8 Detectors

Overview

Applications

Keysight Technologies broadband detectors[1] span frequencies from 100 kHz to 50 GHz. These detectors are widely used on the design and production test bench, as well as for internal components of test system signal interface units. They find use in a variety of test and measurement applications.

– Power monitoring
– Source leveling
– Video detection
– Swept transmission and reflection measurements

Technology

Keysight detectors are available in two families – Silicon Low Barrier Schottky Diode (LBSD) and Gallium Arsenide Planar Doped Barrier Diode (GaAs PDBD) detectors. The Gallium Arsenide detector technology produces diodes with extremely flat frequency response to 50 GHz. Also, the GaAs PDBD detector has a wider operating temperature range (–65 °C to +100 °C), and is less sensitive to temperature changes.

Key Specifications

– Frequency range
– Frequency response
– Open circuit voltage sensitivity
– Tangential sensitivity
– Output voltage versus temperature
– Rise time
– SWR
– Square-law response
– Input power

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Frequency Range

Frequency range can be one of the most important factors to consider when specifying detectors. In the past, broadband frequency coverage was equated with high performance. It is important to note that though broadband coverage may be desirable in multi-octave applications, a good octave range detector may be your best solution for non-swept applications. Broadband coverage saves you from the inconvenience of having to switch between detectors when making measurements, but you may be sacrificing SWR and frequency response flatness.

Frequency Response

Frequency response is the variation in output voltage versus frequency, with a constant input power. Frequency response is referenced to the lowest frequency of the band specified. Keysight typically uses –30 dBm to measure frequency response. Keysight uses precision thin-film input circuitry to provide good, broadband input matching. Exceptionally flat frequency response is provided by the very low internal capacitance of the PDB diode. Also, excellent control of the video resistance of the PDB diode is obtained by the precision growth of molecular beam epitaxy (MBE) layers during diode fabrication.

Figure 1 displays frequency response characteristics comparing Keysight LBSD and PDBD detectors. The figure indicates typical performance of each device and the published specifications. Frequency response specifications include the mismatch effects of the detector input SWR specifications. Note that the Keysight 8474E, representative of PDBD detectors, is exceptionally flat beyond 26.5 GHz.

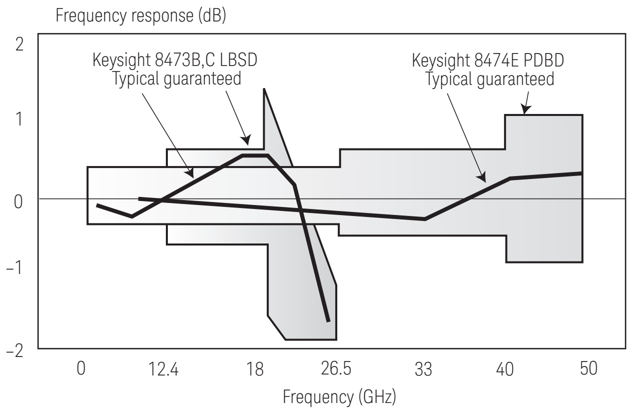


Figure 1. Detector frequency response characteristics

Open Circuit Voltage Sensitivity

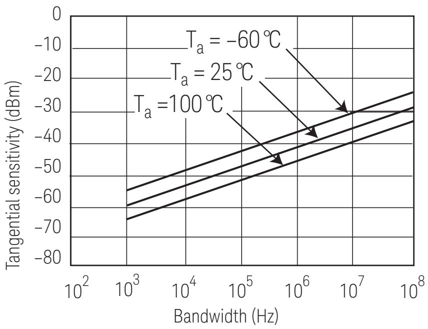
The open circuit voltage sensitivity (K) describes the slope of the transfer function of the detectors. This represents the conversion of RF/microwave power to a voltage at the output connector, typically specified in mV/uW. The value is an indication of the efficiency of the diode in converting the input power to a useful voltage.

Sensitivity is measured with the detector terminated in a high impedance. When used in video pulse applications, the sensitivity will appear to be much lower when terminated in 50 or 75 Ω for connection to an oscilloscope. Another factor, called the Figure of Merit, gives an indication of low-level sensitivity without consideration of a load circuit. It is useful for comparing detectors with different values of K and Rv. Figure of Merit equals $K/\sqrt{Rv}$, where Rv = internal video resistance.

[1] See Waveguide chapter for additional products.

Tangential Sensitivity

Tangential sensitivity is the lowest input signal power level for which the detector will have an 8 dB signal-to-noise ratio at the output of a test video amplifier. Test amplifier gain is not relevant because it applies to both signal and noise. Keysight detectors are designed for optimal flatness and SWR. Figure 2 shows typical tangential sensitivity.



$$P_{tss\,(watts)} = \frac{3.23 \times 10^{-10} \sqrt{BFR_V}}{K} \quad @\ 300\ °K$$

Where:
B = Video amplifier bandwidth (Hz)
F = Video amplifier noise factor = $10^{(\text{Noise figure}/10)}$
R_V = Video resistance (Ω)
K = Open circuit voltage Sensitivity (mV/uW)

Figure 2. Typical tangential sensitivity performance

Output Voltage Versus Temperature

For applications such as power monitoring and leveling that require stable output voltage versus input power, the designer can choose a resistive termination that will optimize the transfer function over a wide temperature range. Figure 3 shows how sensitivity changes over temperature with different load resistances. In this case, a value between 1 kΩ and 10 kΩ will be optimum for 0 to 50 °C.

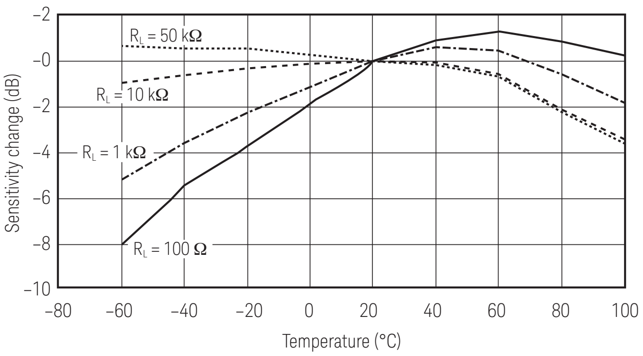


Figure 3: Typical output response with temperature (Pin <-20 dBm) (Planar-Doped Barrier Diode)

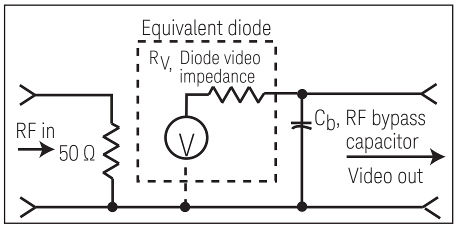
Rise Time

In applications where the frequency response of another microwave device is being measured, or where a fast rise time response is required for accurate measurements, the rise time of the detector becomes very important. It is critical to note that the rise time is dependent upon the characteristics of the detector AND the test equipment.

Figure 4 shows the typical equivalent circuit of a test detector, and can help in devising the external terminations and cables to connect to an oscilloscope or other instrument. The following equation gives the approximate rise time for different conditions of load resistance and capacitance. Note that rise time can be improved (lowered) with a termination of less than 50 Ω. This rise time improvement comes at the expense of lower pulse output voltage. The lower voltage can be overcome with the gain of a high performance oscilloscope.

$$T_r\ (10\%\ \text{to}\ 90\%) = \frac{2.2 * R_L * R_V * (C_L + R_b)}{R_L + R_V} = \frac{0.35}{BW}$$

Where
R_L = Load impedance
R_V = Video impedance
C_L = Load capacitance
C_b = Bypass capacitance



Typical values:
R_V (diode video impedance) = 1.5 kΩ[1]
C_b (RF bypass capacitor) = 27 pF nom.

[1] @ 25 °C and P_{in} <–20 dBm.
Extremely sensitive to power and temperature

Figure 4. Detector model

Broadband Match (SWR)

In many applications, the match (SWR) of the detector is of prime importance in minimizing the uncertainty of power measurements. If the input of the detector is not well matched to the source, simple and multiple mismatch errors will result, reducing the accuracy of the measurement.

Figure 5 represents the mismatch error introduced by multiple reflections caused by a mismatch between the detector and the source. For a detector SWR of 2.0 and source SWR of 2.0, the uncertainty is ±1.0 dB. For the LBSD and PDBD models, the integration of the diode with the 50 Ω matching resistor results in an excellent broadband match. Both LBSD and PDBD detectors utilize thin-film technology which yields a precision matching circuit that minimizes stray reactance and yields very good performance. Figure 6 displays typical SWR for the Keysight 8473B,C LBSD detector and the Keysight 8473D PDBD detector.

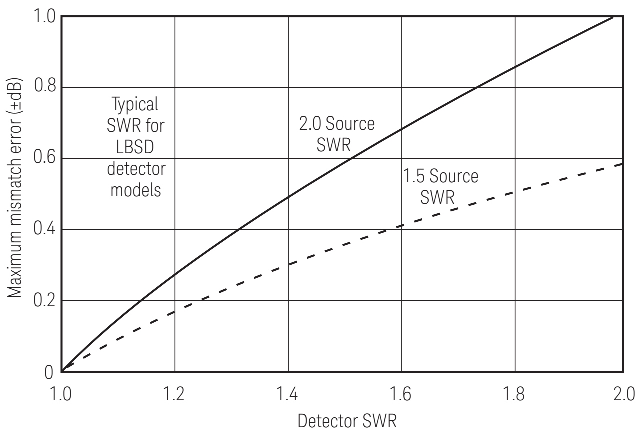


Figure 5. Measurement uncertainty due to detector source mismatch

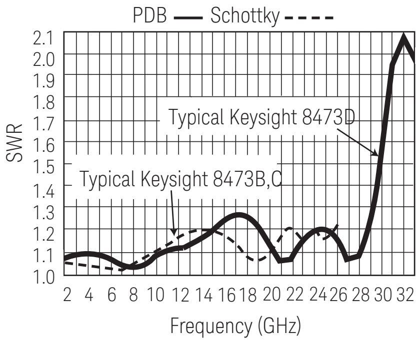


Figure 6. Typical SWR of detectors

Square Law Performance

When detectors are used in reflectometer and insertion loss setups, the measurement uncertainty depends on the output voltage being proportional to input power. The term square law comes from the output voltage being proportional to the input power (input voltage squared). Most microwave detectors are inherently square law from the P_{tss} level up to about –15 dBm. Figure 7 shows this characteristic.

Figure 8 shows detector output in dB relative to P_{in} = –20 dBm. As P_{in} exceeds –20 dBm, the detector response deviates from square law. The user can select a load resistor that will extend the upper limit of the square law range beyond ±15 dBm. By choosing the square law load option, the deviation from ideal square law response will be ±0.5 dB (although the sensitivity specification is decreased by a factor of 4).

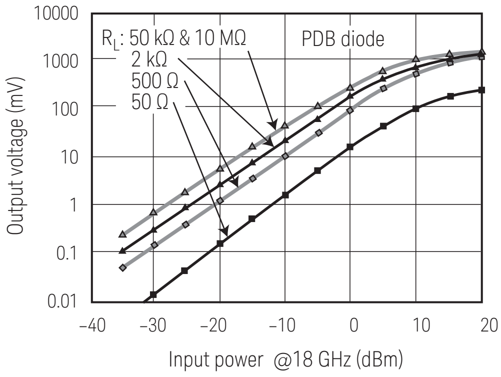


Figure 7. Typical detector square law response (mV)

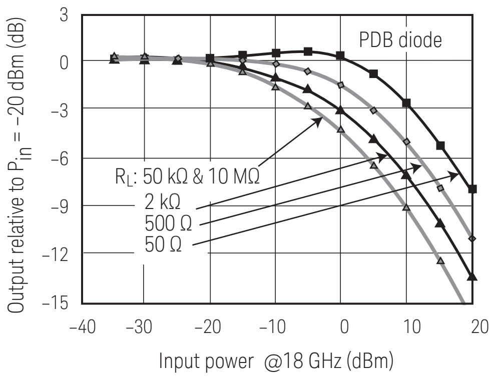


Figure 8. Typical detector square law response (dB)

8471D planar-doped barrier detector


8471E planar-doped barrier detector

8473D planar-doped barrier detector

8474 family of planar-doped barrier detector

Planar-Doped Barrier Detectors

Keysight 8471D and 8471E detectors are planar-doped barrier detectors offering excellent performance to 2 and 12 GHz. The 8471D covers 100 kHz to 2 GHz with a BNC (m) input connector and the 8471E covers 10 MHz to 12 GHz with a SMA (m) input connector. Both detectors come standard with negative polarity output, a positive polarity output is available with option 103.

High Performance Planar-Doped Barrier Detectors

8474B/C/E detectors are the newest additions to the Keysight family of high performance detectors. Utilizing a gallium arsenide, planar-doped barrier detecting diode, these detectors offer superior performance when compared to Schottky diodes. They feature extremely flat frequency response (typically better than ±1 dB to 50 GHz) and very stable frequency response versus temperature.

These detectors are available with type-N, 3.5-mm, or 2.4-mm connectors. They are also offered with an option for positive output polarity (Option 103). Additionally, some detectors have an optimal square law load available (Option 102).

For applications requiring an octave band or less, 8474B/C/E detectors are available with frequency band options that feature lower SWR and flatter frequency response.

Specifications

Model	8471D	8471E	8473D	8474B	8474C	8474E
Frequency range (GHz)	0.0001 to 2	0.01 to 12	0.01 to 33	0.01 to 18	0.01 to 33	0.01 to 50
Frequency response (dB)	±0.2 to 1 GHz ±0.4 to 2 GHz	±0.23 to 4 GHz ±0.6 to 8 GHz ±0.85 to 12 GHz	±0.25 to 14 GHz ±0.4 to 26.5 GHz ±1.25 to 33 GHz (±2.0 dB typical to 40 GHz)	±0.35 to 18 GHz	±0.45 to 26.5 GHz ±0.7 to 33 GHz	±0.4 to 26.5 GHz ±0.6 to 40 GHz ±1.0 to 50 GHz
Maximum SWR	1.23 to 1 GHz 1.46 to 2 GHz	1.2 to 4 GHz 1.7 to 8 GHz 2.4 to 12 GHz	1.2 to 14 GHz 1.4 to 26.5 GHz 3.0 to 33 GHz (3.0 typical to 40 GHz)	1.3 to 18 GHz	1.4 to 26.5 GHz 2.2 to 33 GHz	1.2 to 26.5 GHz 1.6 to 40 GHz 2.8 to 50 GHz
Low-level sensitivity (mV/µW)	> 0.5	> 0.4	> 0.4	> 0.4	> 0.4 > 0.34 to 50 GHz	> 0.4 to 40 GHz
Maximum operating input power	100 mW	200 mW	200 mW	200 mW	200 mW	200 mW
Typical short term maximum input power (<1 minute)	0.7 W	0.75 W	1 W	0.75 W	0.75 W	0.75 W
Video impedance (nom)	1.5 kΩ	1.5 kΩ	1.5 kΩ	1.5 kΩ	1.5 kΩ	1.5 kΩ
RF bypass capacitance (nom)	6800 pF	30 pF	30 pF	27 pF	27 pF	27 pF
Output polarity	Negative	Negative	Negative	Negative	Negative	Negative
Input connector	BNC (m)	SMA (m)	3.5 mm (m)	Type-N (m)	3.5 mm (m)	2.4 mm (m)
Output connector	BNC (f)	SMC (m)	BNC (f)	BNC (f)	SMC (m)	SMC (m)

Options

Model	8471D	8471E	8473D	8474B	8474C	8474E
Optimal square law load [1]	Option 102	N/A	N/A	Option 102	N/A	N/A
Positive polarity output	Option 103	Option 103	Option 003	Option 103	Option 103	N/A
Frequency band	N/A	Option 004 4 GHz operation	N/A	See PDBD frequency band options		

[1] Defined as ±0.5 dB from ideal square law response

PDBD Frequency Band Options

8474B options	001	002	004	008
Frequency range (GHz)	0.01 to 18	0.01 to 2	2 to 4	4 to 8
Frequency response (dB)	±0.35	±0.25	±0.25	±0.25
Maximum SWR	1.31	1.09	1.1	1.2

8474C options	001	008	012	033
Frequency range (GHz)	0.01 to 33	4 to 8	8 to 12.4	26.5 to 33
Frequency response (dB)	±0.3	±0.2	±0.25	±0.3
Maximum SWR	2.2	1.16	1.2	2.2

Environmental Specifications

Operating temperature: –20 °C to +85 °C (Except Keysight 8474B: 0 °C to +75 °C)
Temperature cycling: –55 °C to +85 °C; MIL-STD 883, Method 1010 (non-operating)
Vibration: 0.6 inches D.A. 10 to 80 Hz; 20 g, 80 to 200 Hz; MIL-STD 883, Method 2007
Shock: 500 g, 0.5 ms; MIL-STD 883, Method 2002
Acceleration: 500 g; MIL-STD 883, Method 2001
Altitude: 50,000 ft (15,240 m); MIL-STD 883, Method 1001
Salt atmosphere: 48 hr, 5% solution; MIL-STD 883, Method 1009
Moisture resistance: 25 °C to 40 °C, 95% RH; MIL-STD 883, Method 1004
RFI: MIL-STD 461B
ESD: 10 discharges at 25 kV to the body, not to the center conductor

Outline Drawings

Diagram 1

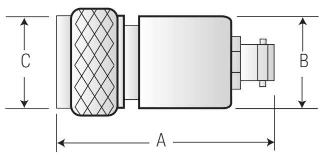


Diagram 2

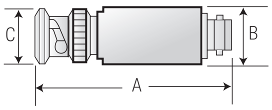


Diagram 3

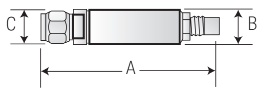
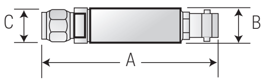


Diagram 4



Model	Length (Dim A)	Barrel diameter (Dim B)	Input connector diameter (Dim C)	Net weight	Shipping weight
Diagram 1					
8474B	60 mm (2.36 in)	19 mm (0.74 in)	21 mm (0.82 in)	85 g (3 oz)	454 g (16 oz)
Diagram 2					
8471D	63 mm (2.50 in)	16 mm (0.62 in)	14 mm (0.54 in)	39 g (1.4 oz)	454 g (16 oz)
Diagram 3					
8471E	39 mm (1.54 in)	9.3 mm (0.36 in)	7.9 mm (0.31 in)	39 g (1.4 oz)	454 g (16 oz)
8474C	41 mm (1.62 in)	9.7 mm (0.38 in)	7.9 mm (0.31 in)	14 g (0.5 oz)	454 g (16 oz)
8474E	41 mm (1.62 in)	9.7 mm (0.38 in)	7.9 mm (0.31 in)	9 g (0.3 oz)	454 g (16 oz)
Diagram 4					
8473D	48 mm (1.89 in)	10 mm (0.39 in)	7.9 mm (0.31 in)	57 g (2 oz)	454 g (16 oz)

Ordering Information

8471D
- **8471D-102** square law load
- **8471D-103** positive polarity

8471E
- **8471E-004** 0.01 to 4 GHz octave only
- **8471E-103** positive polarity

8473D
- **8473D-003** positive polarity

8474B
- **8474B-002** 0.01 to 2 GHz octave only
- **8474B-004** 2 to 4 GHz octave only
- 8474B-008 4 to 8 GHz octave only
- **8474B-102** [1] square law load
- **8474B-103** positive polarity

8474C
- **8474C-008** 4 to 8 GHz octave only
- **8474C-012** 8 to 12.4 GHz octave only
- **8474C-033** 26.5 to 33 GHz octave only
- **8474C-103** positive polarity

[1] Option 102 external square law load extends the square law region of the detector with deviation of ± 0.5 dB from the ideal square law response.

Related Literature

8471D coaxial RF microwave detectors datasheet, part number **5952-0644**

8471E coaxial RF microwave detectors datasheet, part number **5952-0802**

8473D planar-Doped barrier detector datasheet, part number **5954-8878**

8474B/C/E coaxial GaAs microwave detectors datasheet, part number **5952-0801**

Web Link

www.keysight.com/find/mta

33330B LBSD detector

33330C LBSD detector

423B LBSD detector

8470B LBSD detector

8472B LBSD detector

8473B LBSD detector

8473C LBSD detector

Low-Barrier Schottky Diode (LBSD) Detectors

Keysight 423B, 8470B, 8472B, 8473B/C, 33330B/C LBSD detectors have been widely used for many years in a variety of applications including leveling and power sensing. They offer good performance and ruggedness. Matched pairs (Option 001) offer very good detector tracking. A square law load option (Option 002) extends the square law region to at least 0.1 mW (–10 dBm).

Specifications

Model	423B	8470B	8472B	8473B	33330B	8473C	33330C
Freq. range (GHz)	0.01 to 12.4	0.01 to 18	0.01 to 18	0.01 to 18	0.01 to 18	0.01 to 26.5	0.01 to 26.5
Freq. response (dB) (±0.2 dB over any octave from 0.01 to 8 GHz on all models)	±0.3 to 12.4 GHz	±0.3 to 12.4 GHz ±0.5 to 15 GHz ±0.6 to 18 GHz	±0.3 to 12.4 GHz ±0.5 to 15 GHz ±0.6 to 18 GHz	±0.3 to 12.4 GHz ±0.6 to 18 GHz	±0.3 to 12.4 GHz ±0.6 to 18 GHz	±0.3 to 12.4 GHz ±0.6 to 20 GHz ±1.5 to 26.5 GHz[1]	±0.3 to 12.4 GHz ±0.6 to 20 GHz ±1.5 to 26.5 GHz
Maximum SWR (measured at –20 dBm)	1.15 to 4 GHz 1.3 to 12.4 GHz	1.15 to 4 GHz 1.3 to 15 GHz 1.7 to 18 GHz	1.2 to 4.5 GHz 1.35 to 7 GHz 1.5 to 12.4 GHz 1.7 to 18 GHz	1.2 to 4 GHz 1.5 to 18 GHz	1.2 to 4 GHz 1.5 to 18 GHz	1.2 to 4 GHz 1.5 to 18 GHz 2.2 to 26.5 GHz	1.2 to 4 GHz 1.5 to 18 GHz 2.2 to 26.5 GHz
Low-level sensitivity (mV/µW)	> 0.5	> 0.5	> 0.5	> 0.5	> 0.5	> 0.5 to 18 GHz > 0.18 to 26.5 GHz	> 0.5 to 18 GHz > 0.18 to 26.5 GHz
Maximum operating input power	200 mW	200 mW	200 mW	200 mW	200 mW	200 mW	200 mW
Typical short term maximum input power (< 1 minute)	1 W	1 W	1 W	1 W	1 W	1 W	1 W
Noise	< 50 µV	< 50 µV	< 50 µV	< 50 µV	< 50 µV	< 50 µV	< 50 µV
Video impedance (nom)	1.3 kΩ	1.3 kΩ	1.3 kΩ	1.3 kΩ	1.3 kΩ	1.3 kΩ	1.3 kΩ
RF bypass capacitance (nom)	50 pF	50 pF	50 pF	30 pF	30 pF	30 pF	30 pF
Output polarity	Negative	Negative	Negative	Negative	Negative	Negative	Negative
Input connector	Type-N (m)	APC-7 (m)	SMA (m)	3.5 mm (m)	3.5 mm (m)	3.5 mm (m)	3.5 mm (m)
Output connector	BNC (f)	BNC (f)	BNC (f)	BNC (f)	SMC (m)	BNC (f)	SMC (m)

Options

Model	423B	8470B	8472B	8473B	33330B	8473C	33330C
Matched response[2] (Option 001)	±0.2 dB to 12.4 GHz	±0.2 dB to 12.4 GHz ±0.3 dB to 18 GHz	±0.2 dB to 12.4 GHz ±0.3 dB to 18 GHz	±0.2 dB to 12.4 GHz ±0.3 dB to 18 GHz	±0.2 dB to 12.4 GHz ±0.3 dB to 18 GHz	±0.2 dB to 12.4 GHz ±0.3 dB to 18 GHz ±0.5 dB to 26.5 GHz	±0.2 dB to 12.4 GHz ±0.3 dB to 18 GHz ±0.5 dB to 26.5 GHz
Optimal square law load[3]	Option 002	Option 002	Option 002	Option 002		Option 002	
Positive polarity output	Option 003	Option 003	Option 003	Option 003	Option 003	Option 003	Option 003
Connector		Option 012 Type-N (m) input connector	Option 100 OSSM (f) output connector				

1 From a –3.3 dB linear slope beginning at 20 GHz
2 Must order a quantity of 2 standard units and quantity of 2 Option 001 for a pair of detectors with matched frequency response
3 Defined as ±0.5 dB from ideal square law response

Environmental Specifications

Operating temperature: –20 °C to +85 °C (except Keysight 423B: 0 °C to +55 °C)
Vibration: 20 g; 80 to 2000 Hz
Shock: 100 g, 11 ms

8

Dimension Drawings

Diagram 1

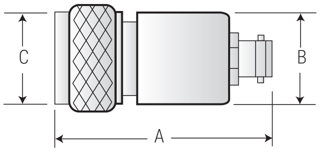


Diagram 2

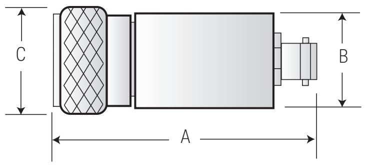


Diagram 3

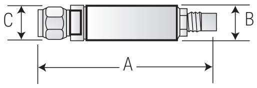


Diagram 4

Model	Length (Dim A)	Barrel diameter (Dim B)	Input connector diameter (Dim C)	Net weight	Shipping weight
Diagram 1					
423B	63 mm (2.47 in)	20 mm (0.78 in)	21 mm (0.82 in)	114 g (4 oz)	454 g (16 oz)
Diagram 2					
8470B	64 mm (2.50 in)	19 mm (0.75 in)	22 mm (0.87 in)	114 g (4 oz)	454 g (16 oz)
Diagram 3					
33330B	43 mm (1.70 in)	9.7 mm (0.38 in)	7.9 mm (0.31 in)	14 g (0.5 oz)	454 g (16 oz)
33330C	43 mm (1.70 in)	9.7 mm (0.38 in)	7.9 mm (0.31 in)	14 g (0.5 oz)	454 g (16 oz)
Diagram 4					
8472B	64 mm (2.50 in)	14 mm (0.56 in)	7.9 mm (0.31 in)	57 g (2 oz)	454 g (16 oz)
8473B	48 mm (1.89 in)	10 mm (0.39 in)	7.9 mm (0.31 in)	14 g (0.5 oz)	454 g (16 oz)
8473C	48 mm (1.89 in)	10 mm (0.39 in)	7.9 mm (0.31 in)	14 g (0.5 oz)	454 g (16 oz)

Ordering Information

To add options to a product, use the following ordering scheme:
Model: 847xB/C (x= 0, 2 or 3)
Example options: 8472B–001, 8473C–001

423B–001 **847xB/C–001** **33330B/C–001**	matched pair of detectors
423B–002 **847xB/C–002**	external square-law load
423B-003 **847xB/C-003** **33330B/C-003**	positive polarity output

Related Literature

423B, 8470B, 8472B, 8473B/C Low barrier schottky diode detectors datasheet, part number **5952-8299**
33330B/C coaxial detectors datasheet , part number **5952-8164E**

Web Link

www.keysight.com/find/mta

83036C broadband directional detector

83036C Broadband Directional Detector

This broadband microwave power sampler operates in much the same way as a directional coupler and detector combination. Comprised of a resistive bridge and PDB diode, this broadband device offers excellent frequency, temperature, and square law response characteristics.

With a 10 MHz to 26.5 GHz frequency range, a single 83036C can be used in many applications where two directional couplers and detectors were once required.

The maximum SWR is 1.7 above 50 MHz on both the input and output ports. Directivity of 14 dB matches that of most miniature couplers currently available. The maximum insertion loss is 2.2 dB.

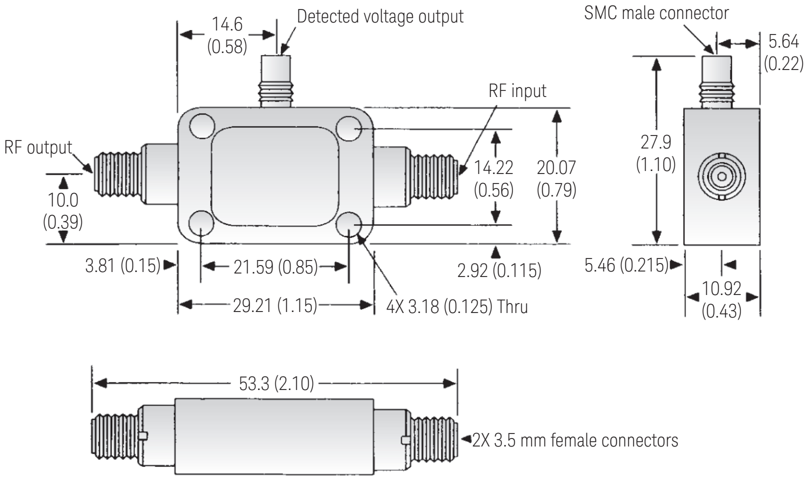
The 83036C has been used with great success as the sampling element for external leveling of broadband swept frequency sources. The detector's extended frequency range increases the usable band to 100 MHz to 26 GHz, giving the user full use of a broadband source with external leveling. Other uses include the internal leveling element for sources, and forward/reverse power monitoring.

Specifications

Model	Frequency range (GHz)	Frequency response (dB)	Max. SWR input/output (50 Ω nom)	Maximum thru line loss (dB)	Low level sensitivity	Maximum input power [1] (into 50 Ω Load)	Maximum input power [1] (into Open)	Input/output connector
83036C	0.01 to 26.5	±1.0	1.7	2.2	18 µV/µW	32 dBm	21 dBm	3.5 mm (f)

[1] With 2:1 source match

83036C Drawing



Dimensions are in mm (inches) nominal, unless otherwise specified.

Related Literature

83036C coaxial GaAs directional detector datasheet, part number **5952-1874**

Web Link

www.keysight.com/find/mta