel(s)' and press [SELECT] then choose Channel C and press [SELECT].
3 Record the Mean value and Standard Deviation in the appropriate place in the Test 12, Frequency Uncertainty Test Record.

Test 13/14/15. Voltage Uncertainty

These tests check the voltage uncertainty specifications of INPUTS A and B.

Test Equipment

Fluke 5500A Multi-Product Calibrator.

Test Setup

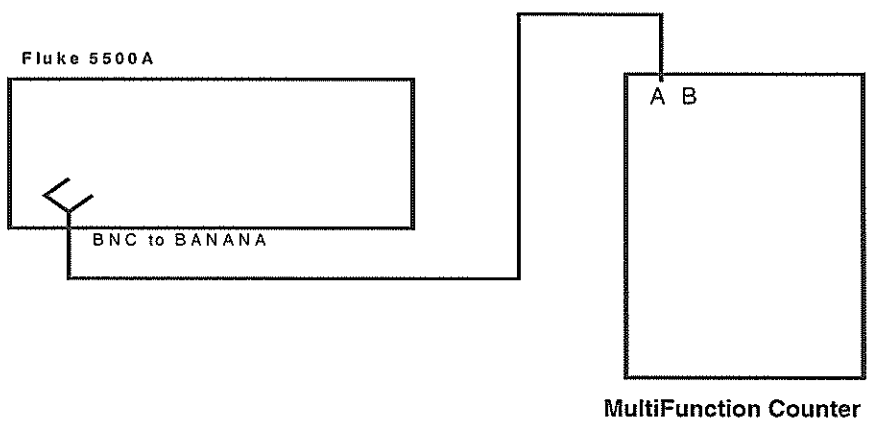


Figure 4-5. Test Setup for Voltage Uncertainty

Test 13. DC Voltage Uncertainty

Procedure

1. Cycle ⏻ to preset MultiFunction Counter.
2. Select Default Settings by: Pressing [SAVE RECALL] and choosing [Recall Default Setup] and then pressing [SELECT].
3. Press [MEASURE FUNCTION]; then choose Voltage; then press [SELECT]
4. Choose Vdc; then press [SELECT].
5. Choose 'VALUES' mode by pressing [1234].
6. Press appropriate ▲▼◀▶ key to position the cursor on the ±5V range of INPUT A, in the INFORMATION MENU, and change to ±0.5V.
7. Set the Calibrator to output 400 mV DC.
8. Record the voltage reading in the appropriate place in the Test 13, DC Voltage Uncertainty Test Record.
9. Repeat steps 6 through 8 to complete the DC Voltage Uncertainty Test Record for INPUT A.
10. Connect the Calibrator to INPUT B and choose Channel B via [INPUT TRIGGER] key and repeat steps 6 through 8 to complete the DC Voltage Uncertainty Test Record for INPUT B.

Test 14. AC Voltage Uncertainty

Procedure

1. Cycle ⏻ to preset MultiFunction Counter.
2. Select Default Settings by: Pressing [SAVE RECALL] and choosing [Recall Default Setup] and then pressing [SELECT].
3. Press [MEASURE FUNCTION]; then choose Voltage; then press [SELECT].
4. Choose Vrms ac; then press [SELECT].
5. Choose 'VALUES' mode by pressing [1234]
6. Press appropriate ▲▼◀▶ key to position the cursor on the ±5V range of INPUT A, in the INFORMATION MENU, and change to ±0.5V.
7. Set the Calibrator to output 300 mVrms, 50 Hz
8. Record the voltage reading in the appropriate place in the Test 14, AC Voltage Uncertainty Test Record.
9. Repeat steps 6 through 8 to perform the AC Voltage Uncertainty tests up to 500 kHz.
10. Connect the Calibrator to INPUT B and choose Channel B via [INPUT TRIGGER] key and repeat steps 6 through 8 for INPUT B tests.
11. Disconnect the Calibrator and connect the Signal Generator via a 50Ω feedthrough termination to INPUT A.
12. Choose Channel A via [INPUT TRIGGER] key.
13. Set the Signal Generator to output 1.00 Vrms, 5 MHz.

14. Press [AUTO SET].

15. Record the voltage reading in the appropriate place in the Test 14, AC Voltage Uncertainty Test Record.

16. Repeat steps 13 through 15 to complete the AC Voltage Uncertainty Test Record for INPUT A.

17. Connect the Signal Generator to INPUT B and choose Channel B via [INPUT TRIGGER] key and repeat steps 13 through 15 for INPUT B tests.

18. Disconnect the Signal Generator.

Test 15. Peak Voltage Uncertainty

Procedure

1. Cycle ⏻ to preset MultiFunction Counter.
2. Select Default Settings by: Pressing [SAVE RECALL] and choosing [Recall Default Setup] and then pressing [SELECT].
3. Press [MEASURE FUNCTION]; then choose Voltage; then press [SELECT].
4. Choose Vp-p; then press [SELECT].
5. Choose 'VALUES' mode by pressing [1234].
6. Connect the Calibrator to INPUT A and set it to output 1.00 Vrms, 2 kHz.
7. Press [AUTO SET].
8. Record the voltage reading in the appropriate place in the Test 15, Peak Voltage Uncertainty Test Record.
9. Connect the Calibrator to INPUT B and choose Channel B via [INPUT TRIGGER] key.
10. Record the voltage reading in the appropriate place in the Test 15, Peak Voltage Uncertainty Test Record.
11. Disconnect the Calibrator and connect the Signal Generator via a 50Ω feedthrough termination to INPUT A.
12. Choose Channel A via [INPUT TRIGGER] key.
13. Set the Signal Generator to output 1.00 Vrms, 5 MHz.
14. Record the voltage reading in the appropriate place in the Test 15, AC Voltage Uncertainty Test Record.
15. Repeat steps 13 and 14 to complete the Test 15, Peak Voltage Uncertainty Test Record for INPUT A.
16. Connect the Signal Generator to INPUT B and choose Channel B via [INPUT TRIGGER] key.
17. Repeat steps 13 and 14 to complete the Test 15, Peak Voltage Uncertainty Test Record for INPUT B.

FLUKE 163 & 164 Performance Test Report

Operational Verification Test Record

(page 4-5)

Test Number	Operational Verification	Test Result	
		Pass	Fail
1	Power-On Self Test		
2	WAVEFORM Test		
3	VALUES Test		
4	STATISTICS Test		
5	Time Interval A to B Test		
6	Totalize, Gated by Time Test		
7	Pulse Group Test		
8	10 MHz External Timebase REF INPUT Test		

Test 9. Internal Timebase Uncertainty Test Record

(page 4-10)

Timebase	Frequency A			Test Result	
	Minimum	Reading	Maximum	Pass	Fail
Standard	9.999 950 MHz		10.000 050 MHz		
TCXO	9.999 990 MHz		10.000 010 MHz		
High Stability Oven	9.999 999 MHz		10.000 001 MHz		

Test 10. Time Interval Uncertainty Test Record

(page 4-11)

Primary Channel	Secondary Channel	Mean		Standard Deviation		Test Result	
		Spec.	Reading	Spec.	Reading	Pass	Fail
A	B	≤±1 ns		≤1 ns			
A	A (via B)	≤±1 ns		≤1 ns			
B	A	≤±1 ns		≤1 ns			
B	B (via A)	≤±1 ns		≤1 ns			

Test 11. Frequency Sensitivity Test Record
(page 4-12)

Primary Channel	Frequency	Reading	Specification	Test Result	
				Pass	Fail
A	1 MHz		≤-21 dBm (20 mV rms)		
A	50 MHz		≤-21 dBm (20 mV rms)		
A	160 MHz		≤-15 dBm (40 mV rms)		
B	1 MHz		≤-21 dBm (20 mV rms)		
B	50 MHz		≤-21 dBm (20 mV rms)		
B	160 MHz		≤-15 dBm (40 mV rms)		
C	70 MHz		≤-27 dBm (10 mV rms)		
C	900 MHz		≤-27 dBm (10 mV rms)		
C	1100 MHz		≤-23.5 dBm (15 mV rms)		
C	1300 MHz		≤-15 dBm (40 mV rms)		

Test 12. Frequency Uncertainty Test Record
(page 4-14)

Primary Channel	Mean			Standard Deviation		Test Result	
	Min.	Reading	Max.	Spec.	Reading	Pass	Fail
A	99.999 900 MHz		100.000 100 MHz	≤ 100 Hz			
B	99.999 900 MHz		100.000 100 MHz	≤ 100 Hz			
C	99.999 900 MHz		100.000 100 MHz	≤ 100 Hz			

Test 13. DC Voltage Uncertainty Test Record
(page 4-16)

Primary Channel	Range	Input Signal	Min.	Reading	Max.	Test Result	
						Pass	Fail
A	±0.5V	400 mV DC	391 mV DC		409 mV DC		
A	±0.5V	-400 mV DC	-409 mV DC		-391 mV DC		
A	±5V	4.00V DC	3.91V DC		4.09V DC		
A	±5V	-4.00V DC	-4.09V DC		-3.91V DC		
A	±50V	40.0V DC	39.1V DC		40.9V DC		
A	±50V	-40.0V DC	-40.9V DC		-39.1V DC		
B	±0.5V	400 mV DC	391 mV DC		409 mV DC		
B	±0.5V	-400 mV DC	-409 mV DC		-391mV DC		
B	±5V	4.00V DC	3.91V DC		4.09V DC		
B	±5V	-4.00V DC	-4.09V DC		-3.91V DC		
B	±50V	40.0V DC	39.1V DC		40.9V DC		
B	±50V	-40.0V DC	-40.9V DC		-39.1V DC		

Test 14. AC Voltage Uncertainty Test Record

(page 4-16)

Primary Channel	Range	Input Signal	Min.	Reading	Max.	Test Result	
						Pass	Fail
A	"0.5V	300 mV rms, 50 Hz	293 mV		307 mV		
A	"5V	300 mV rms, 50 Hz	0.29V		0.31V		
A	"5V	3.00V rms, 50 Hz	2.93V		3.07V		
A	"50V	10V rms, 50 Hz	9.7V		10.3V		
A	"5V	1.00V rms, 500 kHz	0.86V		1.14V		
B	"0.5V	300 mV rms, 50 Hz	293 mV		307 mV		
B	"5V	300 mV rms, 50 Hz	0.29V		0.31V		
B	"5V	3.00V rms, 50 Hz	2.93V		3.07V		
B	"50V	10.0V rms, 50 Hz	9.7V		10.3V		
B	"5V	1.00V rms, 500 kHz	0.86V		1.14V		
A	"5V	1.00V rms, 5 MHz	0.86V		1.14V		
A	"5V	1.00V rms, 20 MHz	0.75V		1.25V		
B	"5V	1.00V rms, 5 MHz	0.86V		1.14V		
B	"5V	1.00V rms, 20 MHz	0.75V		1.25V		

Test 15. Peak Voltage Uncertainty Test Record

(page 4-17)

Primary Channel	Range	Input Signal	Min.	Reading	Max.	Test Result	
						Pass	Fail
A	±5V	1.00V rms, 2 kHz	2.77V		2.89V		
B	±5V	1.00V rms, 2 kHz	2.77V		2.89V		
A	±5V	1.00V rms, 5 MHz	2.71V		2.95V		
A	±5V	1.00V rms, 20 MHz	2.50V		3.16V		
A	±5V	1.00V rms, 50 MHz	2.12V		3.59V		
B	±5V	1.00V rms, 5 MHz	2.71V		2.95V		
B	±5V	1.00V rms, 20 MHz	2.50V		3.16V		
B	±5V	1.00V rms, 50 MHz	2.12V		3.59V		

Chapter 5
Calibration Adjustment

Title Page

Introduction

Calibration adjustment is made in two steps, Closed Case Calibration and Hardware Adjustment. The Closed Case Calibration procedure is the normal calibration to be performed when you want to verify the calibration status of the instrument and compensate for aging. Hardware adjustment should only be made after repair and replacement of components, and when Closed Case Calibration fails.

Fluke 163 &164 Closed Case Calibration Procedures

These procedures allow you to perform closed case calibration and adjustment of the Timebase and Voltmeter functions of the MultiFunction Counter. The following procedures are available

- Make Timebase Adjustment
- Make Voltage Adjustment
- Undo Timebase Adjustment
- Undo Voltage Adjustment

Press [USER OPTIONS] and select [About] to check calibration adjustment date at any time.

Before beginning the calibration adjustments, connect the power adapter and power up the instrument. Leave it on for approximately 60 minutes to reach normal operating temperature.

Pressing [i] when calibrating will give additional information about the current step of the calibration and adjustment procedure.

Timebase Calibration and Adjustments

Calibration equipment

10 MHz reference frequency with at least a 4:1 test uncertainty ratio, e. g. Fluke PM 6685R, PM 6681R or 'house standards' with similar specifications.

Calibration setup

Connect the 10 MHz reference frequency to the input of the MultiFunction Counter as described on the display while running the procedure.

Procedure

The Adjustment Access Code printed on the next page must be entered before you get access to the "Make Adjustment" buttons.

1. Press [USER OPTIONS] to enter the USER OPTIONS menu.
2. Press appropriate [▲][▼][◀][▶] key to position the cursor on the [Test & Adjust] button, then press [SELECT].
3. Press appropriate [▲][▼] key to position the cursor on [Adjust Access Code], then press [SELECT]. A keypad will appear where you can enter the code.

4. Enter the access code "**62 951 413**" by positioning the cursor on a digit, then press SELECT to select it. Repeat this procedure for each digit, and finish with Enter.

5. Position the cursor on Make Timebase Adjustment, then press SELECT. Follow the instructions that appear on the display of the MultiFunction Counter (e.g. Please connect 10 MHz to input A...). A few adjustment cycles will be performed.

   An error message is displayed if the adjustment procedure fails to adjust the Timebase. This can be caused by either an erroneous reference frequency or the Timebase being outside the range of the closed case calibration adjustment.

6. Enter date of adjustment, then press EXIT to finish this procedure.

If you want to cancel the calibration you just finished, then perform steps 7 and 8.

7. Position the cursor on Undo Timebase Adjustment, then press SELECT.

8. Press ▲▼ to select the previous adjustment or the factory adjustment, then press SELECT. Follow the instructions that appear on the display of the MultiFunction Counter.

Voltage Calibration and Adjustments

Calibration equipment

The used calibration voltages are 0V, ±0.5V, ±2V, ±5V, ±20V, ±50V DC (e.g. from a Fluke 5500A Calibrator).

Calibration setup

Connect the calibration voltages to the input of the MultiFunction Counter in the sequence described on the display while running this procedure.

Procedure

The Adjustment Access Code printed below must be entered before you get access to the "Make Adjustment" buttons.

1. Press USER OPTIONS to enter the USER OPTIONS menu.

2. Press appropriate ▲▼◀▶ key to position the cursor on the Test & Adjust button, then press SELECT.

3. Press appropriate ▲▼ key to position the cursor on Adjust Access Code, then press SELECT. A keypad will appear where you can enter the code.

4. Enter the access code "**62 951 413**" by positioning the cursor on a digit, then press SELECT to select it. Repeat this procedure for each digit, and finish with Enter.

5. Position the cursor on [Make Voltage Adjustment], then press [SELECT]. Follow the instructions that appear on the display of the MultiFunction Counter (e.g. connect 0.000V DC to input A). A few adjustment cycles will be performed.
6. Enter date of adjustment, then press [EXIT] to finish this procedure.

If you want to cancel the calibration you just finished, then perform steps 7 and 8.

7. Position the cursor on [Undo Voltage Adjustment], then press [SELECT].
8. Press [▲][▼] to select the previous adjustment or the factory adjustment, then press [SELECT]. Follow the instructions that appear on the display of the MultiFunction Counter.

Hardware Adjustment

Required Test Equipment

Table 5-1. Required Test Equipment

Type	Performance	Recommended Model No
Calibrator	DC/AC	5500A
DMM	5 full digits	PM2534
Counter		PM6669, PM6685R *
Pulse Generator	50 MHz / 4ns	PM5712
Signal Generator	1300 MHz	Gigatronics 6062A
Oscilloscope	>50 MHz, 2 channels	
Passive Probe	10:1 <1.5 pF accurately adjusted	for the oscilloscope above
Feedthrough Terminations	50Ω/1W	PM9585
Power Splitter	50Ω/4W	PM9584
10 MHz Reference	1x10–9	house standard *
BNC-BNC Cables		
Plastic Screwdriver		

* An external reference frequency source is not needed if you use a PM6685R or PM6681R.

Note

If you adjust any trimmer you have to check all points under 'Hardware Adjustment'.

Preparations

1. Make sure that the space around the instrument is free from parts that might cause short circuits.
2. The recommended service position is shown in Figure 6-8. Follow the instructions given in chapter 6.
3. Connect the power adapter and power up the instrument. Leave it on for approximately 60 minutes to reach normal operating temperature before beginning the calibration adjustments.

Note

The following procedure refers to test points that are marked on the digital PCA and on the corresponding layout drawing. See page 9-8.

Note

Use Analog Ground (test point X50) as the reference point for the voltage measurements below. It is not possible to adjust these voltages. Values outside the tolerance range depend on faulty parts and must be corrected before further adjustments.

Reference Voltages

Checks

1. Connect the DMM to test point X48. Check that the voltage is +2.500 ± 0.010 V.
2. Check that the voltage at test point X49 is +5.00 ± 0.05 V.
3. Check that the voltage at test point X51 is +2.50 ± 0.15 V.
4. Check that the voltage at test point X52 is +2.500 ± 0.015 V.
5. Check that the voltage at test point X53 is +2.50 ± 0.15 V.
6. Check that the voltage at test point X54 is +2.500 ± 0.015 V.

Power Supply Voltages

Checks

1. Connect the DMM to test point X22. Check that the voltage is +5.00 ± 0.05 V.
2. Check that the voltage at test point X23 is 12.25 ± 0.25 V.
3. Check that the voltage at test point X24 is –5.5 ± 0.5 V.
4. Check that the voltage at test point X25 is –30.5 ± 1.5 V.

Crystal Oscillators

Note

The adjustment should preferably be made at an ambient temperature of +25°C.

Setup

1. Connect either a 10 MHz reference frequency source to the External Reference Input of the counter used for checking the MFC or use the PM 6685R as a stand-alone calibration instrument.
2. Connect Input A of the counter to the Pulse Output at the top of the MultiFunction Counter. Select 10 MHz output frequency by first pressing [USER OPTIONS], then selecting **Output: On** and **Output Signal: 10 MHz Reference.**

Adjustment

Standard Oscillator (Fluke 163 and Fluke 164)

Adjust C34 until the frequency is 10 MHz ± 5 Hz when the MFC is in its normal working position, i. e. before unfolding the functional parts. The frequency moves about 6 Hz from unfolded to folded position so it may be necessary to readjust once or twice.

Make a software frequency calibration afterwards and measure the filtered control signal OTRIM at test point X58 with the DMM. If the voltage is outside the range +2.5 ± 0.5 V you have to make a new hardware adjustment. This time you should bias the measured frequency outside the normal range. As a rule of thumb, set the frequency

$F_{bias} = 10^7 + 30(V_{otrim} - 2.5)$, where F_{bias} is expressed in Hz and V_{otrim} in V.

Verify by making a new software adjustment and checking the voltage at X58.

TCXO (Fluke 164T) and OCXO (Fluke 164H) oscillators

No hardware adjustments available. These oscillators are fully adjustable via the closed case "Timebase Calibration and Adjustments" procedure on page 5-3. If this fails, the oscillator is faulty and must be replaced.

Input Amplifiers

Step Response

Setup

Table 5-2. Step Response Setup

Fluke 16X MultiFunction Counter	
Function	Time Interval A to B
Input A + B	50 Ω / DC / Manual trigger levels
Voltage Range	5 V
Pulse Generator	
Amplitude	10 V
Pulse Period	1 ms / T/2 (Square Pulse)
Oscilloscope	
Time	0.1 ms/div
Vertical Setting: A	1 V/div DC
Vertical Setting: B	50 mV/div, passive probe 10:1 <1.5 pF, DC

Adjustment

Note

The adjustments should preferably be made at an ambient temperature of +25°C.

Note

It is most important that the output pulses from the pulse generator do not tilt more than 0.1% of the pulse amplitude.

1. Connect the Pulse Generator to input A of the MFC and to Input A of the oscilloscope via the power splitter. Use 50 Ω terminations at the inputs. As regards the oscilloscope it is in general preferred to use the built-in termination if available.
2. Set the attenuator to X1. Connect Input B of the oscilloscope via a probe to test point J2A. Make sure that the probe is correctly compensated.
3. Adjust C1A (with the special screwdriver) and R25A until the shape of the signal traces equal each other without overshoot or undershoot.
4. Change the attenuator setting to X10 and the oscilloscope vertical setting for Input B to 5 mV/div .
5. Adjust C4A and C6A in the same way as under point 3 above.
6. Repeat steps 1 - 5 for Input B of the MFC. Replace index A by B in the part numbers, e. g. J2A by J2B.

Zero Offset

Adjustment

1. Remove the MFC input signal and connect the DMM to J2A.
2. Adjust R24A until the DMM readout is about +5 mV. Note this value as V_A.
3. Select AC coupling and note the DMM value as V_B.
4. Adjust R24A until the DMM readout is about –5 mV. Note this value as V_C.
5. Select DC coupling and note the DMM value as V_D.
6. Calculate V_E by means of the formula $V_E = (V_C - V_B) / (V_D - V_A)$.
7. Calculate V_{offs} by means of the formula $V_{offs} = (V_B - V_A * V_E) / (1 - V_E)$.
8. Adjust R24A until the DMM readout equals $V_{offs} \pm 0.1$ mV and check that the readout does not change as the input coupling is switched between DC and AC.
9. Repeat steps 1 - 8 for Input B of the MFC. Replace index A by B in the part numbers, e. g. J2A by J2B.

Verification

Perform the relevant frequency sensitivity tests in chapter 4 (tests 11-1 and 11-2).

1.3GHz HF-Input (only 164T and 164H)

Sensitivity threshold

Setup

Connect the signal generator HF output to Input C of the MFC. Use the same external reference frequency for both instruments. Select Frequency C by pressing/selecting in turn [1234], [MEASURE FUNCTION], [Frequency (Hz)], [Frequency], [Measure Channel(s)] and [C].

Adjustment

1. Set the signal generator output level to -29.5 dBm and the frequency to 900 MHz.
2. Adjust the potentiometer R30 very gently until the MFC just starts to show the right result.

Verification

Perform the relevant frequency sensitivity tests in chapter 4 (test 11-3).

Check that the display shows no measuring result if the input signal is removed.

Voltage Calibration

Procedure

Hardware adjustments made during the procedures described above affect the voltage calibration. It is therefore absolutely necessary to perform a new software calibration according to the method given earlier in this chapter.

Verification

Perform the relevant voltage uncertainty tests in chapter 4 (tests 13, 14 and 15).

Chapter 6
Disassembling

Title	Page

Introduction

The Fluke 160 series is available in different versions. These are:

Fluke 163	MultiFunction Counter with basic functions and standard XO
Fluke 164	MultiFunction Counter with standard XO
Fluke 164T	Fluke 164 + 1.3 GHz HF input TCXO in place of std. XO
Fluke 164H	Fluke 164 + 1.3 GHz HF input OCXO in place of std. XO

Most screws used to assemble the MFC are of type M3 Torx 10.

Removing the Battery Pack

Note

The MFC will lose all settings within 50 seconds after the battery pack is removed if there is no lithium battery mounted in the instrument. To avoid this keep it connected to the line power via the power adapter, but in power off mode.

1. Turn the MFC upside down.
2. Loosen the two screws "A" holding the battery cover and remove it from the MFC. See Figure 6-1.
3. Use the black pull-strip gently to remove the battery pack.

Note

When reinstalling the rechargeable battery pack be sure that the contact tongue on the battery and the contact strip at the bottom of the battery container mate.

Note

This instrument contains a Nickel-Cadnium battery. Do not dispose of this battery with other solid waste. Used batteries should be disposed of by a qualified recycler or hazardous materials handler. Contact your authorized Fluke Service Center for recycling information.

Opening the MultiFunction Counter

Warning

Do not perform any internal service or adjustment of this instrument unless you are qualified to do so.

Warning

When you remove the covers you will expose live parts and accessible terminals which can cause death.

Warning

To avoid electric shock, disconnect test leads, probes, and power supply from any live source and from the instrument itself.

Warning

Capacitors inside the instrument can hold their charge even if the instrument has been separated from all voltage sources and the batteries have been removed.

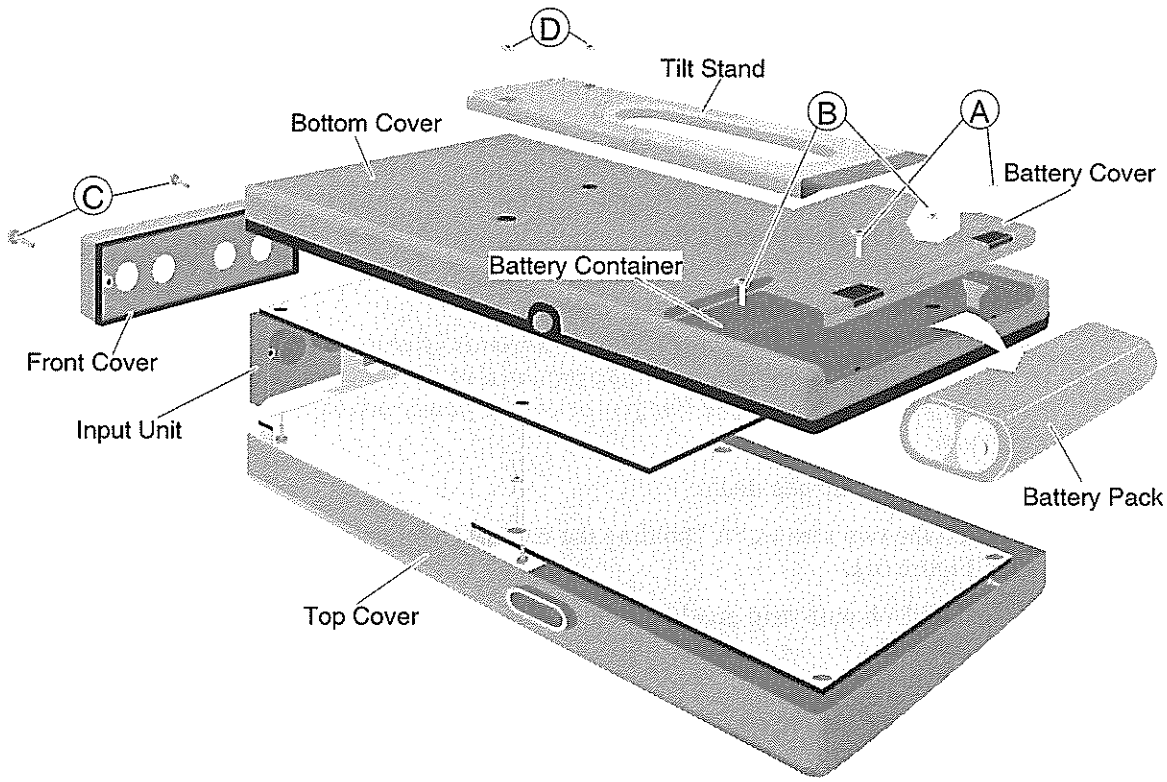


Figure 6-1. Opening of the MultiFunction Counter

1. Remove the battery pack.
2. Loosen the two screws "C" holding the front cover of the MFC.
3. Lift the front cover from the MFC.

Note

The gasket between the front cover and the two case halves is fixed to, and must remain with, the front cover. Do not damage the gasket or separate it from the front cover. A correctly fitted gasket assures proper sealing of the MultiFunction Counter.

4. Loosen the two screws "B" at the bottom of the battery container. See Figure 6-1.Lift the bottom cover from the top cover and flip over the bottom cover.

Removing the Tilt Stand

The tilt stand is fastened to the MFC with two screws and washers.

1. Loosen the screws "D" holding the tilt stand to the MFC. See Figure 6-1.

Removing the Input PCA

1. Open the MFC.
2. Loosen the three screws and spring washers "E" holding the top screening and the Input PCA to the bottom cover. See Figure 6-2.
3. Lift the metal top screening while pulling it backwards.
4. Disconnect the battery wiring plug from the battery connector of the Input PCA.
5. Lift both sides of the upper part of the flat cable connector J3.
6. Pull the flat cable out of the connector.

Note

Do not touch the flat cable ends to avoid that dirt or grease from your hands may cause contact problems!

7. Loosen the two screws "F" holding the input assembly to the bottom cover.
8. Lift the Input PCA out of the bottom cover.

Note

Be sure to put the flat cable in exactly the same position as before when reassembling the MultiFunction Counter.

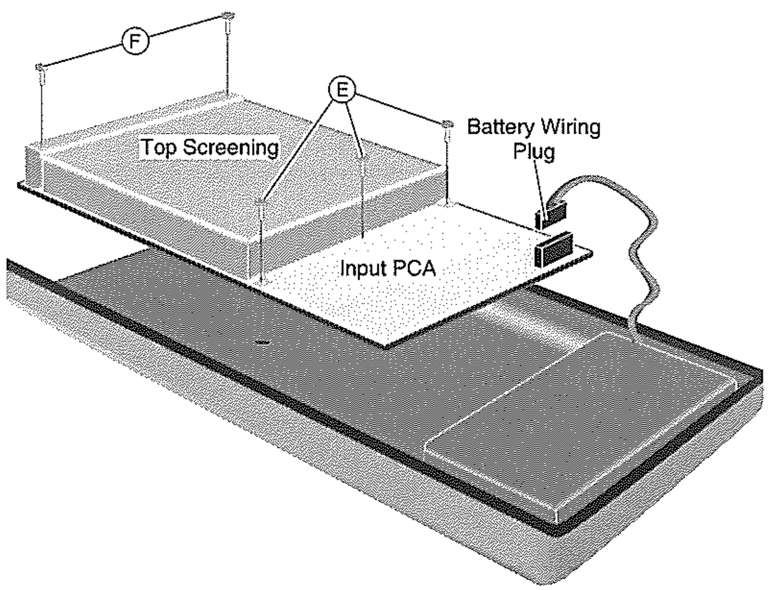


Figure 6-2. Removing the Input PCA

Removing the Display PCA

1. Open the MultiFunction Counter.
2. Lift both sides of the upper part of the flat cable connector J1.
3. Pull the flat cable out of the connector.

Note

Do not touch the flat cable ends to avoid that dirt or grease from your hands may cause contact problems!

4. Lift both sides of the upper part of the flat cable connector J2.
5. Pull the flat cable out of the connector.
6. Loosen the two screws "G" holding the top screening and the Display PCA to the bottom cover. See Figure 6-3.
7. Lift the Display PCA out of the bottom cover.

Note

Be sure to put the flat cable in exactly the same position as before when reassembling the MultiFunction Counter.

Note

Be careful not to damage the infrared LED and photo-transistor of the optical interface.

Note

When reassembling the Display PCA, make sure that the infrared LED and the photo-transistor are exactly aligned with the holes in the top cover.

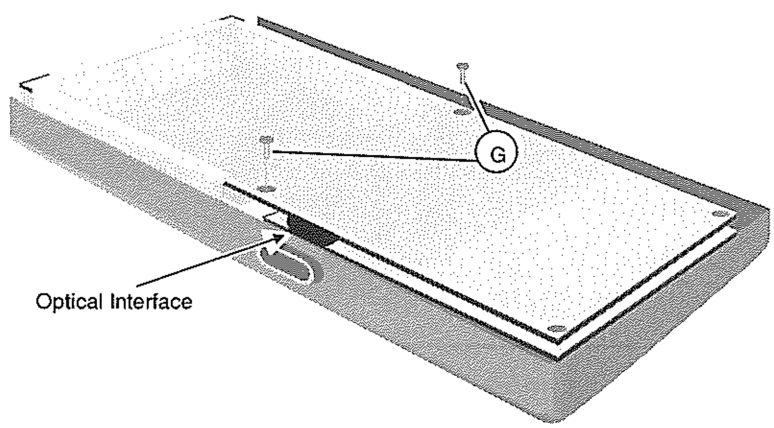


Figure 6-3. Removing the Display PCA

Removing the LCD

Note

Do not disassemble the LCD unit unless you have acquired the special skill needed to reassemble it again in a correct way. Precise alignment, extreme cleanliness and clean air environment are required for a successful result.

1. The following description is only meant to be elementary.
2. Open the MultiFunction Counter.
3. Remove the Display PCA.
4. Pull the three metal clamps from the display. Not shown in Figure 6-4.
5. The rest of the parts are disassembled in alphabetical order

Note

Do not damage the zebra strips when removing them from the display. Do not touch the contact surface of the display or the zebra strips to avoid that dirt or grease from your hands may cause contact problems.

A. LCD Frame	5322 256 10192
B. Si Rubber Connector	5322 460 11046
C. Si Rubber Connector	5322 460 11045
D. LCD	5322 135 00027
E. Dust Filter	5322 480 10121
F. Bracket	5322 402 10618
G. Backlight Assembly CCFL	5322 466 11306

Reassemble the parts in reverse alphabetical order after having prepared parts G and E in the following way:

A. Fold the reflecting foil over the CCFL and fasten it with double-coated adhesive tape to the surface of the diffuser.

E. Make sure the dust filter has the adhesive side down.

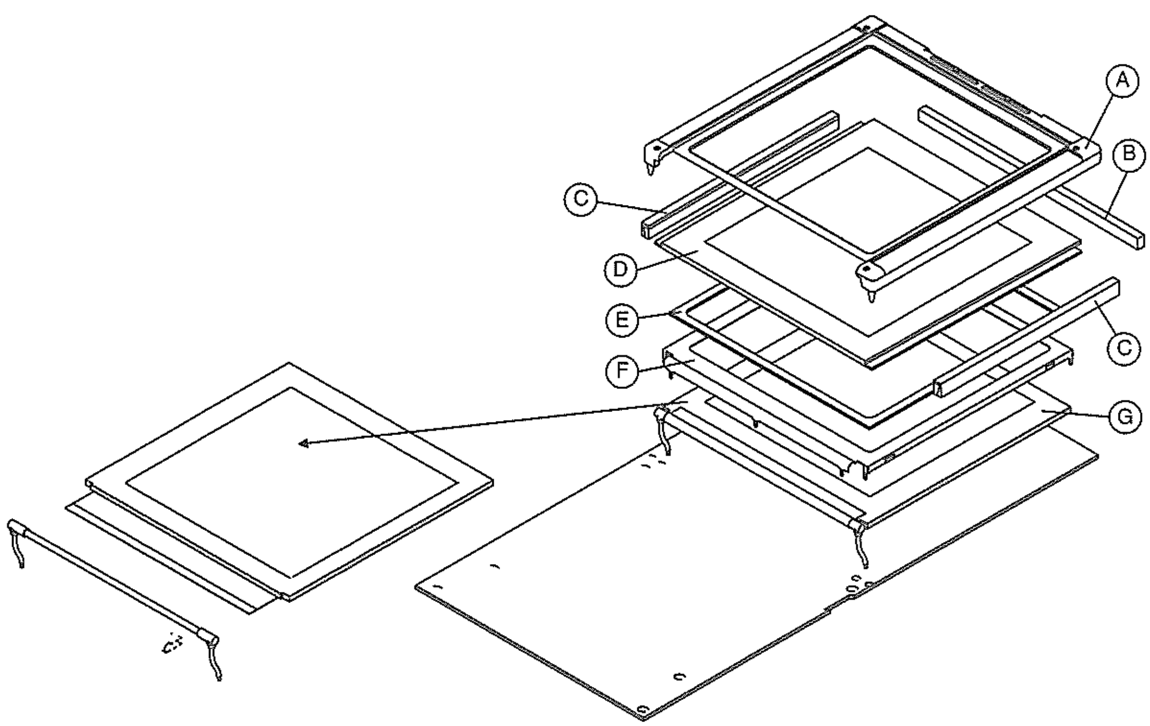


Figure 6-4. Removing the LCD

Removing the HF input

1. Open the MultiFunction Counter.
2. Remove the Input PCA according to Fig. 6-2.
3. Lift the metal top screening while pulling it backwards.
4. Press the two plastic clips apart and lift the HF-input from the guide pins. See Figure 6-5.
5. Pull the HF input backwards out of the input assembly.

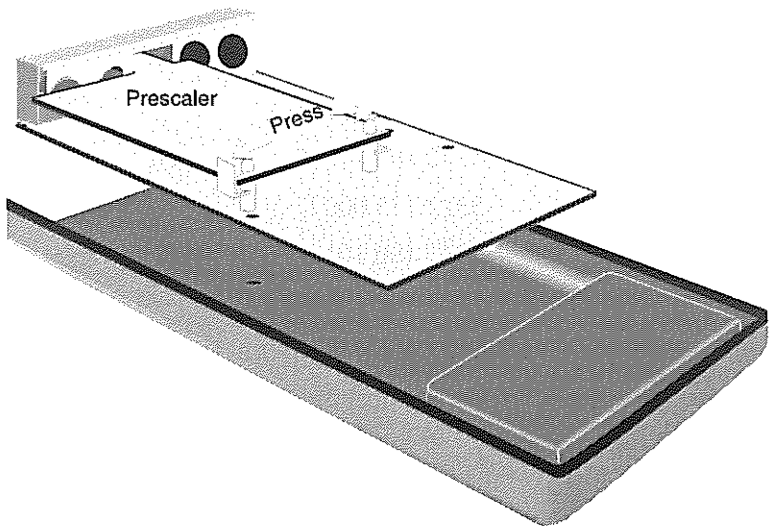


Figure 6-5. Removing the HF-input

Disassembling the keyboard

1. Open the MultiFunction Counter
2. Remove the Display PCA from the top cover according to Fig. 6-3.
3. Loosen the six screws “P” holding the keypad plate “Q” to the top cover. See Fig. 6-6.
4. Lift the keypad foil “R” and the rubber keypad “S” out of the top cover.

Note

When assembling the keyboard and a new rubber keypad is used, some keys may need to be cut out from the keypad to fit the model under service. Use a pair of scissors.

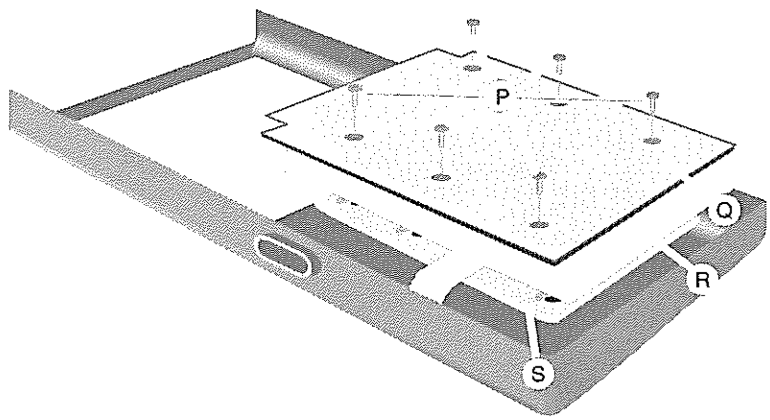


Figure 6-6. Removing the Keyboard

Replacing the BNC connectors

Note

The BNC connectors can not be removed from the Input Unit without jeopardizing the Front Frame. It is rccommended to replace the Input Unit altogether. A kit containing four BNC connectors, four gaskets, four toroid ferrite cores, one Front Frame and one Front Shield is available. See Chapter 8, Replaceable Parts.

1. Open the MultiFunction Counter.
2. Remove the Input PCA according to Fig. 6-2.
3. Lift the metal top screening while pulling it backwards.
4. Remove the HF input if it is fitted. See Fig. 6-5.
5. Unsolder the BNC connectors from the PCA.
6. Remove the old Input Unit.
7. Open the new Input Unit Kit.
8. Fit the gaskets on to the BNC connectors.
9. Press the BNC connectors into the holes in the Front Frame. See Figure 6-7.
10. Fit the Front Shield to the Front Frame.
11. Fit the toroid cores on to the back of the BNC connectors and fix each of them to the front shield with a small amount of fast-hardening glue.
12. Bend the BNC leads in right angle to fit the mounting holes in the Input PCA.
13. Mount the new assembled Input Unit on the Input PCA and solder the BNC leads to the board.
14. Assemble the MFC

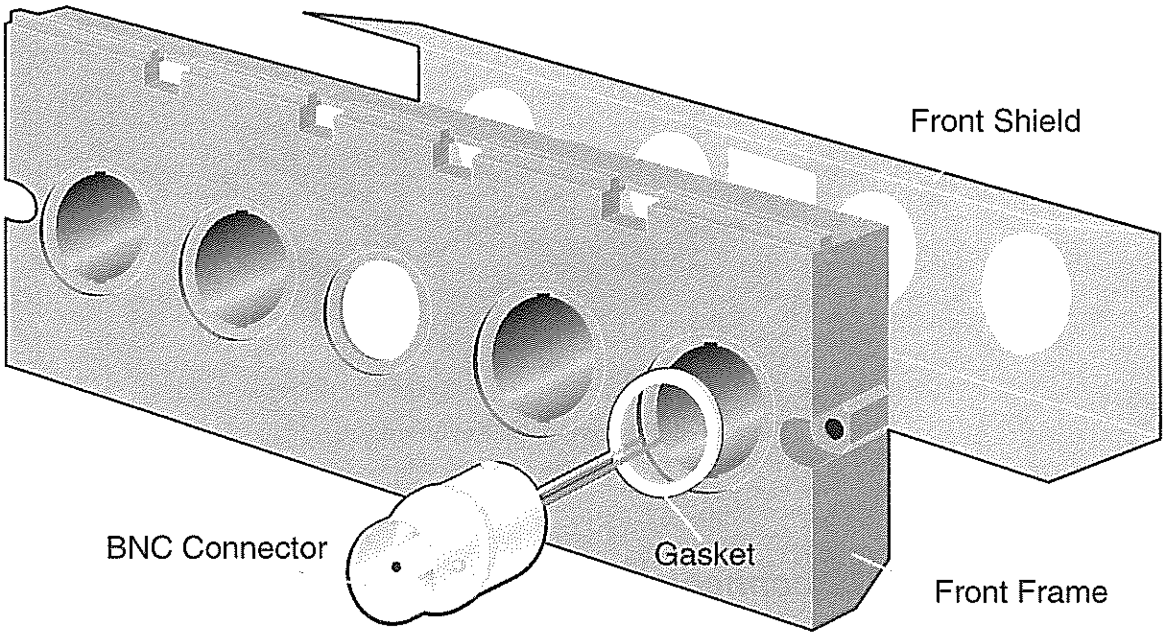


Figure 6-7. Assembling the Input Unit

Service position

By removing the Input PCA and the Display PCA from the top and bottom covers and by unfolding them as shown in Figure 6-8 it is easy to access the parts that are essential for efficient troubleshooting.

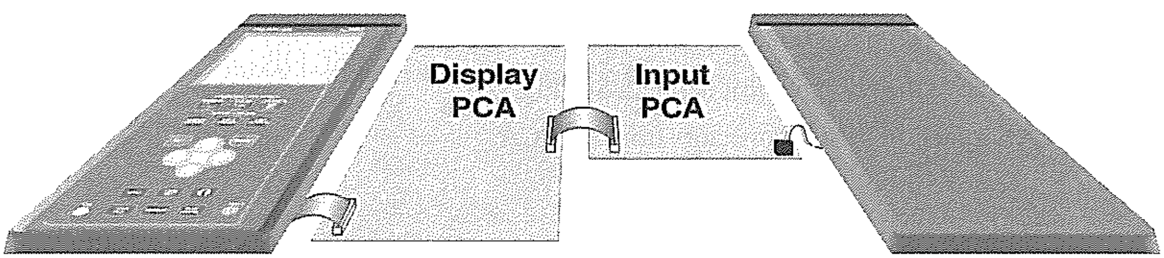


Figure 6-8. Service Position

Chapter 7
Corrective Maintenance

Introduction

This chapter contains information about faultfinding and repair. It only deals with what is not covered by traditional faultfinding/repair using diagrams and function descriptions.

Flash PROM

The firmware in the MultiFunction Counter is stored in Flash PROMs.

Checking the Flash PROM

1. Power ON the MultiFunction Counter.
2. Is the screen blank? No startup screen, nothing?
   If so, make sure the rest of the hardware is OK, then try loading the firmware. It is most likely that you must first replace the Flash PROM circuits.
3. Is the screen checkered (filled with black and white squares)?
   Load new firmware from diskette (see below).
4. Does the MultiFunction Counter start up normally?
   If so, press [USER OPTIONS] and select [Test & Adjust]

   - **Select Self Test: ROM**
   - Press [Run Self Test]

   If the test fails, load new firmware from disk.
   If the test is passed, the Flash PROM is OK.

Loading new Firmware

The disk contain both Fluke 163 and Fluke 164 firmware.

Note:

You cannot make a Fluke 163 into a Fluke 164 by loading the Fluke 164 firmware. (New firmware will be loaded, but functionality remains as Fluke 163.)

Caution:

Loading the Fluke 163 firmware into a Fluke 164 will permanently convert the instrument into a Fluke 163. You cannot reverse the process by loading the Fluke 164 firmware again, bust must replace the Flash PROM circuits, or return the unit to the factory for repair.

Caution:

NEVER EVER INTERRUPT LOADING IN PROGRESS.

If loading fails, rerun loading without interrupting the power to the MultiFunction Counter.

If you disregard these warnings, the FLASH-PROM may have to be replaced!

Required equipment

To load new firmware you need the following:

1. A PC with an unused Serial Communications port (COM 1 or COM 2) and a 1.44 MB 3 ½" diskette station.
2. A PM9080 Optical Serial Interface able.
3. A diskette (4822 872 27004) with firmware.

Preparations

1. Connect the power adapter to the MultiFunction Counter, and then to the power outlet. The MultiFunction Counter must always run on power adapter when loading firmware.
2. Connect the PM9080 between the COM port of the PC and the Serial input of the MultiFunction Counter.

Loading from DOS

1. Insert disk in disk drive
2. Type INSTALL
3. Press Enter
4. Follow instructions on the screen

Loading from Windows 3.X

Start a command(DOS) prompt and follow the DOS procedure, or:

1. Insert disk in disk drive
2. Start File Manager
3. Select Disk Drive, (for instance A:)
4. Double Click on INSTALL.BAT
5. Follow instructions on the screen

Loading from Windows 95 and NT 4.0

1. Follow the Windows 3.X procedure, or:
2. Insert disk in disk drive
3. Start Control Panel
4. Select "Install/Remove Programs"
5. Select "Install" and follow instructions on the screen

Running LDFLASH from command prompt

Advanced DOS users can also run the loader program LDFLASH.EXE directly from the command prompt without using the install program.

Type LDFLASH /? and you will see a help screen with the syntax.

Chapter 8
List of Replaceable Parts

Title **Page**

Introduction

Standard Parts

Electrical and mechanical replacement parts can be obtained through your local Fluke organization or representative. However, many of the standard components can be obtained from other local suppliers. Before purchasing or ordering replacements parts, check the parts list for value, tolerance, rating, and description.

If the value of the physical component differs from what is described in the parts list, you should always replace the part with the same value as originally mounted.

Note

Physical size and shape of a component may affect the performance of the instrument, particularly at high frequencies. Always use direct replacements unless it is known that a substitute will not degrade the performance of the instrument.

Special Parts

In addition to standard electronic components, the following special components are used:

- Components that are manufactured or selected by Fluke to meet specific performance requirements.
- Components that are important for the safety of the instrument.

Both type of components may be replaced only by components obtained through your local Fluke organization.

The above mentioned parts are 'Recommended Replacement Parts' and are marked with an 'R' in the ☆ column of the parts list.

Components marked with a 'P' in the ☆ column are 'Production items' not kept in replacement parts stock. These items can be ordered, but the delivery time is longer than for normal replacement parts.

Assemblies

Item	Description	Part Number	☆
A	Oscillator for Fluke 163 and 164 (Crystal 10MHz)	5322 242 82118	R
A	Oscillator for Fluke 164T (10MHz TCXO)	5322 242 82117	
A	Oscillator for Fluke 164H (10MHz OCXO)	5322 242 82113	P
B	Battery Assembly	PM 9086	
C	Display PCA complete with display. [1]	5322 216 04225	P
D	- Separate LCD Display 240x240	5322 135 00027	P
E	Input PCA for Fluke 163 and 164, including Input Unit	5322 214 91779	P
F	- Separate Input Unit with four safety designed BNC's	5322 693 92121	R
G	Prescaler PCA for Fluke 164T and 164H	5322 214 91781	P
H	Keyboard Flex board (Foil)	5322 466 10694	R
I	Rubber Keyboard Fluke 164	5322 414 20547	R
J	Flat Cable 30-pol Fluke 160-ser	5322 321 63028	R
	Diskette with Fluke 163/164 Firmware	5322 872 27004	P

Note

When replacing either Display PCA or Input PCA, a new software calibration adjustment must be made.

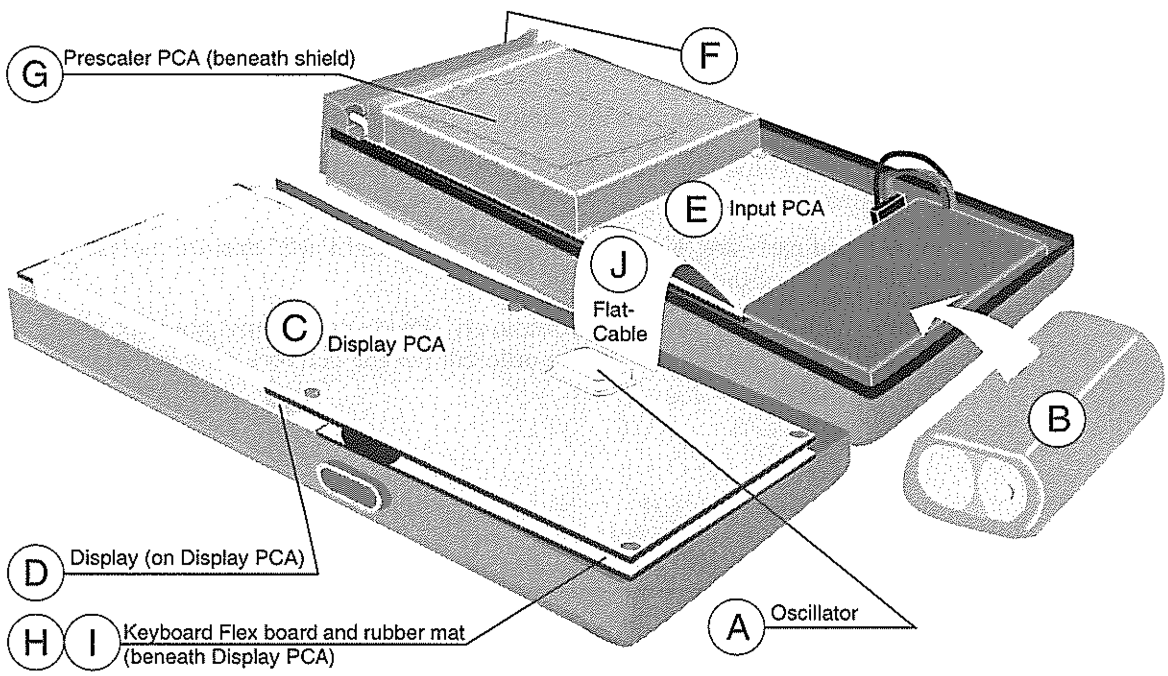


Figure 8-1. Assemblies

[1] The Display PCA replacement part is configured as 164 with standard oscillator on delivery. If you fit the PCA in a 164T or 164H, you must modify it for the TCXO(T) or OCXO(H) oscillator (components included) and transfer the oscillator from the old board. See Chapter 6.
If you fit the PCA in a Fluke 163, you must run the configuration software that is included. (Requires PC with available serial port and PM9080 optical serial interface)

Mechanical parts, all versions[2]

Item	Description	Part Number	✩
1	Top Cover Unit	5322 442 00551	R
2	Bottom Cover	5322 447 70113	
3	Front Rim Fluke 160-ser	5322 447 92377	R
4	Text Plate Kit Fluke 163	5322 455 90489	R
4	Text Plate Kit Fluke 164	5322 455 90488	R
5	Battery Cover	5322 447 70116	
6	Stand Up Assy	5322 456 90416	
7	Foot TM	5322 462 41825	
8	Rubber Keypad Fluke 164	5322 414 20547	R
9	Input Unit	5322 693 92121	R
10	Front Shield Fluke 160-ser	5322 466 30468	P
11	Gasket	5322 530 51238	R
12	Strip Anti Slip	5322 466 62045	
13	Screw MFT 3x16 St FZB TX	5322 502 21643	P
14	Screw MRT 3x12 St FZB TX	5322 502 21642	P
15	Spring Washer KBA 3.2 ST FZ DIN137	4822 530 80173	P

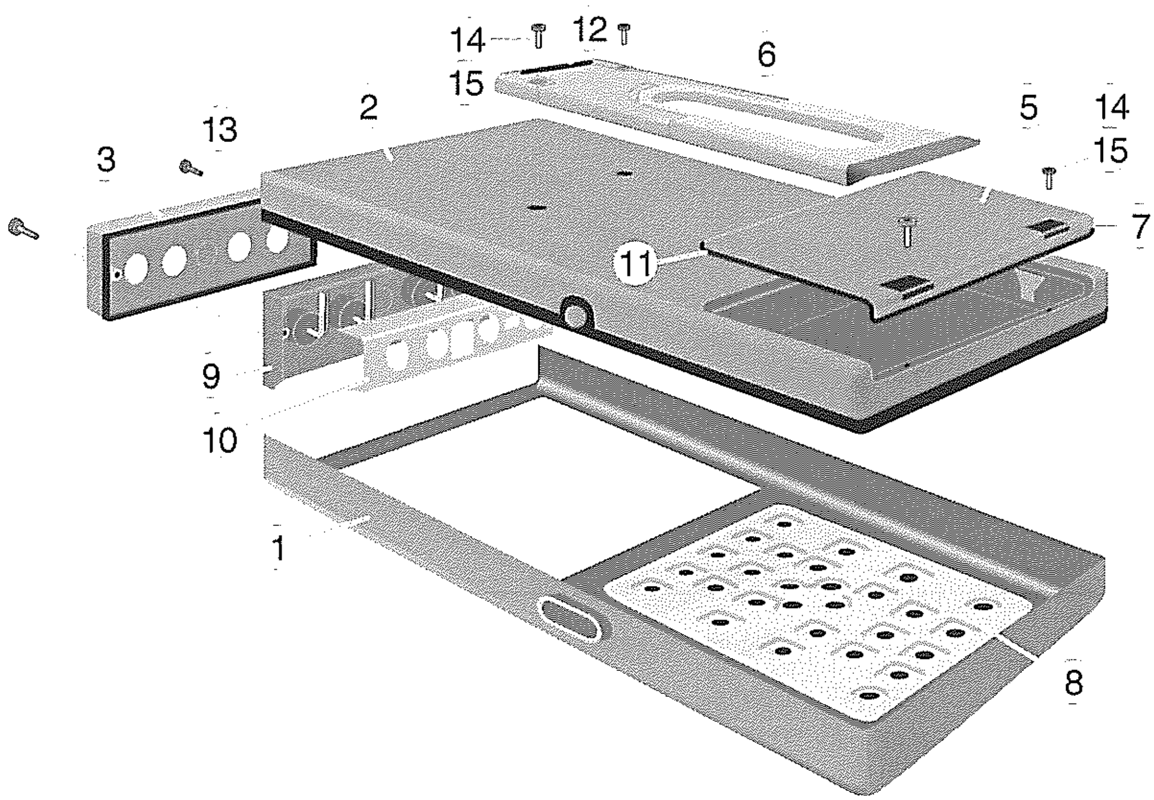


Figure 8-2. Box

Item	Description	Part Number	✩
19	Keyboard Plate Fluke 163, 164	5322 466 70792	
20	Keyboard Foil Fluke 163, 164	5322 466 10694	R

[2] See page 6-9 for replacing the BNC connectors.

Item	Description	Part Number	☆
21	Bottom Shield	5322 466 30471	
22	Top Shield	5322 466 30469	

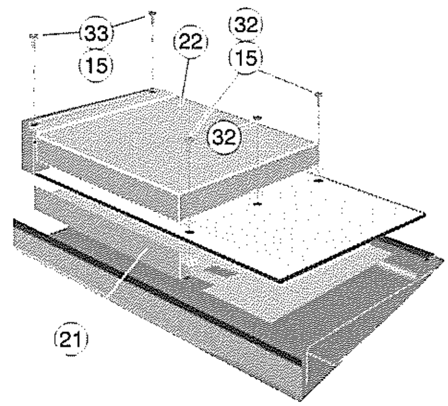


Figure 8-3. Top and bottom shield

Item	Description	Part Number	☆
23	Flat Cable 30-pol	5322 321 63028	R
24	Connector Complete.	5322 321 63029	
25	Pull Strip TM	5322 466 62046	
26	Contact Spring TM	5322 492 70908	
27	Buffer TM	5322 466 62047	
28	Contact Tag TM	5322 466 82843	
29	Contact Strip TM	5322 466 82842	
30	Insulator TM	5322 466 62648	
31	Screw MRT 3x10 St FZB TX	5322 502 21644	P

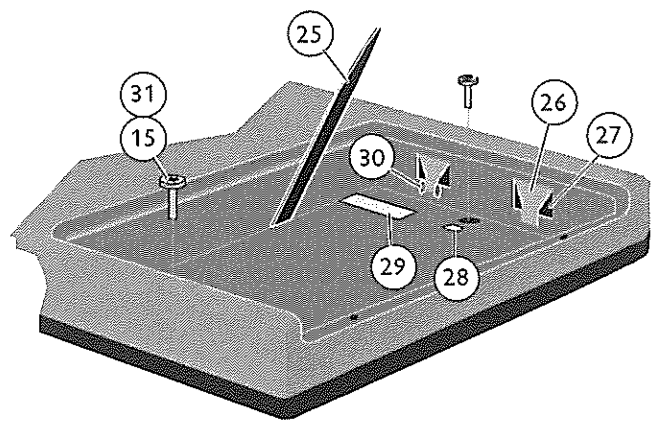


Figure 8-4. Battery compartment

Item	Description	Part Number	☆
32	Screw MRT-TT 3x06 STFZB TX	5322 502 13547	P
33	Screw MRT 3x25 STFZB TX	5322 502 21645	
34	Screw RTK St3.5x06FZB TX	5322 502 30775	P
35	Capacitor-Trim 3-10pF	5322 125 50306	R

Item	Description	Part Number	☆
36	LCD Frame TM	5322 256 10192	P
37	Clamp TM	5322 401 11411	P
38	LCD Display 240x240	5322 135 00027	P
39	Dust Filter LCD	5322 480 10121	P
40	Si-rubber Connector Type: I P=0.1	5322 460 11045	R
41	Si-rubber Connector Type: sec P=0.05	5322 460 11046	R
42	Backlight Assy CCFL	5322 466 11306	R
43	Bracket	5322 402 10618	P

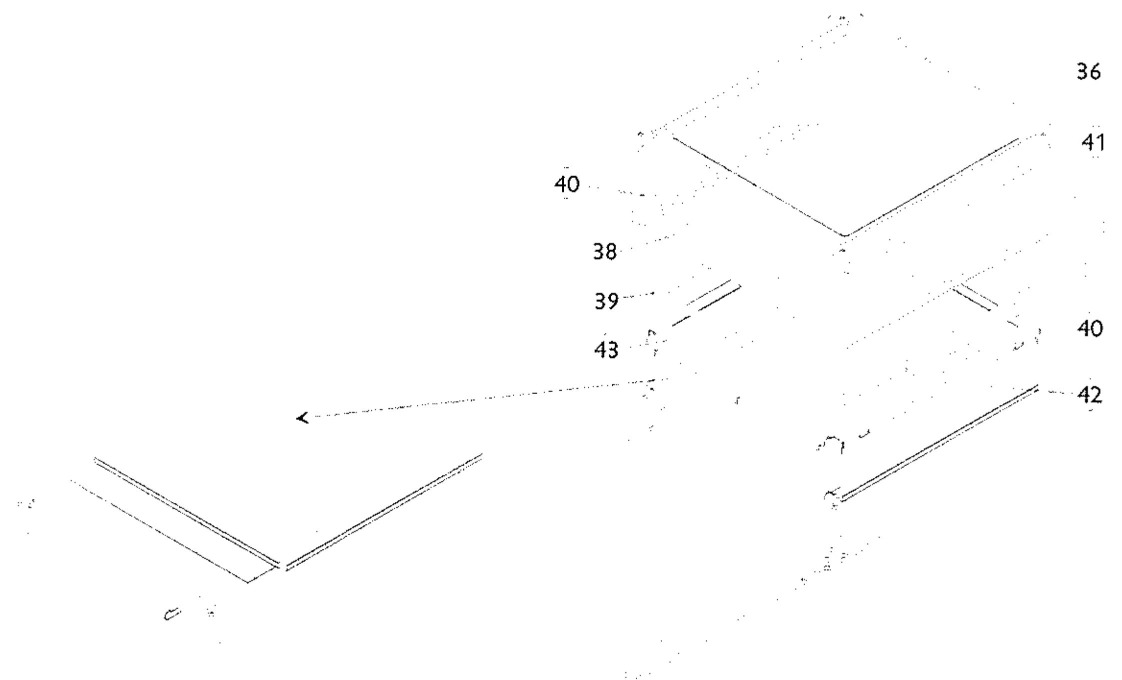


Figure 8-5. Parts for assembling the display

Item	Description	Part Number	☆
44	Sealing Ring 9x7x1 Si	5322 466 62647	R
45	Guide Piece, Optical Interface	5322 405 91772	
46	Guide Piece, Power inlet	5322 405 91784	

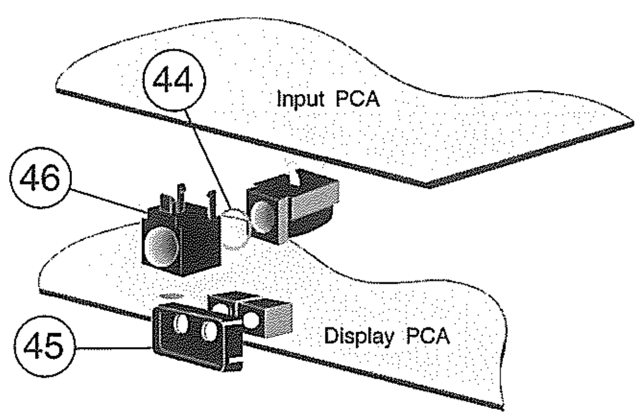


Figure 8-6. Seals for optical interface and power inlet

Item	Description	Part Number	☆
48	Screw RX-PT Z 4-20x6 FZB	5322 502 21646	
50	Stand Off TEHCBS-6-6-19	5322 256 92318	
51	O-ring 10.1x1.6 Black 70_SH A NBR 6370001	5322 466 62646	
52	HF Input Screen (on prescaler, only 164T and 164 H)	5322 466 30474	

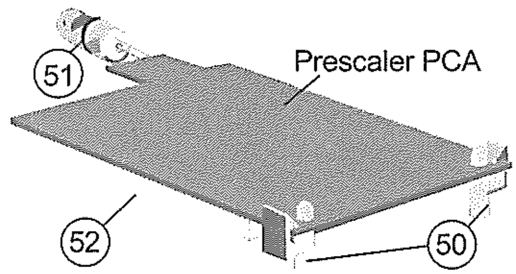


Figure 8-7. Prescaler assembly (Only 164T and 164H)

53	Input Screen Top	5322 466 30472
54	Input Screen Bottom	5322 466 30473

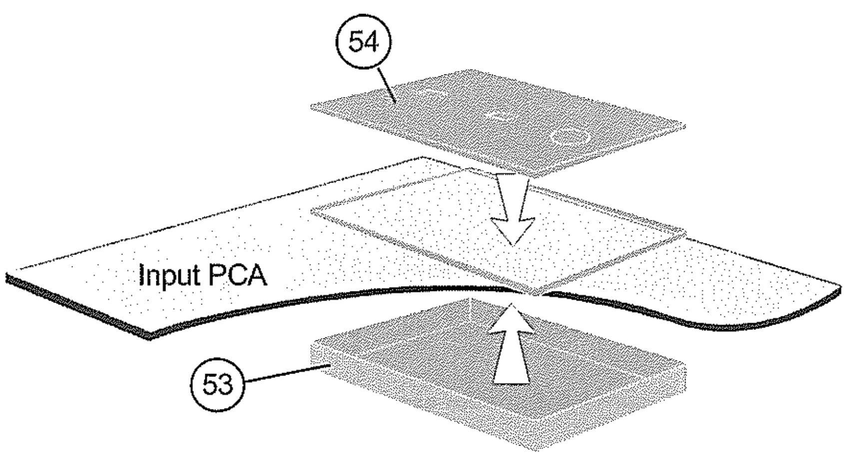


Figure 8-8. Input amplifier screens

Display PCA, Fluke 163, 164

Item	Description	Ordering code	☆
0	PC-Board Assy Interpolator Fluke 160	5322 216 04224	P
0	Status Label 25.4x12.7 Polyimide	5322 454 13144	P
2	Status Label 25.4x12.7 Polyimide	5322 454 13144	P
3	Led Holder 3mm(2x) AST 0035.9611	5322 255 41213	
B1	Crystal 16.000MHz SMD SCM-309	5322 242 82111	R
B3	Crystal 10MHz HC-49U/13 (not fitted on 164T and H)	5322 242 82118	R
C1	Capacitor 22pF 5% 50V NP00805	5322 122 32658	
C2	Capacitor 22pF 5% 50V NP00805	5322 122 32658	
C3	Capacitor 100nF 20% 25V X7R0805	5322 126 13638	
C4	Capacitor 2.20 µF 20%6.3V 3.2x1.6	5322 124 10685	
C5	Capacitor 100nF 20% 25V X7R0805	5322 126 13638	
C6	Capacitor 10nF 20% 50V X7R0805	5322 122 34098	
C7	Capacitor 10nF 20% 50V X7R0805	5322 122 34098	
C8	Capacitor 100nF 20% 25V X7R0805	5322 126 13638	
C10	Capacitor 100nF 20% 25V X7R0805	5322 126 13638	
C11	Capacitor 10nF 20% 50V X7R0805	5322 122 34098	
C12	Capacitor 10nF 20% 50V X7R0805	5322 122 34098	
C13	Capacitor 10nF 20% 50V X7R0805	5322 122 34098	
C14	Capacitor 100nF 20% 25V X7R0805	5322 126 13638	
C15	Capacitor 10nF 20% 50V X7R0805	5322 122 34098	
C16	Capacitor 2.20 µF 20%6.3V 3.2x1.6	5322 124 10685	
C17	Capacitor 82pF 5% 50V NP00805	4822 122 33515	
C18	Capacitor 2.20 µF 20%6.3V 3.2x1.6	5322 124 10685	
C27	Capacitor 10nF 20% 50V X7R0805	5322 122 34098	
C31	Capacitor 82pF 5% 50V NP00805	4822 122 33515	
C32	Capacitor 15pF 5% 50V NP00805	5322 122 33869	
C33	Capacitor 10pF 5% 50V NP00805	5322 122 32448	
C34	Capacitor-Trim 3-10pF (not fitted on 164T and H)	5322 125 50306	R
C35	Capacitor 82pF 5% 50V NP00805	4822 122 33515	
C42	Capacitor 220pF 5% 50V NP00805	4822 122 33575	
C43	Capacitor 100nF 20% 25V X7R0805	5322 126 13638	
C44	Capacitor 100nF 20% 25V X7R0805	5322 126 13638	
C47	Capacitor 100nF 20% 25V X7R0805	5322 126 13638	
C48	Capacitor 100nF 20% 25V X7R0805	5322 126 13638	
C49	Capacitor 100nF 20% 25V X7R0805	5322 126 13638	
C50	Capacitor 100nF 20% 25V X7R0805	5322 126 13638	
C51	Capacitor 100nF 20% 25V X7R0805	5322 126 13638	
C52	Capacitor 100nF 20% 25V X7R0805	5322 126 13638	
C53	Capacitor 100nF 20% 25V X7R0805	5322 126 13638	
C54	Capacitor 100nF 20% 25V X7R0805	5322 126 13638	
C55	Capacitor 10nF 20% 50V X7R0805	5322 122 34098	
C56	Capacitor 6.80 µF 20% 16v 6.0x3.2	5322 124 10687	R
C57	Capacitor 100nF 20% 25V X7R0805	5322 126 13638	

Item	Description	Ordering code	☆
C58	Capacitor 2.20 µF 20%6.3V 3.2x1.6	5322 124 10685	
C59	Capacitor 10nF 20% 50V X7R0805	5322 122 34098	
C60	Capacitor 15 µF 20%6.3V 6.0x3.2	5322 124 11418	
C61	Capacitor 100nF 20% 25V X7R0805	5322 126 13638	
C63	Capacitor 10nF 20% 50V X7R0805	5322 122 34098	
C64	Capacitor 10nF 20% 50V X7R0805	5322 122 34098	
C68	Capacitor 10nF 20% 50V X7R0805	5322 122 34098	
C69	Capacitor 100nF 20% 25V X7R0805	5322 126 13638	
C70	Capacitor 10nF 20% 50V X7R0805	5322 122 34098	
C71	Capacitor 10nF 20% 50V X7R0805	5322 122 34098	
C72	Capacitor 100nF 20% 25V X7R0805	5322 126 13638	
C74	Capacitor 2.20µF 20%6.3V 3.2x1.6	5322 124 10685	
C75	Capacitor 100nF 20% 25V X7R0805	5322 126 13638	
C76	Capacitor 2.20 µF 20%6.3V 3.2x1.6	5322 124 10685	
C77	Capacitor 100nF 20% 25V X7R0805	5322 126 13638	
C78	Capacitor 100nF 20% 25V X7R0805	5322 126 13638	
C79	Capacitor 100nF 20% 25V X7R0805	5322 126 13638	
C80	Capacitor 100nF 20% 25V X7R0805	5322 126 13638	
C81	Capacitor 100nF 20% 25V X7R0805	5322 126 13638	
C82	Capacitor 10nF 20% 50V X7R0805	5322 122 34098	
C83	Capacitor 10nF 20% 50V X7R0805	5322 122 34098	
C84	Capacitor 2.20 µF 20%6.3V 3.2x1.6	5322 124 10685	
C86	Capacitor 100nF 20% 25V X7R0805	5322 126 13638	
C87	Capacitor 10nF 20% 50V X7R0805	5322 122 34098	
C88	Capacitor 10nF 20% 50V X7R0805	5322 122 34098	
C89	Capacitor 10nF 20% 50V X7R0805	5322 122 34098	
C90	Capacitor 100nF 20% 25V X7R0805	5322 126 13638	
C91	Capacitor 100nF 20% 25V X7R0805	5322 126 13638	
C92	Capacitor 10nF 20% 50V X7R0805	5322 122 34098	
C93	Capacitor 10nF 20% 50V X7R0805	5322 122 34098	
C94	Capacitor 10nF 20% 50V X7R0805	5322 122 34098	
C95	Capacitor 10nF 20% 50V X7R0805	5322 122 34098	
C96	Capacitor 10nF 20% 50V X7R0805	5322 122 34098	
C97	Capacitor 10nF 20% 50V X7R0805	5322 122 34098	
C98	Capacitor 10nF 20% 50V X7R0805	5322 122 34098	
C99	Capacitor 10nF 20% 50V X7R0805	5322 122 34098	
C100	Capacitor 10nF 20% 50V X7R0805	5322 122 34098	
C101	Capacitor 2.20 µF 20% 6.3V 3.2x1.6	5322 124 10685	
C102	Capacitor 10nF 20% 50V X7R0805	5322 122 34098	
C103	Capacitor 10nF 20% 50V X7R0805	5322 122 34098	
C104	Capacitor 10nF 20% 50V X7R0805	5322 122 34098	
C105	Capacitor 10nF 20% 50V X7R0805	5322 122 34098	
C106	Capacitor 10nF 20% 50V X7R0805	5322 122 34098	
C107	Capacitor 10nF 20% 50V X7R0805	5322 122 34098	
C108	Capacitor 10nF 20% 50V X7R0805	5322 122 34098	

Item	Description	Ordering code	☆
C109	Capacitor 10nF 20% 50V X7R0805	5322 122 34098	
C112	Capacitor 100nF 20% 25V X7R0805	5322 126 13638	
C113	Capacitor 100nF 20% 25V X7R0805	5322 126 13638	
C114	Capacitor 100nF 20% 25V X7R0805	5322 126 13638	
C115	Capacitor 82pF 5% 50V NP00805	4822 122 33515	
C116	Capacitor 82pF 5% 50V NP00805	4822 122 33515	
C117	Capacitor 100nF 20% 25V X7R0805	5322 126 13638	
C118	Capacitor 100nF 20% 25V X7R0805	5322 126 13638	
C119	Capacitor 100nF 20% 25V X7R0805	5322 126 13638	
C120	Capacitor 100nF 20% 25V X7R0805	5322 126 13638	
C121	Capacitor 100nF 20% 25V X7R 0805	5322 126 13638	
C122	Capacitor 6.80 µF 20% 16v 6.0x3.2	5322 124 10687	R
C123	Capacitor 2.20 µF 20%6.3V 3.2x1.6	5322 124 10685	
C124	Capacitor 10nF 20% 50V X7R0805	5322 122 34098	
C125	Capacitor 100nF 20% 25V X7R0805	5322 126 13638	
C126	Capacitor 100nF 20% 25V X7R0805	5322 126 13638	
C127	Capacitor 100nF 20% 25V X7R0805	5322 126 13638	
C128	Capacitor 2.20 µF 20%6.3V 3.2x1.6	5322 124 10685	
C132	Capacitor 2.20 µF 20% 35V 6.0x3.2	5322 124 11465	
C133	Capacitor 5.6pF "0.5pF 63V NP0 0805	5322 122 32967	
C135	Capacitor 5.6pF "0.5pF 63V NP00805	5322 122 32967	
C137	Capacitor 100nF 20% 25V X7R0805	5322 126 13638	
C138	Capacitor 100nF 20% 25V X7R0805	5322 126 13638	
C139	Capacitor 100nF 20% 25V X7R0805	5322 126 13638	
C140	Capacitor 100nF 20% 25V X7R0805	5322 126 13638	
C141	Capacitor 100nF 20% 25V X7R0805	5322 126 13638	
C142	Capacitor 100nF 20% 25V X7R0805	5322 126 13638	
C143	Capacitor 100nF 20% 25V X7R0805	5322 126 13638	
C144	Capacitor 100nF 20% 25V X7R0805	5322 126 13638	
C145	Capacitor 100nF 20% 25V X7R0805	5322 126 13638	
C146	Capacitor 100nF 20% 25V X7R0805	5322 126 13638	
C147	Capacitor 100nF 20% 25V X7R0805	5322 126 13638	
C148	Capacitor 100nF 20% 25V X7R0805	5322 126 13638	
C149	Capacitor 100nF 20% 25V X7R0805	5322 126 13638	
C150	Capacitor 2.20 µF 20%6.3V 3.2x1.6	5322 124 10685	
C151	Capacitor 1nF 5% 50V NP00805	5322 126 10511	
C152	Capacitor 1nF 5% 50V NP00805	5322 126 10511	
C153	Capacitor 1nF 5% 50V NP00805	5322 126 10511	
C154	Capacitor 1nF 5% 50V NP00805	5322 126 10511	
C157	Capacitor 2.20 µF 20%6.3V 3.2x1.6	5322 124 10685	
C158	Capacitor 100nF 20% 25V X7R0805	5322 126 13638	
C163	Capacitor 10nF 20% 50V X7R0805	5322 122 34098	
C164	Capacitor 10nF 20% 50V X7R0805	5322 122 34098	
C165	Capacitor 10nF 20% 50V X7R0805	5322 122 34098	
C166	Capacitor 10nF 20% 50V X7R0805	5322 122 34098	

Item	Description	Ordering code	☆
C167	Capacitor 10nF 20% 50V X7R0805	5322 122 34098	
C169	Capacitor 10nF 20% 50V X7R0805	5322 122 34098	
C170	Capacitor 10nF 20% 50V X7R0805	5322 122 34098	
C171	Capacitor 10nF 20% 50V X7R0805	5322 122 34098	
C172	Capacitor 10nF 20% 50V X7R0805	5322 122 34098	
C173	Capacitor 100nF 20% 25V X7R0805	5322 126 13638	
C174	Capacitor 100nF 20% 25V X7R0805	5322 126 13638	
C175	Capacitor 1 µF 20% 16v 3.2x1.6	5322 124 10686	
C176	Capacitor SMD 150nF 10% 25V 2220	5322 123 14013	
C177	Capacitor 2.20 µF 20% 35V 6.0x3.2	5322 124 11465	
C178	Capacitor 1nF 5% 50V NP00805	5322 126 10511	
C179	Capacitor 2.20 µF 20%6.3V 3.2x1.6	5322 124 10685	
C180	Capacitor 27pF 3kV SMD	5322 126 14052	
D1	Diode-Sch 0.2A BAT54s SOT23 SMD	4822 130 82262	
D2	Diode 0.10A BAV99SOT23	5322 130 34337	
D3	Diode BBY31SOT23	5322 130 34689	
D4	Diode-Sch 0.2A BAT54s SOT23 SMD	4822 130 82262	
D5	Diode-Sch 0.2A BAT54s SOT23 SMD	4822 130 82262	
D6	Diode-Sch 0.2A BAT54s SOT23 SMD	4822 130 82262	
D7	Diode-Sch 0.2A BAT54s SOT23 SMD	4822 130 82262	
D12	Diode 0.10A BAV99SOT23	5322 130 34337	
D14	Diode 0.10A BAV99SOT23	5322 130 34337	
D15	Diode 0.25A BAS2875VSOT143	5322 130 80214	
D28	LED 3mm SFH409-2 IR 950NM	5322 130 61296	
D29	Diode 0.10A BAV99SOT23	5322 130 34337	
D35	Diode-Sch 0.2A BAT54s SOT23 SMD	4822 130 82262	
D37	Diode 0.35 Ω BZX84-C4V7 SOT23	5322 130 31937	
D38	Diode 0.25A BAS2875VSOT143	5322 130 80214	
D40	Diode 0.10A BAV99SOT23	5322 130 34337	
D41	Diode 0.10A BAV99SOT23	5322 130 34337	
D42	Diode 0.35 Ω BZX84-C3V6 SOT23	5322 130 32731	
D43	Diode-Sch 0.2A BAT54s SOT23 SMD	4822 130 82262	
D44	Diode-Sch 1A 30V BYG90-30 SOT106a	5322 130 10681	
J1	Connector Socket 30 Pole 52030-3010	4822 267 51143	
J2	Connector Socket 14 Pole 52207-1490	5322 267 51467	
L1	Choke-CCFL CTX100-4 Parallel 99.23µH "20%	5322 146 10406	
L5	Choke 31 Ω CB50-321611T	5322 157 61919	
L6	Choke 31 Ω CB50-321611T	5322 157 61919	
L7	Choke 31 Ω CB50-321611T	5322 157 61919	
L8	Choke 31 Ω CB50-321611T	5322 157 61919	
L9	Choke 31 Ω CB50-321611T	5322 157 61919	
L12	Choke 31 Ω CB50-321611T	5322 157 61919	
R2	Resistor 15.0kΩ 1% 1/8W 100ppm	5322 116 82261	
R8	Resistor 1.00kΩ 1% 1/8W 100ppm	4822 051 51002	
R9	Resistor 39 Ω 1% 1/8W 100ppm	5322 116 82263	

Item	Description	Ordering code	☆
R15	Resistor 100kΩ 1% 1/8W 100ppm	4822 051 51004	
R16	Resistor 100kΩ 1% 1/8W 100ppm	4822 051 51004	
R17	Resistor 100kΩ 1% 1/8W 100ppm	4822 051 51004	
R18	Resistor 100kΩ 1% 1/8W 100ppm	4822 051 51004	
R21	Resistor 100kΩ 1% 1/8W 100ppm	4822 051 51004	
R22	Resistor 100kΩ 1% 1/8W 100ppm	4822 051 51004	
R24	Resistor 100kΩ 1% 1/8W 100ppm	4822 051 51004	
R25	Resistor 5.60kΩ 1% 1/8W 100ppm	4822 051 10562	
R34	Resistor 10.0kΩ 1% 1/8W 100ppm	4822 051 51003	
R35	Resistor 100kΩ1% 1/8W 100ppm	4822 051 51004	
R36	Resistor 10.0kΩ 1% 1/8W 100ppm	4822 051 51003	
R38	Resistor 100kΩ 1% 1/8W 100ppm	4822 051 51004	
R39	Resistor 470 Ω 1% 1/8W 100ppm	4822 051 54701	
R42	Resistor 100kΩ 1% 1/8W 100ppm	4822 051 51004	
R45	Resistor 100 Ω 1% 1/8W 100ppm	4822 051 51001	
R47	Resistor 100 Ω 1% 1/8W 100ppm	4822 051 51001	
R53	Resistor 470 kΩ 1% 1/8W 100ppm	5322 116 80447	
R54	Resistor 470 kΩ 1% 1/8W 100ppm	5322 116 80447	
R55	Resistor 470 kΩ 1% 1/8W 100ppm	5322 116 80447	
R56	Resistor 470 kΩ 1% 1/8W 100ppm	5322 116 80447	
R57	Resistor 5.60kΩ 1% 1/8W 100ppm	4822 051 10562	
R58	Resistor 390 Ω 1% 0.1W 100ppm	5322 117 12508	
R59	Resistor 4.70kΩ 1% 1/8W 100ppm	4822 051 54702	
R60	Resistor 27.0kΩ 1% 1/8W 100ppm	4822 051 52703	
R61	Resistor 15.0kΩ 1% 1/8W 100ppm	5322 116 82261	
R62	Resistor 33.0kΩ 1% 1/8W 100ppm	4822 051 53303	
R63	Resistor 470 kΩ 1% 1/8W 100ppm	5322 116 80447	
R64	Resistor 470 kΩ 1% 1/8W 100ppm	5322 116 80447	
R65	Resistor 2.70kΩ 1% 1/8W 100ppm	4822 051 52702	
R66	Resistor 3.90kΩ 1% 1/8W 100ppm	4822 051 53902	
R67	Resistor 680 kΩ 1% 1/8W 100ppm	5322 117 11787	
R68	Resistor 15.0kΩ 1% 1/8W 100ppm	5322 116 82261	
R69	Resistor 220.0Ω 1% 1/8W 100ppm	4822 051 52201	
R70	Resistor 180 kΩ 1% 1/8W 100ppm	4822 051 51804	
R71	Resistor 27.0kΩ 1% 1/8W 100ppm	4822 051 52703	
R72	Resistor 5.60kΩ 1% 1/8W 100ppm	4822 051 10562	
R73	Resistor 4.70kΩ 1% 1/8W 100ppm	4822 051 54702	
R74	Resistor 390 Ω 1% 0.1W 100ppm	5322 117 12508	
R75	Resistor 33.0kΩ 1% 1/8W 100ppm	4822 051 53303	
R76	Resistor 15.0kΩ 1% 1/8W 100ppm	5322 116 82261	
R77	Resistor 470 kΩ 1% 1/8W 100ppm	5322 116 80447	
R78	Resistor 470 kΩ 1% 1/8W 100ppm	5322 116 80447	
R79	Resistor 2.70kΩ 1% 1/8W 100ppm	4822 051 52702	
R80	Resistor 3.90kΩ 1% 1/8W 100ppm	4822 051 53902	
R81	Resistor 680 kΩ 1% 1/8W 100ppm	5322 117 11787	

Item	Description	Ordering code	☆
R82	Resistor 15.0kΩ 1% 1/8W 100ppm	5322 116 82261	
R83	Resistor 220.0Ω 1% 1/8W 100ppm	4822 051 52201	
R84	Resistor 180 kΩ 1% 1/8W 100ppm	4822 051 51804	
R85	Resistor 2.20kΩ 1% 1/8W 100ppm	4822 051 52202	
R86	Resistor 2.20kΩ1% 1/8W 100ppm	4822 051 52202	
R87	Resistor 2.20kΩ 1% 1/8W 100ppm	4822 051 52202	
R88	Resistor 2.20kΩ 1% 1/8W 100ppm	4822 051 52202	
R89	Resistor 470 kΩ 1% 1/8W 100ppm	5322 116 80447	
R90	Resistor 100kΩ 1% 1/8W 100ppm	4822 051 51004	
R91	Resistor 1.00kΩ 1% 1/8W 100ppm	4822 051 51002	
R92	Resistor 10.0kΩ 1% 1/8W 100ppm	4822 051 51003	
R93	Resistor 270 Ω 1% 1/8W 100ppm	4822 051 10271	
R98	Resistor 39 Ω 1% 1/8W 100ppm	5322 116 82263	
R100	Resistor 5.60kΩ 1% 1/8W 100ppm	4822 051 10562	
R101	Resistor 5.60kΩ 1% 1/8W 100ppm	4822 051 10562	
R102	Resistor 5.60kΩ 1% 1/8W 100ppm	4822 051 10562	
R103	Resistor 5.60kΩ 1% 1/8W 100ppm	4822 051 10562	
R104	Resistor 68.0kΩ 1% 1/8W 100ppm	4822 051 56803	
R105	Resistor 10.0 Ω 1% 1/8W 100ppm	4822 051 10109	
R106	Resistor 10.0 Ω 1% 1/8W 100ppm	4822 051 10109	
R107	Resistor 33 Ω 1% 0.1W 100ppm	5322 117 12504	
R108	Resistor 33 Ω 1% 0.1W 100ppm	5322 117 12504	
R109	Resistor 33 Ω 1% 0.1W 100ppm	5322 117 12504	
R110	Resistor 33 Ω 1% 0.1W 100ppm	5322 117 12504	
R111	Resistor 47 Ω 1% 0.1W 100ppm	5322 117 12505	
R112	Resistor 100kΩ 1% 1/8W 100ppm	4822 051 51004	
R113	Resistor 2.20kΩ 1% 1/8W 100ppm	4822 051 52202	
R114	Resistor 0 Ω Jumper RC-01	4822 051 10008	
R115	Resistor 22.0kΩ 1% 1/8W 100ppm	4822 051 52203	
R116	Resistor 15.0kΩ 1% 1/8W 100ppm	5322 116 82261	
R117	Resistor 100kΩ 1% 1/8W 100ppm	4822 051 51004	
R118	Resistor 10.0kΩ 1% 1/8W 100ppm	4822 051 51003	
R119	Resistor 10.0kΩ 1% 1/8W 100ppm	4822 051 51003	
R120	Resistor 2.70kΩ 1% 1/8W 100ppm	4822 051 52702	
R122	Resistor 33.0kΩ 1% 1/8W 100ppm	4822 051 53303	
R123	Resistor 10.0kΩ 1% 1/8W 100ppm	4822 051 51003	
R124	Resistor 2.20kΩ 1% 1/8W 100ppm	4822 051 52202	
R125	Resistor 33.0kΩ 1% 1/8W 100ppm	4822 051 53303	
R126	Sensor-Temp KTY82/120	5322 130 10682	
R132	Resistor 47 Ω 1% 0.1W 100ppm	5322 117 12505	
R133	Resistor 120 Ω 1% 0.1W 100ppm	5322 117 12506	
R134	Resistor 390 Ω 1% 0.1W 100ppm	5322 117 12508	
R135	Resistor 390 Ω 1% 0.1W 100ppm	5322 117 12508	
R136	Resistor 47 Ω 1% 0.1W 100ppm	5322 117 12505	
R137	Resistor 47 Ω 1% 0.1W 100ppm	5322 117 12505	

Item	Description	Ordering code	☆
R138	Resistor 22 Ω 1% 0.1W 100ppm	5322 117 12507	
R139	Resistor 100kΩ 1% 1/8W 100ppm	4822 051 51004	
R140	Resistor 33.0kΩ 1% 1/8W 100ppm	4822 051 53303	
R141	Resistor 10.0kΩ 1% 1/8W 100ppm	4822 051 51003	
R142	Resistor 10.0kΩ 1% 1/8W 100ppm	4822 051 51003	
R143	Resistor 220.0Ω 1% 1/8W 100ppm	4822 051 52201	
R144	Resistor 220.0Ω 1% 1/8W 100ppm	4822 051 52201	
R145	Resistor 47 Ω 1% 0.1W 100ppm	5322 117 12505	
R146	Resistor 120 Ω 1% 0.1W 100ppm	5322 117 12506	
R147	Resistor 390 Ω 1% 0.1W 100ppm	5322 117 12508	
R148	Resistor 390 Ω 1% 0.1W 100ppm	5322 117 12508	
R149	Resistor 47 Ω 1% 0.1W 100ppm	5322 117 12505	
R150	Resistor 47 Ω 1% 0.1W 100ppm	5322 117 12505	
R151	Resistor 22 Ω 1% 0.1W 100ppm	5322 117 12507	
R152	Resistor 100kΩ 1% 1/8W 100ppm	4822 051 51004	
R153	Resistor 33.0kΩ 1% 1/8W 100ppm	4822 051 53303	
R154	Resistor 10.0kΩ 1% 1/8W 100ppm	4822 051 51003	
R155	Resistor 10.0kΩ 1% 1/8W 100ppm	4822 051 51003	
R156	Resistor 220.0Ω 1% 1/8W 100ppm	4822 051 52201	
R157	Resistor 220.0Ω 1% 1/8W 100ppm	4822 051 52201	
R160	Resistor 390 Ω 1% 0.1W 100ppm	5322 117 12508	
R161	Resistor 390 Ω 1% 0.1W 100ppm	5322 117 12508	
R162	Resistor 120 Ω 1% 0.1W 100ppm	5322 117 12506	
R163	Resistor 47 Ω 1% 0.1W 100ppm	5322 117 12505	
R164	Resistor 47 Ω 1% 0.1W 100ppm	5322 117 12505	
R165	Resistor 680 Ω 1% 0.1W 100ppm	5322 117 12509	
R166	Resistor 680 Ω 1% 0.1W 100ppm	5322 117 12509	
R167	Resistor 100kΩ 1% 1/8W 100ppm	4822 051 51004	
R168	Resistor 10.0kΩ 1% 1/8W 100ppm	4822 051 51003	
R169	Resistor 220.0Ω 1% 1/8W 100ppm	4822 051 52201	
R178	Resistor 100kΩ 1% 1/8W 100ppm	4822 051 51004	
R179	Resistor 680 Ω 1% 0.1W 100ppm	5322 117 12509	
R180	Resistor 33.0kΩ 1% 1/8W 100ppm	4822 051 53303	
R182	Resistor 100kΩ 1% 1/8W 100ppm	4822 051 51004	
R184	Resistor 100kΩ 1% 1/8W 100ppm	4822 051 51004	
R186	Resistor 1.00kΩ 1% 1/8W 100ppm	4822 051 51002	
R187	Resistor 15.0kΩ 1% 1/8W 100ppm	5322 116 82261	
R188	Resistor 1.00kΩ 1% 1/8W 100ppm	4822 051 51002	
R189	Resistor 1.00mΩ 1% 1/8W 100ppm	4822 051 10105	
R190	Resistor 100kΩ 1% 1/8W 100ppm	4822 051 51004	
R191	Resistor 10.0kΩ 1% 1/8W 100ppm (not on 164H)	4822 051 51003	
R192	Resistor 10.0kΩ 1% 1/8W 100ppm	4822 051 51003	
R193	Resistor 680 Ω 1% 0.1W 100ppm	5322 117 12509	
R194	Resistor 33.0kΩ 1% 1/8W 100ppm	4822 051 53303	
R195	Resistor 39 Ω 1% 1/8W 100ppm	5322 116 82263	

Item	Description	Ordering code	☆
R196	Resistor 39 Ω 1% 1/8W 100ppm	5322 116 82263	
R197	Resistor 39 Ω 1% 1/8W 100ppm	5322 116 82263	
R198	Resistor 39 Ω 1% 1/8W 100ppm	5322 116 82263	
R199	Resistor 39 Ω 1% 1/8W 100ppm	5322 116 82263	
R200	Resistor 39 Ω 1% 1/8W 100ppm	5322 116 82263	
R201	Resistor 39 Ω 1% 1/8W 100ppm	5322 116 82263	
R202	Resistor 39 Ω 1% 1/8W 100ppm	5322 116 82263	
R203	Resistor 39 Ω 1% 1/8W 100ppm	5322 116 82263	
R204	Resistor 39 Ω 1% 1/8W 100ppm	5322 116 82263	
R205	Resistor 39 Ω 1% 1/8W 100ppm	5322 116 82263	
R206	Resistor 39 Ω 1% 1/8W 100ppm	5322 116 82263	
R207	Resistor 39 Ω 1% 1/8W 100ppm	5322 116 82263	
R208	Resistor 39 Ω 1% 1/8W 100ppm	5322 116 82263	
R209	Resistor 39 Ω 1% 1/8W 100ppm	5322 116 82263	
R210	Resistor 39 Ω 1% 1/8W 100ppm	5322 116 82263	
R213	Resistor 1.50kΩ 1% 1/8W 100ppm	4822 051 51502	
R214	Resistor 1.50kΩ 1% 1/8W 100ppm	4822 051 51502	
R215	Resistor 1.50kΩ 1% 1/8W 100ppm	4822 051 51502	
R216	Resistor 330 kΩ 1% 1/8W 100ppm	5322 117 10969	
R222	Resistor 100 Ω 1% 1/8W 100ppm	4822 051 51001	
R223	Resistor 47 Ω 1% 1/8W 100ppm	5322 116 80448	
R225	Resistor 0 Ω Jumper RC-01 (not on 164H)	4822 051 10008	
R226	Resistor 0 Ω Jumper RC-01 (only 164H)	4822 051 10008	
R231	Resistor 10.0kΩ 1% 1/8W 100ppm	4822 051 51003	
R232	Resistor 10.0kΩ 1% 1/8W 100ppm	4822 051 51003	
R233	Resistor 10.0kΩ 1% 1/8W 100ppm	4822 051 51003	
R234	Resistor 180 kΩ 1% 1/8W 100ppm	4822 051 51804	
R235	Resistor 39 Ω 1% 1/8W 100ppm	5322 116 82263	
R237	Resistor 39 Ω 1% 1/8W 100ppm	5322 116 82263	
R238	Resistor 39 Ω 1% 1/8W 100ppm	5322 116 82263	
R244	Resistor 100kΩ 1% 1/8W 100ppm	4822 051 51004	
R245	Resistor 10.0kΩ 1% 1/8W 100ppm	4822 051 51003	
R246	Resistor 10.0kΩ 1% 1/8W 100ppm	4822 051 51003	
R247	Resistor 10.0kΩ 1% 1/8W 100ppm	4822 051 51003	
R256	Resistor 100kΩ 1% 1/8W 100ppm	4822 051 51004	
R257	Resistor 100kΩ 1% 1/8W 100ppm	4822 051 51004	
R258	Resistor 100kΩ 1% 1/8W 100ppm	4822 051 51004	
R259	Resistor 100kΩ 1% 1/8W 100ppm	4822 051 51004	
R260	Resistor 100 Ω 1% 1/8W 100ppm	4822 051 51001	
R261	Resistor 100kΩ 1% 1/8W 100ppm	4822 051 51004	
R262	Resistor 100kΩ 1% 1/8W 100ppm	4822 051 51004	
R263	Resistor 100kΩ 1% 1/8W 100ppm	4822 051 51004	
R264	Resistor 100kΩ 1% 1/8W 100ppm	4822 051 51004	
R265	Resistor 10.0kΩ 1% 1/8W 100ppm	4822 051 51003	
R266	Resistor 100 Ω 1% 1/8W 100ppm	4822 051 51001	

Item	Description	Ordering code	☆
R267	Resistor 1.00k Ω 1% 1/8W 100ppm (only 164H)	4822 051 51002	
R268	Resistor 100 Ω 1% 1/8W 100ppm	4822 051 51001	
R269	Resistor 100 Ω 1% 1/8W 100ppm	4822 051 51001	
R271	Res. Network 100kΩx 4 1% 664A1003F	5322 117 12496	
R277	Resistor 39 Ω 1% 1/8W 100ppm	5322 116 82263	
R280	Resistor 33.0kΩ 1% 1/8W 100ppm	4822 051 53303	
R281	Resistor 33.0kΩ 1% 1/8W 100ppm	4822 051 53303	
R285	Resistor 10.0kΩ 1% 1/8W 100ppm	4822 051 51003	
R286	Resistor 100kΩ 1% 1/8W 100ppm	4822 051 51004	
R289	Resistor 10.0kΩ 1% 1/8W 100ppm	4822 051 51003	
R303	Resistor 22.0kΩ 1% 1/8W 100ppm	4822 051 52203	
R304	Resistor 100kΩ 1% 1/8W 100ppm	4822 051 51004	
R306	Resistor 100 Ω 1% 1/8W 100ppm	4822 051 51001	
R307	Resistor 100 Ω 1% 1/8W 100ppm	4822 051 51001	
R308	Resistor 39 Ω 1% 1/8W 100ppm	5322 116 82263	
R309	Resistor 39 Ω 1% 1/8W 100ppm	5322 116 82263	
R310	Resistor 39 Ω 1% 1/8W 100ppm	5322 116 82263	
R317	Resistor 100kΩ 1% 1/8W 100ppm	4822 051 51004	
R320	Resistor 2.70kΩ 1% 1/8W 100ppm	4822 051 52702	
R321	Resistor 2.20kΩ 1% 1/8W 100ppm	4822 051 52202	
R323	Resistor 820 Ω 1% 1/8W 100ppm	5322 116 82264	
R324	Resistor 2.70kΩ 1% 1/8W 100ppm	4822 051 52702	
R325	Resistor 100kΩ 1% 1/8W 100ppm	4822 051 51004	
R326	Resistor 68.0kΩ 1% 1/8W 100ppm	4822 051 56803	
R327	Resistor 68.0kΩ 1% 1/8W 100ppm	4822 051 56803	
T1	Transformer-CCFL CTX210657	5322 146 10405	R
U1	IC-CPU N80C196NT16 SMD PLCC68	5322 209 52775	R
U2	IC-SRAM HM628128ALFP-7 128KX8	5322 209 52773	
U4	IC-prom Fluke 160-ser Bas Sw U4	5322 209 15028	R
U5	IC-Reg LT1184CS	5322 209 12971	R
U6	IC-SRAM HM628128ALFP-7 128KX8	5322 209 52773	
U10	IC-CMOS MC74AC138D SO14 SMD	5322 209 90428	
U11	IC-CMOS MC74AC573DW 8 Latch	5322 209 90435	
U12	IC-CMOS MC74AC573DW 8 Latch	5322 209 90435	
U13	IC-LCD MSM6355GS-K	5322 209 52774	R
U14	IC-CMOS PC74HC163T SMD SO16	5322 209 30675	
U15	IC 256 Kbit UPD43256GU-12LSO28	5322 209 62421	
U17	IC-Ana TL7705BCD SMD Low V Detect	5322 209 90426	R
U18	IC-CMOS PC74HC00TSO14	5322 209 71802	
U19	IC-CMOS 74AC32D 4X0R2 SO14	5322 209 33104	
U22	IC-CMOS74AC20SC SMD SO14	5322 209 90427	
U23	IC-CMOS MC74AC573DW 8 Latch	5322 209 90435	
U25	IC-Op Amp LF453CM SMD SO8 JFET	4822 209 63757	
U26	IC-Op Amp LF453CM SMD SO8 JFET	4822 209 63757	
U27	IC-Op Amp LM358 X2 SMDSo8	4822 209 60175	R

Item	Description	Ordering code	☆
U28	IC-Op Amp TLE2022C SMD SO	5322 209 90433	R
U29	IC-CMOS PC74HC574T SMD SO20	4822 209 60451	
U30	IC-CMOS 74AC02D 4XNOR2 SO14	5322 209 33101	
U31	IC-CMOS74AC20SC SMD SO14	5322 209 90427	
U32	IC-Op Amp LM358 X2 SMDSo8	4822 209 60175	R
U33	IC-Op Amp LM358 X2 SMDSo8	4822 209 60175	R
U34	IC-CMOS PC74HC393T SMD SO14	5322 209 11996	
U35	IC-CMOS PC74HC86TSO14	5322 209 71562	
U36	IC-CMOS PC74HC393T SMD SO14	5322 209 11996	
U37	IC-CMOS 74AC08D 4XAND2 SO14	5322 209 33102	
U38	IC-CMOS PC74HC541T SMD SO20	4822 209 63763	
U39	IC-Op Amp LM358 X2 SMDSo8	4822 209 60175	R
U41	IC-CMOS PC74HC541T SMD SO20	4822 209 63763	
U42	IC-asic Fluke 160-ser	5322 209 90513	R
U43	IC-CMOS 74AC32D 4X0R2 SO14	5322 209 33104	
U44	Oscillator 10MHz TCXO, Optional	5322 242 82117	
U45	Oscillator 10MHz OCXO, Optional	5322 242 82113	P
U46	IC-Ref 2.5V LT1009CD-2.52.5V"0.2%	5322 209 90434	R
U47	IC-CMOS 74AC02D 4XNOR2 SO14	5322 209 33101	
U48	IC-Op Amp TLE2022C SMD SO	5322 209 90433	R
U49	IC-CMOS 74AC32D 4X0R2 SO14	5322 209 33104	
U52	IC-Display Driver SMD HD61105A FP100	4822 209 63761	
U53	IC- Display Driver SMD HD61105A FP100	4822 209 63761	
U54	IC- Display Driver SMD HD61105A FP100	4822 209 63761	
U55	IC- Display Driver SMD HD61104A FP100	4822 209 63759	
U56	IC- Display Driver SMD HD61104A FP100	4822 209 63759	
U57	IC- Display Driver SMD HD61104A FP100	4822 209 63759	
V1	Transistor BC857B .1A45V SOT23	5322 130 60508	
V2	Transistor BC847B .1A45V SOT23	4822 130 60511	
V3	Transistor BC847B .1A45V SOT23	4822 130 60511	
V4	Transistor BC857B .1A45V SOT23	5322 130 60508	
V5	Transistor BC847B .1A45V SOT23	4822 130 60511	
V6	Transistor BC847B .1A45V SOT23	4822 130 60511	
V7	Transistor BC847B .1A45V SOT23	4822 130 60511	
V8	Transistor BC857B .1A45V SOT23	5322 130 60508	
V9	Transistor BFS17 0.05A 15V SOT23	5322 130 40781	
V10	Transistor BC847B .1A45V SOT23	4822 130 60511	
V11	Transistor BC847B .1A45V SOT23	4822 130 60511	
V12	Transistor BFS17 0.05A 15V SOT23	5322 130 40781	
V13	Transistor BC857B .1A45V SOT23	5322 130 60508	
V14	Transistor BFS17 0.05A 15V SOT23	5322 130 40781	
V15	Transistor BC847B .1A45V SOT23	4822 130 60511	
V16	Transistor BC847B .1A45V SOT23	4822 130 60511	
V17	Transistor BFS17 0.05A 15V SOT23	5322 130 40781	
V18	Transistor BC857B .1A45V SOT23	5322 130 60508	

Item	Description	Ordering code	☆
V19	Transistor, Photo 3mm SFH309F-4 IR900nm	5322 130 62923	
V20	Transistor BC857B .1A45V SOT23	5322 130 60508	
V21	Transistor BSR12 0.1A 15V SOT23	5322 130 44743	
V22	Transistor BSR12 0.1A 15V SOT23	5322 130 44743	
V23	Transistor BC857B .1A45V SOT23	5322 130 60508	
V31	Transistor BC857B .1A45V SOT23	5322 130 60508	
V47	Transistor BC847B .1A45V SOT23	4822 130 60511	
V48	Transistor BC857B .1A45V SOT23	5322 130 60508	
V49	Transistor BC847B .1A45V SOT23	4822 130 60511	
V51	Transistor BC857B .1A45V SOT23	5322 130 60508	
V52	Transistor BC847B .1A45V SOT23	4822 130 60511	
V53	Transistor BC847B .1A45V SOT23	4822 130 60511	
V54	Transistor-Sw N FZT849 SOT223 SMD	5322 130 10191	R
V55	Transistor-Sw N FZT849 SOT223 SMD	5322 130 10191	R
V56	Transistor BC857B .1A45V SOT23	5322 130 60508	

INPUT PCA

Item	Description	Ordering code	☆
2	Shield Cover Top Fluke 160-ser	5322 466 30472	
3	Shield Cover Bottom Fluke 160-ser	5322 466 30473	
4	Shielding Strip Fluke 160-ser	5322 466 11304	
5	Status Label 25.4x12.7 Polyimide	5322 454 13144	P
C1	Capacitor 100nF 10% 63V X7R	4822 122 33496	
C1a	Cap-trim 2.5-10pF 500VDC AT2320-2	5322 125 50689	
C1b	Cap-trim 2.5-10pF 500VDC AT2320-2	5322 125 50689	
C2	Capacitor 470pF 5% 63V NP0	4822 122 31727	
C2a	Capacitor 10pF 5% 500V NP0	5322 126 13643	
C2b	Capacitor 10pF 5% 500V NP0	5322 126 13643	
C3	Capacitor 100nF 10% 63V X7R	4822 122 33496	
C4	Capacitor 100nF 10% 63V X7R	4822 122 33496	
C4a	Cap-trim 3-10pF TZBX4Z100BB110	5322 125 50306	
C4b	Cap-trim 3-10pF TZBX4Z100BB110	5322 125 50306	
C5a	Capacitor 5.6pF "0.25 100V NP0	5322 126 14048	
C5b	Capacitor 5.6pF "0.25 100V NP0	5322 126 14048	
C6a	Cap-trim 3-10pF TZBX4Z100BB110	5322 125 50306	
C6b	Cap-trim 3-10pF TZBX4Z100BB110	5322 125 50306	
C7a	Capacitor 10nF 10% 63V X7R	4822 122 32442	
C7b	Capacitor 10nF 10% 63V X7R	4822 122 32442	
C10a	Capacitor 10nF 10% 63V X7R	4822 122 32442	
C10b	Capacitor 10nF 10% 63V X7R	4822 122 32442	
C11a	Capacitor 22nF 20% 200V 2F4	5322 126 10527	
C11b	Capacitor 22nF 20% 200V 2F4	5322 126 10527	
C12a	Capacitor 10nF 10% 63V X7R	4822 122 32442	
C12b	Capacitor 10nF 10% 63V X7R	4822 122 32442	
C13a	Capacitor 10nF 10% 63V X7R	4822 122 32442	
C13b	Capacitor 10nF 10% 63V X7R	4822 122 32442	
C16a	Capacitor 10nF 10% 63V X7R	4822 122 32442	
C16b	Capacitor 10nF 10% 63V X7R	4822 122 32442	
C17a	Capacitor 3.30nF 10% 63V X7R	5322 122 33446	
C17b	Capacitor 3.30nF 10% 63V X7R	5322 122 33446	
C18a	Capacitor 5.6pF "0.5pF 63V NP0	4822 122 32506	
C18b	Capacitor 5.6pF "0.5pF 63V NP0	4822 122 32506	
C19a	Capacitor33pF 5% 63V NP0	4822 126 10324	
C19b	Capacitor33pF 5% 63V NP0	4822 126 10324	
C20a	Capacitor 47pF 5% 63V NP0	4822 122 31772	
C20b	Capacitor 47pF 5% 63V NP0	4822 122 31772	
C21a	Capacitor 100nF 10% 63V X7R	4822 122 33496	
C21b	Capacitor 100nF 10% 63V X7R	4822 122 33496	
C22a	Capacitor 1nF 5% 63V NP0	4822 122 31746	
C22b	Capacitor 1nF 5% 63V NP0	4822 122 31746	
C23a	Capacitor 100nF 10% 63V X7R	4822 122 33496	

Item	Description	Ordering code	☆
C23b	Capacitor 100nF 10% 63V X7R	4822 122 33496	
C24a	Capacitor 100nF 10% 63V X7R	4822 122 33496	
C24b	Capacitor 100nF 10% 63V X7R	4822 122 33496	
C25a	Capacitor33pF 5% 63V NP0	4822 126 10324	
C25b	Capacitor33pF 5% 63V NP0	4822 126 10324	
C26a	Capacitor 100nF 10% 63V X7R	4822 122 33496	
C26b	Capacitor 100nF 10% 63V X7R	4822 122 33496	
C27a	Capacitor 1nF 5% 63V NP0	4822 122 31746	
C27b	Capacitor 1nF 5% 63V NP0	4822 122 31746	
C28a	Capacitor 10nF 10% 63V X7R	4822 122 32442	
C28b	Capacitor 10nF 10% 63V X7R	4822 122 32442	
C29b	Capacitor 100nF 10% 63V X7R	4822 122 33496	
C31a	Capacitor 100nF 10% 63V X7R	4822 122 33496	
C31b	Capacitor 100nF 10% 63V X7R	4822 122 33496	
C32a	Capacitor 100nF 10% 63V X7R	4822 122 33496	
C32b	Capacitor 100nF 10% 63V X7R	4822 122 33496	
C34a	Capacitor 100nF 10% 63V X7R	4822 122 33496	
C34b	Capacitor 100nF 10% 63V X7R	4822 122 33496	
C36a	Capacitor 10nF 10% 63V X7R	4822 122 32442	
C36b	Capacitor 10nF 10% 63V X7R	4822 122 32442	
C37a	Capacitor 10nF 20% 50V X7R0805	5322 122 34098	
C37b	Capacitor 10nF 10% 63V X7R	4822 122 32442	
C38a	Capacitor 100pF 5% 63V NP0	4822 122 31765	
C38b	Capacitor 100pF 5% 63V NP0	4822 122 31765	
C41a	Capacitor 100nF 10% 63V X7R	4822 122 33496	
C41b	Capacitor 100nF 10% 63V X7R	4822 122 33496	
C42a	Capacitor 100nF 10% 63V X7R	4822 122 33496	
C42b	Capacitor 100nF 10% 63V X7R	4822 122 33496	
C43b	Capacitor 100nF 10% 63V X7R	4822 122 33496	
C45	Capacitor 100nF 10% 63V X7R	4822 122 33496	
C46	Capacitor 1nF 5% 63V NP0	4822 122 31746	
C47	Capacitor 68µF "20% 16v 5x11	5322 124 41384	
C49	Capacitor 82pF 5% 63V NP0	4822 122 31839	
C50	Capacitor 22nF 20% 200V 2F4	5322 126 10527	
C51	Capacitor 1000µF 20% 25V	5322 124 81189	R
C52	Capacitor 100µF "20%40V10x12	5322 124 81194	
C58	Capacitor 2.20nF 10% 63V X7R	4822 122 31644	
C59	Capacitor 68µF "20% 16v 5x11	5322 124 41384	
C060	Capacitor 220nF 10% 63V X7R	5322 126 13642	
C61	Capacitor 22nF 20% 200V 2F4	5322 126 10527	
C62	Capacitor 68µF "20% 16v 5x11	5322 124 41384	
C63	Capacitor 22nF 20% 200V 2F4	5322 126 10527	
C064	Capacitor 470nF 10% 25V X7R1210	4822 126 12549	
C65	Capacitor 1000µF "20% 6.3V 10x20	5322 124 81192	
C66	Capacitor 100µF "20%40V10x12	5322 124 81194	

Item	Description	Ordering code	☆
C67	Capacitor 22nF 20% 200V 2F4	5322 126 10527	
C68	Capacitor 22nF 20% 200V 2F4	5322 126 10527	
C69	Capacitor 22nF 20% 200V 2F4	5322 126 10527	
C70	Capacitor 470µF "20% 6.3V10x12	5322 124 81193	
C71	Capacitor 1000µF "20% 6.3V10x20	5322 124 81192	
C72	Capacitor 470µF "20% 6.3V10x12	5322 124 81193	
C74	Capacitor 680pF 20% 63V NP0	4822 126 12075	
C75	Capacitor 68nF 10% 63V X7R	4822 122 32891	
C76	Capacitor 2.20nF 10% 63V X7R	4822 122 31644	
C77	Capacitor 470µF 20% 25V	5322 124 81191	
C78	Capacitor 10nF 10% 63V X7R	4822 122 32442	
C81	Capacitor 100nF 10% 63V X7R	4822 122 33496	
C83	Capacitor 47pF 5% 63V NP0	4822 122 31772	
C84	Capacitor 47pF 5% 63V NP0	4822 122 31772	
C85a	Capacitor 100pF 5% 63V NP0	4822 122 31765	
C85b	Capacitor 100pF 5% 63V NP0	4822 122 31765	
C86	Capacitor 100nF 10% 63V X7R	4822 122 33496	
C87	Capacitor 100pF 5% 63V NP0	4822 122 31765	
C88	Capacitor 100pF 5% 63V NP0	4822 122 31765	
C90	Capacitor 100pF 5% 63V NP0	4822 122 31765	
C91	Capacitor 100nF 10% 63V X7R	4822 122 33496	
C92	Capacitor 15 µF 20%6.3V 6.0x3.2 Mold	5322 124 11418	
C93	Capacitor 100nF 10% 63V X7R	4822 122 33496	
C94	Capacitor 6.80 µF 20% 16v 6.0x3.2 Mold	5322 124 10687	R
C95	Capacitor 100pF 5% 63V NP0	4822 122 31765	
C96	Capacitor 100nF 10% 63V X7R	4822 122 33496	
C97	Capacitor 2.20µF 20%6.3V 3.2x1.6 Mold	5322 124 10685	
C98	Capacitor 100nF 10% 63V X7R	4822 122 33496	
C99	Capacitor 100nF 10% 63V X7R	4822 122 33496	
C100	Capacitor 100nF 10% 63V X7R	4822 122 33496	
C101	Capacitor 10nF 10% 63V X7R	4822 122 32442	
C102	Capacitor 10nF 10% 63V X7R	4822 122 32442	
C103	Capacitor 10nF 10% 63V X7R	4822 122 32442	
C104	Capacitor 10nF 10% 63V X7R	4822 122 32442	
C106	Capacitor 100nF 10% 63V X7R	4822 122 33496	
C107	Capacitor 100pF 5% 63V NP0	4822 122 31765	
C108	Capacitor 6.80 µF 20% 16v 6.0x3.2 Mold	5322 124 10687	R
C110	Capacitor 100pF 5% 63V NP0	4822 122 31765	
C111	Capacitor 100pF 5% 63V NP0	4822 122 31765	
C113	Capacitor 10nF 10% 63V X7R	4822 122 32442	
C114	Capacitor 10nF 10% 63V X7R	4822 122 32442	
C115	Capacitor 100nF 10% 63V X7R	4822 122 33496	
C116	Capacitor 100nF 10% 63V X7R	4822 122 33496	
C117	Capacitor 100nF 10% 63V X7R	4822 122 33496	
C119	Capacitor 6.80 µF 20% 16v 6.0x3.2 Mold	5322 124 10687	R

Item	Description	Ordering code	☆
C120	Capacitor 470nF 10% 25V X7R1210	4822 126 12549	
C123	Capacitor 220pF 5% 63V NP0	4822 122 31965	
C126	Capacitor 100nF 10% 63V X7R	4822 122 33496	
C127	Capacitor 100nF 10% 63V X7R	4822 122 33496	
C128	Capacitor 100nF 10% 63V X7R	4822 122 33496	
C129	Capacitor 100nF 10% 63V X7R	4822 122 33496	
C130	Capacitor 100nF 10% 63V X7R	4822 122 33496	
C131	Capacitor 10nF 10% 63V X7R	4822 122 32442	
C132	Capacitor 10nF 10% 63V X7R	4822 122 32442	
C133	Capacitor 10nF 10% 63V X7R	4822 122 32442	
C134	Capacitor 10nF 10% 63V X7R	4822 122 32442	
D1	Diode 0.10A BAV99SOT23	5322 130 34337	
D2	Diode-Sch MBRD630CT SMD 369-04	5322 130 62922	R
D3	Diode 0.10A BAV99SOT23	5322 130 34337	
D3a	Diode 0.10A BAT18 35V 1pFSOT23	5322 130 32076	
D3b	Diode 0.10A BAT18 35V 1pFSOT23	5322 130 32076	
D4	Diode 0.10A BAV99SOT23	5322 130 34337	
D4a	Diode 0.10A BAT18 35V 1pFSOT23	5322 130 32076	
D4b	Diode 0.10A BAT18 35V 1pFSOT23	5322 130 32076	
D5	Diode 0.25A BAS2875VSOT143	5322 130 80214	
D6	Diode-Sch MBRD630CT SMD 369-04	5322 130 62922	R
D9	Diode 0.25A BAS2875VSOT143	5322 130 80214	
D12	Diode 0.25A BAS2875VSOT143	5322 130 80214	
D13	Diode 0.25A BAS2875VSOT143	5322 130 80214	
D14	Diode 0.10A BAV99SOT23	5322 130 34337	
D15	Diode 0.10A BAV99SOT23	5322 130 34337	
D19	Diode 0.25A BAS2875VSOT143	5322 130 80214	
D22	Diode-Sch MBRD630CT SMD 369-04	5322 130 62922	R
D24	Diode-Sch MBRD630CT SMD 369-04	5322 130 62922	R
D25	Diode-Sch MBRD630CT SMD 369-04	5322 130 62922	R
D27	Diode 0.10A BAV99SOT23	5322 130 34337	
D29	Diode 0.35 Ω BZX84-C6V8 SOT23	5322 130 80406	
D30	Diode 0.10A BAV99SOT23	5322 130 34337	
D33	Diode 0.10A BAV99SOT23	5322 130 34337	
D36	Diode 0.25A BAS2875VSOT143	5322 130 80214	
D37	Diode 0.25A BAS2875VSOT143	5322 130 80214	
D46	Diode 0.25A BAS2875VSOT143	5322 130 80214	
D49	Diode 0.25A BAS2875VSOT143	5322 130 80214	
D52	Diode 0.25A BAS2875VSOT143	5322 130 80214	
D55	Diode 0.35 Ω BZX84-C6V8 SOT23	5322 130 80406	
D56	Diode 0.25A BAS2875VSOT143	5322 130 80214	
D58	Led 3mm HLMP-1503-101 Green	5322 130 83933	
D59	Diode 0.25A BAS2875VSOT143	5322 130 80214	
D62	Diode 0.35w Bzx84-b5v6 2%SOT23	4822 130 33004	
J3	Connector Socket 30 Pole 52030-3010	4822 267 51143	

Item	Description	Ordering code	☆
K1a	Relay SMD EB2-5T Latching	5322 280 70383	R
K1b	Relay SMD EB2-5T Latching	5322 280 70383	R
K2a	Relay SMD EB2-5T Latching	5322 280 70383	R
K2b	Relay SMD EB2-5T Latching	5322 280 70383	R
K3a	Relay SMD EB2-5T Latching	5322 280 70383	R
K3b	Relay SMD EB2-5T Latching	5322 280 70383	R
L1	Choke 31 Ω CB50-321611T	5322 157 61919	
L2	Choke 31 Ω CB50-321611T	5322 157 61919	
L3	Choke 31 Ω CB50-321611T	5322 157 61919	
L4	Choke 31 Ω CB50-321611T	5322 157 61919	
L11	Choke 1 µH 10% MLF3216D1R0K	5322 157 62555	
L12	Choke 1 µH 10% MLF3216D1R0K	5322 157 62555	
L13	Choke 22.0 µH 10% LQH4N220K04	5322 157 10998	
L14	Choke 33 µH TSL0807-330K1R2	5322 157 53568	
L15	Choke KM-2 L47	5322 157 71688	
L16	Filter-EMI 10A 50V BNX002-01	5322 156 11139	R
P1	Conn. Dc Power Jack HEC0739-01-010	4822 267 30431	R
P2	Connector Pin 3pole 90136-1103	5322 265 30434	
P4	Connector 16 Pol F095 Double Row	5322 265 40262	
R1	Resistor 100Ω 1% 1/8W 100ppm 1206	4822 051 51001	
R1a	Resistor 47 Ω 1% 1/8W 100ppm	5322 116 80448	
R1b	Resistor 47 Ω 1% 1/8W 100ppm	5322 116 80448	
R2a	Resistor 470 kΩ 1% 1/8W 100ppm	5322 116 80447	
R2b	Resistor 470 kΩ 1% 1/8W 100ppm	5322 116 80447	
R3	Resistor 47 Ω 1% 1/8W 100ppm	5322 116 80448	
R3a	Resistor 120 kΩ 1% 1/8W 100ppm	4822 051 51204	
R3b	Resistor 120 kΩ 1% 1/8W 100ppm	4822 051 51204	
R4	Resistor 1.0 Ω 1% 1/8W 100ppm	5322 117 10967	
R5	Thermistor 2.2kΩ 3% ¼ W NTC	5322 116 30458	
R5a	Resistor 10.0 Ω 1% 1/8W 100ppm	4822 051 10109	
R5b	Resistor 10.0 Ω 1% 1/8W 100ppm	4822 051 10109	
R6	Resistor 47 Ω 1% 1/8W 100ppm	5322 116 80448	
R6a	Resistor 680 kΩ 1% 1/8W 100ppm	5322 117 11787	
R6b	Resistor 680 kΩ 1% 1/8W 100ppm	5322 117 11787	
R7	Resistor 47 kΩ 1% 1/8W 100ppm	5322 116 80446	
R7a	Resistor 15.0kΩ 1% 1/8W 100ppm	5322 116 82261	
R7b	Resistor 15.0kΩ 1% 1/8W 100ppm	5322 116 82261	
R8	Resistor 150 kΩ 1% 1/8W 100ppm	4822 051 51504	
R8a	Resistor 10.0kΩ 1% 1/8W 100ppm	4822 051 51003	
R8b	Resistor 10.0kΩ 1% 1/8W 100ppm	4822 051 51003	
R9	Resistor 47 kΩ 1% 1/8W 100ppm	5322 116 80446	
R9a	Resistor 10.0kΩ 1% 1/8W 100ppm	4822 051 51003	
R9b	Resistor 10.0kΩ 1% 1/8W 100ppm	4822 051 51003	
R10	Resistor 15.0kΩ 1% 1/8W 100ppm	5322 116 82261	
R10a	Resistor 1.0 Ω 1% 1/8W 100ppm	5322 117 10967	

Item	Description	Ordering code	☆
R10b	Resistor 1.0 Ω 1% 1/8W 100ppm	5322 117 10967	
R11	Resistor 47 kΩ 1% 1/8W 100ppm	5322 116 80446	
R11a	Resistor 680 kΩ 1% 1/8W 100ppm	5322 117 11787	
R11b	Resistor 680 kΩ 1% 1/8W 100ppm	5322 117 11787	
R12a	Resistor 220 kΩ 1% 1/8W 100ppm	4822 051 52204	
R12b	Resistor 220 kΩ 1% 1/8W 100ppm	4822 051 52204	
R13a	Resistor 470 kΩ 1% 1/8W 100ppm	5322 116 80447	
R13b	Resistor 470 kΩ 1% 1/8W 100ppm	5322 116 80447	
R14a	Resistor 10.0 Ω 1% 1/8W 100ppm	4822 051 10109	
R14b	Resistor 10.0 Ω 1% 1/8W 100ppm	4822 051 10109	
R15a	Resistor 10.0 Ω 1% 1/8W 100ppm	4822 051 10109	
R15b	Resistor 10.0 Ω 1% 1/8W 100ppm	4822 051 10109	
R16a	Resistor 100kΩ 1% 1/8W 100ppm	4822 051 51004	
R16b	Resistor 100kΩ 1% 1/8W 100ppm	4822 051 51004	
R17a	Resistor 12.0kΩ 1% 1/8W 100ppm	5322 117 10968	
R17b	Resistor 12.0kΩ 1% 1/8W 100ppm	5322 117 10968	
R18a	Resistor 100kΩ 1% 1/8W 100ppm	4822 051 51004	
R18b	Resistor 100kΩ 1% 1/8W 100ppm	4822 051 51004	
R19a	Resistor 470 Ω 1% 1/8W 100ppm	4822 051 54701	
R19b	Resistor 470 Ω 1% 1/8W 100ppm	4822 051 54701	
R20a	Resistor 1.00mΩ 1% 1/8W 100ppm	4822 051 10105	
R20b	Resistor 1.00mΩ 1% 1/8W 100ppm	4822 051 10105	
R21a	Resistor 100kΩ 1% 0.1W 100ppm 0805	5322 117 12501	
R21b	Resistor 100kΩ 1% 1/8W 100ppm	4822 051 51004	
R22	Resistor 220 kΩ 1% 1/8W 100ppm	4822 051 52204	
R22a	Resistor 1.00mΩ 1% 1/8W100ppm	4822 051 10105	
R22b	Resistor 1.00mΩ 1% 1/8W 100ppm	4822 051 10105	
R23	Resistor 120 Ω 1% 1/8W 100ppm	4822 051 10121	
R23a	Resistor 1.00kΩ 1% 1/8W 100ppm	4822 051 51002	
R23b	Resistor 1.00kΩ 1% 1/8W 100ppm	4822 051 51002	
R24	Resistor 10.0kΩ 1% 1/8W 100ppm	4822 051 51003	
R24a	Potentiometer 100 kΩ 3304X-1-104	5322 101 10841	
R24b	Potentiometer 100 kΩ 3304X-1-104	5322 101 10841	
R25	Resistor 4.70kΩ 1% 1/8W 100ppm	4822 051 54702	
R25a	Potentiometer 100 kΩ 3304X-1-104	5322 101 10841	
R25b	Potentiometer 100 kΩ 3304X-1-104	5322 101 10841	
R26a	Resistor 180 kΩ 1% 1/8W 100ppm	4822 051 51804	
R26b	Resistor 180 kΩ 1% 1/8W 100ppm	4822 051 51804	
R27a	Resistor 220 kΩ 1% 1/8W 100ppm	4822 051 52204	
R27b	Resistor 220 kΩ 1% 1/8W 100ppm	4822 051 52204	
R28a	Resistor 6.80kΩ 1% 1/8W 100ppm	4822 051 10682	
R28b	Resistor 6.80kΩ 1% 1/8W 100ppm	4822 051 10682	
R29a	Resistor 10 MΩ 10% ¼W RC01	4822 051 10106	
R29b	Resistor 10 MΩ 10% ¼W RC01	4822 051 10106	
R30a	Resistor 10.0kΩ 1% 1/8W 100ppm 1206	4822 051 51003	

Item	Description	Ordering code	☆
R30b	Resistor 10.0kΩ 1% 1/8W 100ppm	4822 051 51003	
R31a	Resistor 10kΩ1% 0.1W 100ppm 0805	5322 117 12499	
R31b	Resistor 10.0kΩ 1% 1/8W 100ppm	4822 051 51003	
R32a	Resistor 47 Ω 1% 0.1W 100ppm 0805	5322 117 12505	
R32b	Resistor 47 Ω 1% 1/8W 100ppm	5322 116 80448	
R33	Resistor 47 kΩ 1% 1/8W 100ppm	5322 116 80446	
R33a	Resistor 33.0 Ω 1% 1/8W 100ppm	4822 051 10339	
R33b	Resistor 33.0 Ω 1% 1/8W 100ppm	4822 051 10339	
R34	Resistor 1.80kΩ 1% 1/8W 100ppm	4822 051 10182	
R34a	Resistor 10 MΩ 10% ¼W RC01	4822 051 10106	
R34b	Resistor 10 MΩ 10% ¼W RC01	4822 051 10106	
R35	Resistor 100kΩ 1% 1/8W 100ppm	4822 051 51004	
R35a	Resistor 470 Ω 1% 1/8W 100ppm	4822 051 54701	
R35b	Resistor 470 Ω 1% 1/8W 100ppm	4822 051 54701	
R36	Resistor 100kΩ 1% 1/8W 100ppm	4822 051 51004	
R36a	Resistor 10 Ω 1% 0.1W 100ppm 0805	5322 117 12502	
R36b	Resistor 10 Ω 1% 0.1W 100ppm 0805	5322 117 12502	
R37	Resistor 47 kΩ 1% 1/8W 100ppm	5322 116 80446	
R37a	Resistor 100 Ω 1% 1/8W 100ppm	4822 051 51001	
R37b	Resistor 100 Ω 1% 0.1W 100ppm 0805	5322 117 12497	
R38	Resistor 22.0kΩ 1% 1/8W 100ppm	4822 051 52203	
R38a	Resistor 100 Ω 1% 1/8W 100ppm	4822 051 51001	
R38b	Resistor 100 Ω 1% 1/8W 100ppm	4822 051 51001	
R39	Resistor 10.0kΩ 1% 1/8W 100ppm	4822 051 51003	
R39a	Resistor 3.30 Ω 1% 1/8W 100ppm	5322 117 11788	
R39b	Resistor 3.30 Ω 1% 0.1W 100ppm 0805	5322 117 12503	
R40	Resistor 22.0kΩ 1% 1/8W 100ppm	4822 051 52203	
R40a	Resistor 1kΩ 1% 0.1W 100ppm 0805	5322 117 12498	
R40b	Resistor 1kΩ 1% 0.1W 100ppm 0805	5322 117 12498	
R41a	Resistor 1kΩ 1% 0.1W 100ppm 0805	5322 117 12498	
R41b	Resistor 1.00kΩ 1% 1/8W 100ppm	4822 051 51002	
R42a	Resistor 1kΩ 1% 0.1W 100ppm 0805	5322 117 12498	
R42b	Resistor 1.00kΩ 1% 1/8W 100ppm	4822 051 51002	
R43a	Resistor 10kΩ 1% 0.1W 100ppm 0805	5322 117 12499	
R43b	Resistor 10.0kΩ 1% 1/8W 100ppm	4822 051 51003	
R44a	Resistor 1.80kΩ 1% 1/8W 100ppm	4822 051 10182	
R44b	Resistor 1.80kΩ 1% 1/8W 100ppm	4822 051 10182	
R45a	Resistor 1.00mΩ 1% 1/8W 100ppm	4822 051 10105	
R45b	Resistor 1.00mΩ 1% 1/8W 100ppm	4822 051 10105	
R46a	Resistor 3.30 Ω 1% 0.1W 100ppm 0805	5322 117 12503	
R46b	Resistor 3.30 Ω 1% 1/8W 100ppm	5322 117 11788	
R48a	Resistor 1.00mΩ 1% 1/8W 100ppm	4822 051 10105	
R48b	Resistor 1.00mΩ 1% 1/8W 100ppm	4822 051 10105	
R49	Resistor 100kΩ 1% 1/8W 100ppm	4822 051 51004	
R49a	Resistor 1.00kΩ 1% 1/8W 100ppm	4822 051 51002	

Item	Description	Ordering code	☆
R49b	Resistor 1.00kΩ 1% 1/8W 100ppm	4822 051 51002	
R50	Resistor 10.0kΩ 1% 1/8W 100ppm	4822 051 51003	
R50a	Resistor 0 Ω Jumper RC-01	4822 051 10008	
R50b	Resistor 0 Ω Jumper RC-01	4822 051 10008	
R51	Resistor 10.0kΩ 1% 1/8W 100ppm	4822 051 51003	
R51a	Resistor 0 Ω Jumper RC-01	4822 051 10008	
R51b	Resistor 0 Ω Jumper RC-01	4822 051 10008	
R52	Resistor 10.0kΩ 1% 1/8W 100ppm	4822 051 51003	
R52a	Resistor 390 Ω 1% 1/8W 100ppm	4822 051 53901	
R52b	Resistor 390 Ω 1% 1/8W 100ppm	4822 051 53901	
R53	Resistor 10.0kΩ 1% 1/8W 100ppm	4822 051 51003	
R53a	Resistor 100 Ω 1% 1/8W 100ppm	4822 051 51001	
R53b	Resistor 100 Ω 1% 1/8W 100ppm	4822 051 51001	
R54	Resistor 10.0kΩ 1% 1/8W 100ppm	4822 051 51003	
R54a	Resistor 68 Ω 1% 1/8W 100ppm	4822 051 10689	
R54b	Resistor 68 Ω 1% 1/8W 100ppm	4822 051 10689	
R55	Resistor 47 kΩ 1% 1/8W 100ppm	5322 116 80446	
R55a	Resistor 68 Ω 1% 1/8W 100ppm	4822 051 10689	
R55b	Resistor 68 Ω 1% 1/8W 100ppm	4822 051 10689	
R56	Resistor 10.0kΩ 1% 1/8W 100ppm	4822 051 51003	
R56a	Resistor 10.0kΩ 1% 1/8W 100ppm	4822 051 51003	
R56b	Resistor 10.0kΩ 1% 1/8W 100ppm	4822 051 51003	
R57	Resistor 15.0kΩ 1% 1/8W 100ppm	5322 116 82261	
R57a	Resistor 100 Ω 1% 1/8W 100ppm	4822 051 51001	
R57b	Resistor 100 Ω 1% 1/8W 100ppm	4822 051 51001	
R58	Resistor 33.0kΩ 1% 1/8W 100ppm	4822 051 53303	
R58a	Resistor 100 Ω 1% 1/8W 100ppm	4822 051 51001	
R58b	Resistor 100 Ω 1% 0.1W 100ppm 0805	5322 117 12497	
R59	Resistor 470 kΩ 1% 1/8W 100ppm	5322 116 80447	
R59a	Resistor 100 Ω 1% 1/8W 100ppm	4822 051 51001	
R59b	Resistor 100 Ω 1% 0.1W 100ppm 0805	5322 117 12497	
R60	Resistor 680 kΩ 1% 1/8W 100ppm	5322 117 11787	
R60a	Resistor 150 Ω 1% 1/8W 100ppm	4822 051 51501	
R60b	Resistor 150 Ω 1% 1/8W 100ppm	4822 051 51501	
R61	Resistor 47 Ω 1% 1/8W 100ppm	5322 116 80448	
R62	Resistor 56 Ω 1% 1/8W 100ppm	4822 051 10569	
R62a	Resistor 33 Ω 1% 0.1W 100ppm 0805	5322 117 12504	
R62b	Resistor 33 Ω 1% 0.1W 100ppm 0805	5322 117 12504	
R63	Resistor 10.0 Ω 1% 1/8W 100ppm	4822 051 10109	
R63a	Resistor 33 Ω 1% 0.1W 100ppm 0805	5322 117 12504	
R63b	Resistor 33 Ω 1% 0.1W 100ppm 0805	5322 117 12504	
R64	Resistor 10.0kΩ 1% 1/8W 100ppm	4822 051 51003	
R65	Resistor 270 Ω 1% 1/8W 100ppm	4822 051 10271	
R66	Resistor 33.0kΩ 1% 1/8W 100ppm	4822 051 53303	
R67	Resistor 33.0 Ω 1% 1/8W 100ppm	4822 051 10339	

Item	Description	Ordering code	☆
R68	Resistor 100 Ω 1% 1/8W 100ppm	4822 051 51001	
R69	Resistor 39.0kΩ 1% 1/8W 100ppm	4822 051 53903	
R70	Resistor 10.0kΩ 1% 1/8W 100ppm	4822 051 51003	
R71	Resistor 10.0kΩ 1% 1/8W 100ppm	4822 051 51003	
R72	Resistor 8.20kΩ 1% 1/8W 100ppm	4822 051 10822	
R73	Resistor 1.60kΩ 1% 1/8W 100ppm	4822 051 51602	
R74	Resistor 2.20kΩ 1% 1/8W 100ppm	4822 051 52202	
R75	Resistor 10.0kΩ 1% 1/8W 100ppm	4822 051 51003	
R76	Resistor 56 Ω 1% 1/8W 100ppm	4822 051 10569	
R78	Resistor 10.0kΩ 1% 1/8W 100ppm	4822 051 51003	
R79	Resistor 5.60kΩ 1% 1/8W 100ppm	4822 051 10562	
R80	Resistor 0.22Ω 5% 1/8W LRC01 3.2x1.6	5322 117 11786	R
R81	Resistor 0.22Ω 5% 1/8W LRC01 3.2x1.6	5322 117 11786	R
R82	Resistor 0.22Ω 5% 1/8W LRC01 3.2x1.6	5322 117 11786	R
R83	Resistor 0.22Ω 5% 1/8W LRC01 3.2x1.6	5322 117 11786	R
R87	Resistor 1.00kΩ 1% 1/8W 100ppm	4822 051 51002	
R88	Resistor 1.00kΩ 1% 1/8W 100ppm	4822 051 51002	
R89	Resistor 1.00kΩ 1% 1/8W 100ppm	4822 051 51002	
R90	Resistor 1.00kΩ 1% 1/8W 100ppm	4822 051 51002	
R91	Resistor 220.0Ω 1% 1/8W 100ppm	4822 051 52201	
R92	Resistor 47 Ω 1% 1/8W 100ppm	5322 116 80448	
R93	Resistor 4.70kΩ 1% 1/8W 100ppm	4822 051 54702	
R94	Resistor 4.70kΩ1% 1/8W 100ppm	4822 051 54702	
R98	Resistor 2.20kΩ 1% 1/8W 100ppm	4822 051 52202	
R99	Resistor 18.0 Ω 1% 1/8W 100ppm	5322 111 90139	
R100	Resistor 18.0 Ω 1% 1/8W 100ppm	5322 111 90139	
R101	Resistor 470 Ω 1% 1/8W 100ppm	4822 051 54701	
R102	Resistor 4.70kΩ 1% 1/8W 100ppm	4822 051 54702	
R103	Resistor 100 Ω 1% 1/8W 100ppm	4822 051 51001	
R104	Resistor 100 Ω 1% 1/8W 100ppm	4822 051 51001	
R105	Resistor 100kΩ 1% 1/8W 100ppm	4822 051 51004	
R106	Resistor 100kΩ 1% 1/8W 100ppm	4822 051 51004	
R107	Resistor 100kΩ 1% 1/8W 100ppm	4822 051 51004	
R108	Resistor 100kΩ 1% 1/8W 100ppm	4822 051 51004	
R109	Resistor 100kΩ 1% 1/8W 100ppm	4822 051 51004	
R110	Resistor 100kΩ 1% 1/8W 100ppm	4822 051 51004	
R111	Resistor 100kΩ1% 1/8W 100ppm	4822 051 51004	
R112	Resistor 100kΩ 1% 1/8W 100ppm	4822 051 51004	
R113	Resistor 10.0kΩ 1% 1/8W 100ppm	4822 051 51003	
R114	Resistor 33.0kΩ 1% 1/8W 100ppm	4822 051 53303	
R115	Resistor 120 kΩ 1% 1/8W 100ppm	4822 051 51204	
R116	Resistor 120 kΩ 1% 1/8W 100ppm	4822 051 51204	
R117	Resistor 15.0kΩ 1% 1/8W 100ppm	5322 116 82261	
R118	Resistor 15.0kΩ 1% 1/8W 100ppm	5322 116 82261	
R119	Resistor 180 kΩ 1% 1/8W 100ppm	4822 051 51804	

Item	Description	Ordering code	☆
R120	Resistor 180 kΩ 1% 1/8W 100ppm	4822 051 51804	
R121	Resistor 6.80kΩ 1% 1/8W 100ppm	4822 051 10682	
R122	Resistor 6.80kΩ 1% 1/8W 100ppm	4822 051 10682	
R123	Resistor 10.0 Ω 1% 1/8W 100ppm	4822 051 10109	
R124	Resistor 10.0 Ω 1% 1/8W 100ppm	4822 051 10109	
R125	Resistor 5.60kΩ 1% 1/8W 100ppm	4822 051 10562	
R126	Resistor 5.60kΩ 1% 1/8W 100ppm	4822 051 10562	
R127	Resistor 100kΩ 1% 1/8W 100ppm	4822 051 51004	
R128	Resistor 100kΩ 1% 1/8W 100ppm	4822 051 51004	
R136	Resistor 120 kΩ 1% 1/8W 100ppm	4822 051 51204	
R140	Resistor 100kΩ 1% 1/8W 100ppm	4822 051 51004	
R141	Resistor 100kΩ 1% 1/8W 100ppm	4822 051 51004	
R143	Resistor 0 Ω Jumper RC-01	4822 051 10008	
R144	Resistor 0 Ω Jumper RC-01	4822 051 10008	
R145	Resistor 0 Ω Jumper RC-01	4822 051 10008	
R146	Resistor 56.0kΩ 1% 1/8W 100ppm	5322 117 10971	
R147	Resistor 2.20kΩ 1% 1/8W 100ppm	4822 051 52202	
R148	Resistor 680 kΩ 1% 1/8W 100ppm	5322 117 11787	
R149	Resistor 0.22Ω 5% 1/8W LRC01 3.2x1.6	5322 117 11786	R
R150	Resistor 0.22Ω 5% 1/8W LRC01 3.2x1.6	5322 117 11786	R
R151	Resistor 2.20kΩ 1% 1/8W 100ppm	4822 051 52202	
R152	Resistor 56.0kΩ 1% 1/8W 100ppm	5322 117 10971	
R153	Resistor 100kΩ 1% 1/8W 100ppm	4822 051 51004	
R154	Resistor 100kΩ 1% 1/8W 100ppm	4822 051 51004	
R155	Resistor 100kΩ 1% 1/8W 100ppm	4822 051 51004	
R156	Resistor 100 Ω 1% 1/8W 100ppm	4822 051 51001	
R157	Resistor 1.00mΩ 1% 1/8W 100ppm	4822 051 10105	
R160	Resistor 100kΩ 1% 1/8W 100ppm	4822 051 51004	
R162	Resistor 100kΩ 1% 1/8W 100ppm	4822 051 51004	
R164	Resistor 10.0kΩ 1% 1/8W 100ppm	4822 051 51003	
R165	Resistor 10.0kΩ 1% 1/8W 100ppm	4822 051 51003	
R166	Resistor 100 Ω 1% 1/8W 100ppm	4822 051 51001	
R170	Resistor 100kΩ 1% 1/8W 100ppm	4822 051 51004	
R171	Resistor 100kΩ 1% 1/8W 100ppm	4822 051 51004	
R172	Resistor 150 kΩ 1% 1/8W 100ppm	4822 051 51504	
R181	Resistor 100kΩ 1% 1/8W 100ppm	4822 051 51004	
R186	Resistor 10.0kΩ 1% 1/8W 100ppm	4822 051 51003	
R191	Resistor 680 kΩ 1% 1/8W 100ppm	5322 117 11787	
R192	Resistor 1.00kΩ 1% 1/8W 100ppm	4822 051 51002	
R194	Resistor 100kΩ 1% 1/8W 100ppm	4822 051 51004	
R195	Resistor 100kΩ 1% 1/8W 100ppm	4822 051 51004	
R196	Resistor 100kΩ 1% 1/8W 100ppm	4822 051 51004	
R197	Resistor 100kΩ 1% 1/8W 100ppm	4822 051 51004	
R198	Resistor 100kΩ 1% 1/8W 100ppm	4822 051 51004	
R199	Resistor 100kΩ 1% 1/8W 100ppm	4822 051 51004	

Item	Description	Ordering code	☆
R202	Resistor 0 Ω Jumper RC-01	4822 051 10008	
R203	Resistor 100 Ω 1% 1/8W 100ppm	4822 051 51001	
R204	Resistor 1.00mΩ 1% 1/8W 100ppm	4822 051 10105	
R205	Resistor 100kΩ 1% 1/8W 100ppm	4822 051 51004	
R209	Resistor 100kΩ 1% 1/8W 100ppm	4822 051 51004	
R210	Resistor 100kΩ 1% 1/8W 100ppm	4822 051 51004	
R211	Resistor 6.80kΩ 1% 1/8W 100ppm	4822 051 10682	
R212	Resistor 1.00kΩ 1% 1/8W 100ppm	4822 051 51002	
R213	Resistor 470 Ω 1% 1/8W 100ppm	4822 051 54701	
R214	Resistor 0.22Ω 5% 1/8W LRC01 3.2x1.6	5322 117 11786	R
R215	Resistor 0.22Ω 5% 1/8W LRC01 3.2x1.6	5322 117 11786	R
R216	Resistor 10.0kΩ 1% 1/8W 100ppm	4822 051 51003	
T1	Transformer-Control Fluke 160-ser	5322 148 20044	R
U1	IC-CompAD96687BP PLCC20	4822 209 62795	R
U1a	IC-Op AmpLF453CM SMD SO8 JFET	4822 209 63757	
U1b	IC-Op Amp LF453CM SMD SO8 JFET	4822 209 63757	
U2	IC-Op Amp TLE2022C SMD SO	5322 209 90433	R
U3	IC-Ref 2.5V TL431I-D SO8	5322 209 62422	R
U5	IC-CMOS 74HC4094 SO16 SMD	5322 209 12171	
U6	IC-CMOS PC74HC299T SMD SO20	5322 209 60423	
U7	IC-CMOS PC74HC299T SMD SO20	5322 209 60423	
U8	IC-CMOS PC74HC299T SMD SO20	5322 209 60423	
U10	IC-Reg ChargeTEA1101T SMD	5322 209 90514	R
U12	IC-Op Amp LM358 X2 SMDSO8	4822 209 60175	R
U13	IC-CMOS PC74HC126T SMD SO14	5322 209 32402	
U14	IC-CMOS 74HC4094 SO16 SMD	5322 209 12171	
U15	IC-CMOS 74HC4316 SO14 SMD	5322 209 90437	
U16	IC-Op AmpTLE2022C SMD SO	5322 209 90433	R
U17	IC-Op Amp TLE2022C SMD SO	5322 209 90433	R
U19	IC PC74HC00T SO14	5322 209 71802	
U20	IC-Bus Transc. 75ALS176D SO-8SMD	5322 209 33171	R
U21	IC PC74HC74TSO14	5322 209 71589	
V1	Transistor 0.5A BC817-25 45V SOT23	4822 130 42804	
V1a	Transistor-FET SMD BF991 SOT23	5322 130 61707	
V1b	Transistor-FET SMD BF991 SOT23	5322 130 61707	
V2	Transistor 0.5A BC817-25 45V SOT23	4822 130 42804	
V2a	Transistor BFS17 0.05A 15V SOT23	5322 130 40781	
V2b	Transistor BFS17 0.05A 15V SOT23	5322 130 40781	
V3	Transistor 0.5A BC817-25 45V SOT23	4822 130 42804	
V3a	Transistor 25mA BFR92A 20VSOT23	5322 130 60647	
V3b	Transistor 25mA BFR92A 20V SOT23	5322 130 60647	
V4	Transistor 0.5A BC817-25 45V SOT23	4822 130 42804	
V4a	Transistor-Sw N PMBTH10 SOT23	5322 130 63821	
V4b	Transistor-Sw N PMBTH10 SOT23	5322 130 63821	
V5a	Transistor BFR93 35mA12V SOT23	5322 130 44801	

Item	Description	Ordering code	☆
V5b	Transistor BFR93 35mA12V SOT23	5322 130 44801	
V6a	Transistor BFT93 35mA12V SOT23	5322 130 44824	
V6b	Transistor BFT93 35mA12V SOT23	5322 130 44824	
V7	Transistor 0.5A BC807-25 45V SOT23	5322 130 60845	
V7a	Transistor-Sw P PMBTH81 SOT23	5322 130 63822	
V7b	Transistor-Sw P PMBTH81 SOT23	5322 130 63822	
V8a	Transistor BFR31 .01A 25V SOT23	5322 130 44787	
V8b	Transistor BFR31 .01A 25V SOT23	5322 130 44787	
V9	Transistor 0.5A BC807-25 45V SOT23	5322 130 60845	
V10	Transistor 0.5A BC807-25 45V SOT23	5322 130 60845	
V11	Transistor 0.5A BC807-25 45V SOT23	5322 130 60845	
V12	Transistor 0.5A BC817-25 45V SOT23	4822 130 42804	
V13	Transistor 0.5A BC817-25 45V SOT23	4822 130 42804	
V14	Transistor 0.5A BC817-25 45V SOT23	4822 130 42804	
V15	Transistor 0.5A BC817-25 45V SOT23	4822 130 42804	
V16	Transistor 0.5A BC807-25 45V SOT23	5322 130 60845	
V18	Transistor-Pow N MOSFET BUZ11A SMD	5322 130 62654	R
V19	Transistor-Pow N MOSFET BUZ11A SMD	5322 130 62654	R
V20	Transistor-Pow N MOSFET BUZ11A SMD	5322 130 62654	R
V21	Thyristor BRY62 SMD SOT143	5322 130 62661	R
V24	Transistor BC857B .1A45V SOT23	5322 130 60508	
V25	Transistor BC857B .1A45V SOT23	5322 130 60508	
V27	Transistor BC857B .1A45V SOT23	5322 130 60508	
V28	Transistor 0.5A BC817-25 45V SOT23	4822 130 42804	
V30	Transistor BC847B .1A45V SOT23	4822 130 60511	
V33	Transistor 0.5A BC807-25 45V SOT23	5322 130 60845	
V34	Transistor-FET SMD MOS SI4435DY SO8	5322 130 10679	

Interpolator PCA (Part of Display PCA)

Item	Description	Part Number	☆
C1	Capacitor 470pF 1% 63V NP0	5322 126 14051	
C2	Capacitor 22pF 5% 50V NP0	5322 122 32658	
C3	Capacitor 390pF 5% 50V NP0	4822 122 32636	
C4	Capacitor 470pF 1% 63V NP0	5322 126 14051	
C5	Capacitor 22pF 5% 50V NP0	5322 122 32658	
C6	Capacitor 390pF 5% 50V NP0	4822 122 32636	
C7	Capacitor 100nF 20% 25V X7R	5322 126 13638	
C8	Capacitor 100nF 20% 25V X7R	5322 126 13638	
C9	Capacitor 100nF 20% 25V X7R	5322 126 13638	
C10	Capacitor 100nF 20% 25V X7R	5322 126 13638	
C11	Capacitor 100nF 20% 25V X7R	5322 126 13638	
C12	Capacitor 15 µF 20%6.3V 6.0x3.2 Mold	5322 124 11418	
D1	Diode 0.10A BAV99SOT23	5322 130 34337	
D2	Diode 0.10A BAV99SOT23	5322 130 34337	
D4	Diode 0.10A BAV99SOT23	5322 130 34337	
D5	Diode 0.10A BAV99SOT23	5322 130 34337	
D7	Diode 0.25A BAS2875VSOT143	5322 130 80214	
R1	Resistor 2.20kΩ 1% 1/8W 100ppm	4822 051 52202	
R2	Resistor 8.20kΩ 1% 1/8W 100ppm	4822 051 10822	
R3	Resistor 820 Ω 1% 1/8W 100ppm 1206	5322 116 82264	
R4	Resistor 100 Ω 1% 1/8W 100ppm 1206	4822 051 51001	
R5	Resistor 33.0kΩ 1% 1/8W 100ppm	4822 051 53303	
R6	Resistor 33.0kΩ 1% 1/8W 100ppm	4822 051 53303	
R7	Resistor 2.20kΩ 1% 1/8W 100ppm	4822 051 52202	
R8	Resistor 270 Ω 1% 1/8W 100ppm 1206	4822 051 10271	
R9	Resistor 560 Ω 1% 1/8W 100ppm 1206	4822 051 10561	
R10	Resistor 33.0 Ω 1% 1/8W 100ppm 1206	4822 051 10339	
R11	Resistor 220.0Ω 1% 1/8W 100ppm	4822 051 52201	
R12	Resistor 2.20kΩ 1% 1/8W 100ppm	4822 051 52202	
R13	Resistor 8.20kΩ 1% 1/8W 100ppm	4822 051 10822	
R14	Resistor 820 Ω 1% 1/8W 100ppm 1206	5322 116 82264	
R15	Resistor 100 Ω 1% 1/8W 100ppm 1206	4822 051 51001	
R16	Resistor 33.0kΩ 1% 1/8W 100ppm	4822 051 53303	
R17	Resistor 33.0kΩ 1% 1/8W 100ppm	4822 051 53303	
R18	Resistor 2.20kΩ 1% 1/8W 100ppm	4822 051 52202	
R19	Resistor 22 Ω 1% 1/8W 100ppm 1206	4822 051 10229	
R20	Resistor 120 Ω 1% 1/8W 100ppm 1206	4822 051 10121	
R21	Resistor 68 Ω 1% 1/8W 100ppm 1206	4822 051 10689	
R22	Resistor 220.0Ω 1% 1/8W 100ppm	4822 051 52201	
R23	Resistor 12.0 Ω 1% 1/8W 100ppm 1206	4822 051 10109	
R24	Resistor 33.0 Ω 1% 1/8W 100ppm 1206	4822 051 10339	
2	IC-CMOS PC74HC541T SMD SO20	4822 209 63763	
3	IC-ADC 8bit SO20 ADC0820CNED	5322 209 14861	R

Item	Description	Part Number	☆
5	IC-ADC 8bit SO20 ADC0820CNED	5322 209 14861	R
6	IC-CMOS PC74HC541T SMD SO20	4822 209 63763	
V1	Transistor BFT92 25mA15V SOT23	5322 130 44711	
V2	Transistor BFS17 0.05A 15V SOT23	5322 130 40781	
V3	Transistor BFT92 25mA15V SOT23	5322 130 44711	
V4	Transistor BFS17 0.05A 15V SOT23	5322 130 40781	
Z1	IC PC74HC00T SO14	5322 209 71802	
Z5	IC PC74HC00T SO14	5322 209 71802	

Prescaler PCA (1.3 GHz HF-input, only 164T and 164H)

Item	Description	Ordering code	☆
11	Capacitor 330pF	5322 122 32335	
12	BNC Holder	5322 256 10295	
13	Spring	4031 100 58080	
14	Shield Cover	5322 466 30474	R
15	Shielding Strip	5322 466 11304	

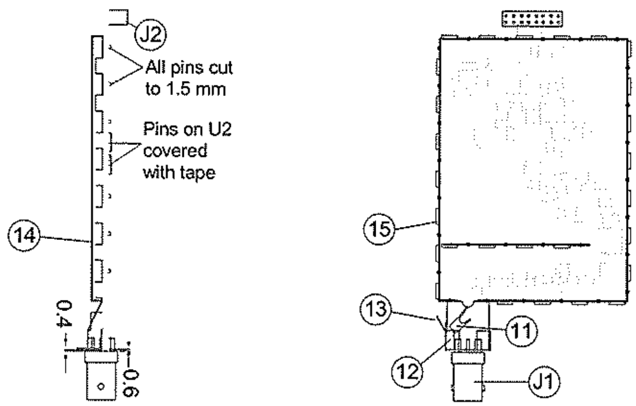


Figure 8-9. Mecanical parts of Prescaler PCA

C1	Capacitor 100pF 5% 50V NP0 (Not Fitted)	5322 122 32531
C2	Capacitor 1nF 20% 50V X7R	5322 122 34123
C3	Capacitor 1nF 20% 50V X7R	5322 122 34123
C4	Capacitor 10nF 20% 50V X7R	5322 122 34098
C5	Capacitor 1nF 20% 50V X7R	5322 122 34123
C6	Capacitor 1nF 20% 50V X7R	5322 122 34123
C7	Capacitor 47pF 5% 50V NP0	5322 122 32452
C8	Capacitor 1nF 20% 50V X7R	5322 122 34123
C10	Capacitor 4.7pF 5% 50V NP0	5322 122 32287
C11	Capacitor 1nF 20% 50V X7R	5322 122 34123
C12	Capacitor 1nF 20% 50V X7R	5322 122 34123
C13	Capacitor 15pF 5% 50V NP0	5322 122 33869
C14	Capacitor 1nF 20% 50V X7R	5322 122 34123
C16	Capacitor 1pF 5% 50V NP0	5322 122 32447
C17	Capacitor 1nF 20% 50V X7R	5322 122 34123
C18	Capacitor 10nF 20% 50V X7R	5322 122 34098
C19	Capacitor 10nF 20% 50V X7R	5322 122 34098
C20	Capacitor 10nF 20% 50V X7R	5322 122 34098
C21	Capacitor 10nF 20% 50V X7R	5322 122 34098
C22	Capacitor 10nF 20% 50V X7R	5322 122 34098
C23	Capacitor 15 µF 20%6.3V 6.0x3.2	5322 124 11418
C24	Capacitor 1nF 20% 50V X7R	5322 122 34123
C25	Capacitor 10nF 20% 50V X7R	5322 122 34098
C26	Capacitor 10nF 20% 50V X7R	5322 122 34098
C27	Capacitor 10nF 20% 50V X7R	5322 122 34098

Item	Description	Ordering code	☆
C31	Capacitor 1pF 5% 50V NP0	5322 122 32447	
C32	Capacitor 3.3pF 5% 50V NP0	5322 122 32286	
C34	Capacitor 3.3pF 5% 50V NP0	5322 122 32286	
C35	Capacitor 22pF 5% 50V NP0	5322 122 32658	
C36	Capacitor 10nF 20% 50V X7R	5322 122 34098	
C38	Capacitor 10nF 20% 50V X7R	5322 122 34098	
C39	Capacitor 1nF 20% 50V X7R	5322 122 34123	
C40	Capacitor 1nF 20% 50V X7R	5322 122 34123	
C42	Capacitor 10nF 20% 50V X7R	5322 122 34098	
C43	Capacitor 10nF 20% 50V X7R	5322 122 34098	
C46	Capacitor 10nF 20% 50V X7R	5322 122 34098	
C47	Capacitor 10nF 20% 50V X7R	5322 122 34098	
C49	Capacitor 10nF 20% 50V X7R	5322 122 34098	
C50	Capacitor 10nF 20% 50V X7R	5322 122 34098	
C51	Capacitor 2.2pF 5% 50V NP0	5322 122 33063	
D1	Diode 0.03A BAT17SOT23	5322 130 31544	
D2	Diode 0.03A BAT17SOT23	5322 130 31544	
D3	Diode BAR16-1 SOT23	5322 130 80246	
D5	Diode 0.03A BAT17SOT23	5322 130 31544	
D6	Diode 0.03A BAT17SOT23	5322 130 31544	
D7	Diode 0.03A BAT17SOT23	5322 130 31544	
D8	Diode 0.10A BAV99SOT23	5322 130 34337	
D9	Diode 0.03A BAT17SOT23	5322 130 31544	
D10	Diode 0.03A BAT17SOT23	5322 130 31544	
D11	Diode 0.10A BAV99SOT23	5322 130 34337	
D12	Diode 0.10A BAV99SOT23	5322 130 34337	
D13	Diode 0.10A BAV99SOT23	5322 130 34337	
J1	Connector-Coax 31-5329-52RFX	5322 265 10297	
J2	Connector Socket 16 Pole 70182 1 5-44-3716	5322 267 70355	
L1	Choke 0.10 µH 10% MLF3216DR10K	5322 157 52986	
L7	Choke 0.10 µH 10% MLF3216DR10K	5322 157 52986	
L8	Choke 0.10 µH 10% MLF3216DR10K	5322 157 52986	
L9	Choke 0.10 µH 10% MLF3216DR10K	5322 157 52986	
L10	Choke 31 Ω CB50-321611T	5322 157 61919	
L12	Choke 31 Ω CB50-321611T	5322 157 61919	
R1	Resistor 470 Ω 1% 1/8W 100ppm	4822 051 54701	
R2	Resistor 470 Ω 1% 1/8W 100ppm	4822 051 54701	
R3	Resistor 470 Ω 1% 1/8W 100ppm	4822 051 54701	
R4	Resistor 22 Ω 1%1/8W 100ppm	4822 051 10229	
R5	Resistor 22 Ω 1% 1/8W 100ppm	4822 051 10229	
R6	Resistor 22 Ω 1% 1/8W 100ppm	4822 051 10229	
R7	Resistor 22 Ω 1% 1/8W 100ppm	4822 051 10229	
R8	Resistor 22 Ω 1% 1/8W 100ppm	4822 051 10229	
R9	Resistor 22 Ω 1% 1/8W 100ppm	4822 051 10229	
R10	Resistor 270 Ω 1% 1/8W 100ppm	4822 051 10271	

Item	Description	Ordering code	☆
R11	Resistor 330 Ω 1% 1/8W 100ppm	4822 051 53301	
R12	Resistor 330 Ω 1% 1/8W 100ppm	4822 051 53301	
R13	Resistor 8.2 Ω 10% ¼W RC-01	4822 051 10828	
R14	Resistor 150 Ω 1% 1/8W 100ppm	4822 051 51501	
R15	Resistor 8.2 Ω 10% ¼W RC-01	4822 051 10828	
R16	Resistor 220.0Ω 1% 1/8W 100ppm	4822 051 52201	
R19	Resistor 33.0 Ω 1% 1/8W 100ppm	4822 051 10339	
R20	Resistor 10.0 Ω 1% 1/8W 100ppm	4822 051 10109	
R21	Resistor 47 Ω 1% 1/8W 100ppm	5322 116 80448	
R22	Resistor 47 Ω 1% 1/8W 100ppm	5322 116 80448	
R24	Resistor 180.0Ω 1% 1/8W 100ppm	4822 051 10181	
R25	Resistor 2.70kΩ 1% 1/8W 100ppm	4822 051 52702	
R26	Resistor 47 kΩ 1% 1/8W 100ppm	5322 116 80446	
R27	Resistor 2.20kΩ 1% 1/8W 100ppm	4822 051 52202	
R28	Resistor 270 Ω 1% 1/8W 100ppm	4822 051 10271	
R29	Resistor 330 Ω 1% 1/8W 100ppm	4822 051 53301	
R30	Potentiometer 1 kΩ 3304X-1-102E	5322 101 11095	
R31	Resistor 47 kΩ 1% 1/8W 100ppm	5322 116 80446	
R32	Resistor 4.70kΩ 1% 1/8W 100ppm	4822 051 54702	
R33	Resistor 3.30kΩ 1% 1/8W 100ppm	4822 051 53302	
R35	Resistor 220 kΩ 1% 1/8W 100ppm	4822 051 52204	
R38	Resistor 1.00kΩ 1% 1/8W 100ppm	4822 051 51002	
R39	Resistor 470 kΩ 1% 1/8W 100ppm	5322 116 80447	
R40	Resistor 33.0kΩ 1% 1/8W 100ppm	4822 051 53303	
R42	Resistor 27.0 Ω 1% 1/8W 100ppm	5322 116 82262	
R43	Resistor 1.80kΩ 1% 1/8W 100ppm	4822 051 10182	
R44	Resistor 3.30kΩ 1% 1/8W 100ppm	4822 051 53302	
R47	Resistor 470 Ω 1% 1/8W 100ppm	4822 051 54701	
R48	Resistor 82 Ω 1% 1/8W 100ppm	4822 051 10829	
R52	Resistor 47 kΩ 1% 1/8W 100ppm	5322 116 80446	
R53	Resistor 10.0kΩ 1% 1/8W 100ppm	4822 051 51003	
R55	Resistor 33.0 Ω 1% 1/8W 100ppm	4822 051 10339	
R56	Resistor 22 Ω 1% 1/8W 100ppm	4822 051 10229	
R57	Resistor 100 Ω 1% 1/8W 100ppm	4822 051 51001	
R60	Resistor 27.0 Ω 1% 1/8W 100ppm	5322 116 82262	
R61	Resistor 1.00kΩ 1% 1/8W 100ppm	4822 051 51002	
R62	Resistor 1.00kΩ 1% 1/8W 100ppm	4822 051 51002	
R64	Resistor 470 kΩ 1% 1/8W 100ppm	5322 116 80447	
R65	Resistor 220 kΩ 1% 1/8W 100ppm	4822 051 52204	
R66	Resistor 0 Ω Jumper RC-01	4822 051 10008	
R67	Resistor 120 Ω 1% 1/8W 100ppm	4822 051 10121	
R68	Resistor 120 Ω 1% 1/8W 100ppm	4822 051 10121	
R69	Resistor 470 Ω 1% 1/8W 100ppm	4822 051 54701	
U1	IC NEC UPC1652G SO-8 Var	5322 209 71557	R
U2	IC Telefunken U893BSE DIL8	5322 209 90432	R

Item	Description	Ordering code	☆
U3	IC NE532D Dual OP-AMP SO-8	5322 209 71553	
V1	Transistor BFQ67SOT23	5322 130 42567	
V2	Transistor BFQ67SOT23	5322 130 42567	
V3	Transistor BC847B .1A45V SOT23	4822 130 60511	
V4	Transistor BC847B .1A45V SOT23	4822 130 60511	
V5	Transistor BFT92 25mA15V SOT23	5322 130 44711	
V6	Transistor BFT92 25mA15V SOT23	5322 130 44711	
V7	Transistor 0.5A BC807-25 45VSOT23	5322 130 60845	
V8	Transistor BFS17 0.05A 15V SOT23	5322 130 40781	
V9	Transistor BFS17 0.05A 15V SOT23	5322 130 40781	
V10	Transistor BFS17 0.05A 15V SOT23	5322 130 40781	
V11	Transistor BFS17 0.05A 15V SOT23	5322 130 40781	

Chapter 9
Circuit Diagrams

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