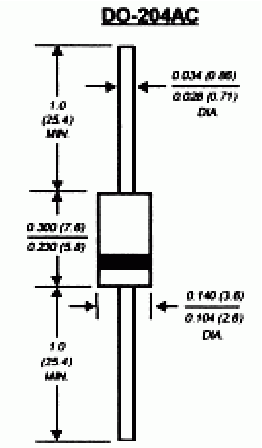
1SS16

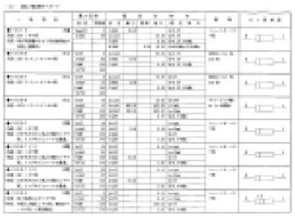
Country: Japan	**Brand:**	NEC Corporation, Nippon Electric Co. Ltd. (Nippon Denki); Tokyo	
	Tube type:	Solid-State-Diode Detector	
Identical to	**1SS16**		

Base	Wires
Filament	Solid State
Description	Silicon Schottky Barrier UHF Detector / Mixer Diode Text in other languages (may differ)
Dimensions (WHD) incl. pins / tip	3 x 7 x mm / 0.12 x 0.28 x inch
Weight	1 g / 0.04 oz

1SS16: Ebay auction by user electronics-salon 130656033785 Anonymous 38 Collector



1SS16: DVT 1971 ECA Günther Stabe

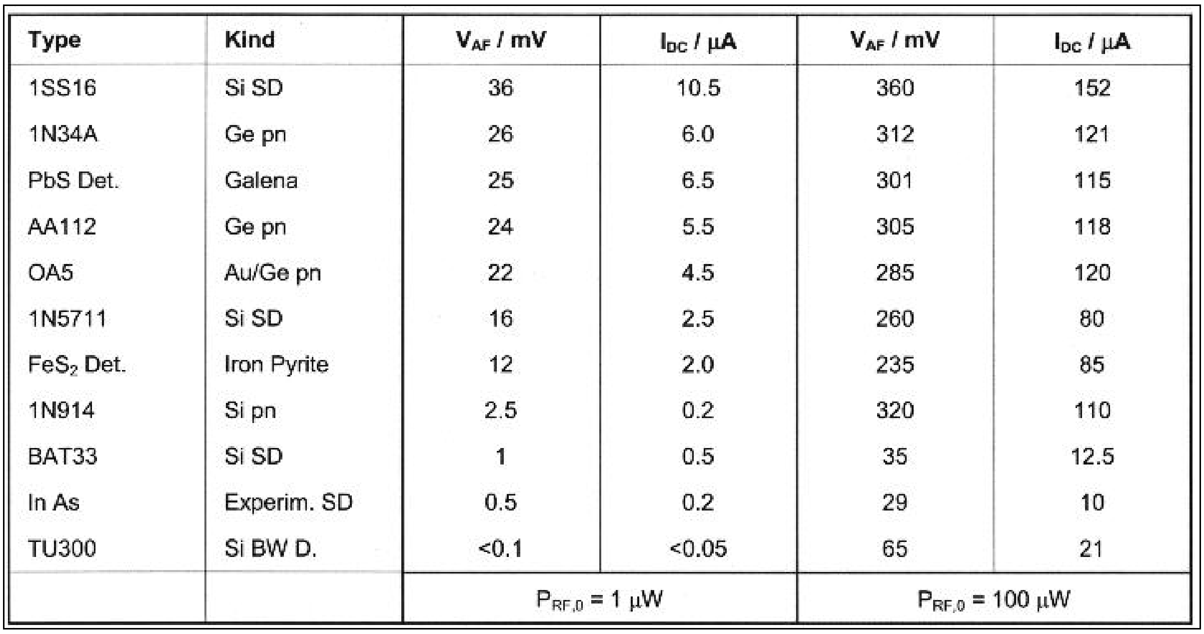


1SS16: Common manufacturers literature Anonymous 38 Collector

Very interesting is the performance of modern low-barrier Schottky diodes made from silicon, like the NEC 1SS16 (almost identical: 1SS99, BAT32, BAT63), which show turn-ons at 0.15 to 0.18 V. And, indeed, they show superb performance at low levels. One should expect that the InAs Schottky diode (which was specially made for my experiments) and the TU 300, a backward diode made by Siemens, would according to the curves shown be even more sensitive detectors. But this is not the case.

As mentioned, a low turn-on voltage is inevitably associated with a high reverse current. This current reaches values of a few hundred µA for the InAs diode, as also for the TU300 and the Schottky diode BAT33. If the reverse current, i.e. an unwanted back current, reaches such high values we have strong counteracting effects, and ultimately the detector action disappears completely. Anticipating the results of computer simulations described in Sec. 7 one can state that diodes like the 1SS16 show the optimum relation between low turn-on and still acceptable reverse current, thus making them the best choice of presently available diodes as regards detector sensitivity.

To show and compare the capability of various diodes the Table summarizes values of measured AF voltages and of rectified currents, for 1 and 100 µW of available RF power. A power of 1 µW is in my set typical for DX stations at night, and 100 µW for stations 30 to 50 km away. As is seen the 1SS16 leads the field. - For 3 mW of RF (my local station) I obtained with a 1SS16 a DC current of 715 µA, which increased to 1.85 mA in the short-circuit case (AF/DC load = 0), and to 2.95 mA when under these conditions the set was retuned.



Type	Kind	V_{AF} / mV	I_{DC} / µA	V_{AF} / mV	I_{DC} / µA
1SS16	Si SD	36	10.5	360	152
1N34A	Ge pn	26	6.0	312	121
PbS Det.	Galena	25	6.5	301	115
AA112	Ge pn	24	5.5	305	118
OA5	Au/Ge pn	22	4.5	285	120
1N5711	Si SD	16	2.5	260	80
FeS_2 Det.	Iron Pyrite	12	2.0	235	85
1N914	Si pn	2.5	0.2	320	110
BAT33	Si SD	1	0.5	35	12.5
In As	Experim. SD	0.5	0.2	29	10
TU300	Si BW D.	<0.1	<0.05	65	21
		$P_{RF,0}$ = 1 µW		$P_{RF,0}$ = 100 µW	

(Table: Measured values of AF voltage (across phones of 4 k at DC) and of rectified DC current for various diodes and two levels of RF power)

Sometimes a DC bias from a battery is applied for shifting the operating point of the diode closer to the turn-on voltage and so improving the detection efficiency. By this method the AF voltage obtained can be increased, for example when using the 1N5711 and the 1N914 at low RF levels. The 1SS16 group of diodes, however, hardly gains from a DC bias. Only at RF powers below about 200 nW I was able to measure a certain rise in AF voltage. At the lowest detectable RF level of 50 nW (Sec. 1), the AF voltage increased by 20 percent (i.e. power by 45 percent) when the optimum bias was applied. But this effect was measurable only, being still too small to be noticed by the ear.

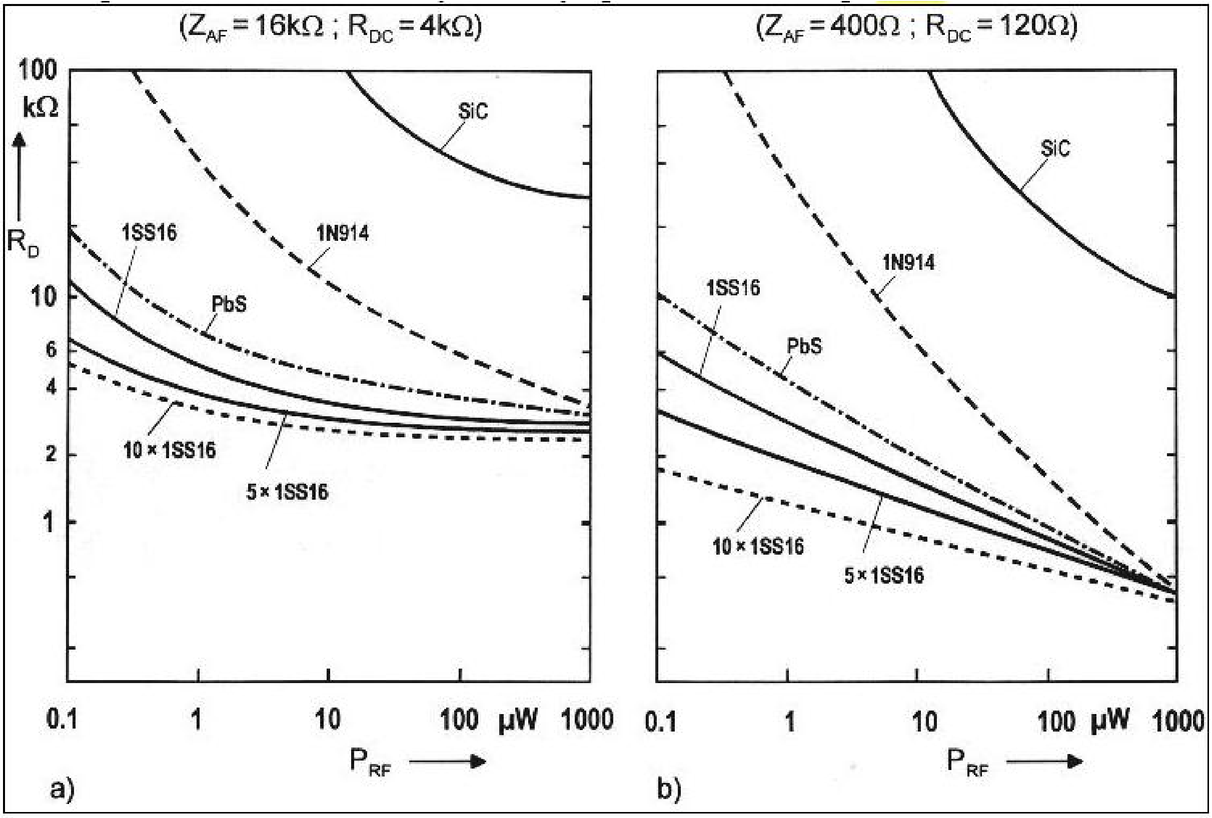
Note added in Jan. 2002: Backward diodes (BWD), like the TU300, are good detectors at extremely low RF signal levels, below about 1 nW with associated voltages of only a few mV. This is due to the relatively sharp bend in the BWD characteristic at zero volts. The generated AF signal is, however, too small for operating phones directly and calls for an AF amplifier. Then stations can be copied which are not heard when in such a set-up with AF amplifier a "normal" sensitive diode, like the 1SS16, is used instead of the BWD.

5. RF Diode Resistances and RF Matching

For achieving best performance it is required to RF match the diode to the tuned circuit. The dynamic resistance of the diode depends on the amplitude of the RF voltage applied to it, and on the kind of AF load impedance.

In AM tube radios the detector diode operates at a high level (linear detection) and has a load consisting of a large (ohmic) resistor shunted by a small capacitor. Calculations show that in this case the RF diode resistance, as presented to the tuned circuit, is roughly half of the ohmic load resistance. In a crystal set the calculation is somewhat more complicated since there the RF voltage on the diode is generally lower and the diode load is more complex (see equivalent circuit of phones in Fig. 2). Hence I preferred to measure the RF diode resistance **R**D. The measurements were carried out under actual working conditions using a signal generator. Figs. 5(a) and (b) show the results obtained for high-impedance phones with 4 k ohms DC resistance and for low-impedance ones with 120 ohms, respectively. The RF frequency used in these measurements was 1000 kHz, the modulation frequency 1 kHz with a modulation factor of 0.4 (given by the signal generator). Figs. 5 give the measured diode resistances, as a function of the RF power applied, for an 1SS16 (also some in parallel), a silicon p-n diode 1N914, and for natural galena as well as carborundum (silicon carbide; SiC) crystals. The diode circuit was in turn connected to the various taps on the coil **L**2 .When the RF voltage measured across the tuned circuit dropped by a factor of radicle (2)=1.41 compared to its value without diode, matching was achieved. Then the RF diode resistance equalled the RF resistance of the tuned circuit at the tap point. To avoid an error one must readjust the coupling to the antenna when the diode is connected to the first found (V/1.4) tap point and then repeat the search for the now somewhat altered (V/1.4) tap. A second iteration further improves the result, but not much.

As in principle to be expected from the characteristics, the diode resistances vary rather widely, from some 100 ohms to some 10 k ohms, with lower values obtained when the DC resistance of the phones is low. The galena detector shows values only moderately higher than those of a single 1SS16. The silicon diode 1N914 presents high values due to its high turn-on, which even more applies to carborundum.



(Fig. 5:Measured RF diode resistances versus available RF power: (a) for high-impedance phones (4 k ohms at DC), (b) for low-impedance phones (120 ohms at DC)

The data obtained then indicate that the optimum tap position on coil **L**2 (for matching) depends on the diode type, the strength of the received station, and on the DC resistance of the phones. The larger the value of the diode resistance is, the higher must the tap position be up the coil. Sometimes it was suggested in the literature to have a fixed tap at a point of about 1/4 to 1/3 of the windings counting from the earth point. In the present case the tuned circuit has a resistance of approximately 6 k at the 1/3 tap point. As Fig. 5a shows, this indeed is a rather good choice for a galena detector when high-impedance phones are used and weak stations received. Impedance matching requires that the reactances of source and load cancel out. But in our case the resistance of the tuned circuit has no reactive part at resonance, and the reactance of the diode, caused mainly by the diode junction capacitance of at most a few pF, can be neglected.

Connected to a particular tap, the diode resistance is (auto-)transformed up and appears in parallel to the resonance resistance of the tuned circuit. This means that not all of the available RF power reaches the diode since a reasonable fraction of it is dissipated in the resistance of the tuned circuit. In order to really transfer the maximum of power from the antenna to the diode branch, the diode (of generally low resistance compared to that of the tuned circuit) should be connected untapped to the top of the coil **L**2. This, however, strongly reduces the selectivity of the set and requires a readjustment of the coupling of the tuned circuit to the antenna. With high incident high RF power (and/or low impedance of the phones) the tuned circuit can, under these conditions, become loaded to such an extend that variations of the capacitor **C**2 have no tuning effect any longer, which means that **C**2 is obsolete and can be omitted. The diode circuit is then aperiodically coupled to the (tuned) antenna circuit, while the coil L2 merely acts as the secondary winding of the transformer which matches the diode to the antenna.

6. AF Matching

If a crystal ear phone is used or the diode detector is followed by an amplifier (generally of high input impedance) one has to design for maximum voltage at the detector output. Here, we rather have to deliver a maximum of *power* to the phones. Hence the impedance of the phones (or the speaker) as the AF load should have such a value that a maximum of AF power is transferred to it. The AF source resistance **R**G is at low RF levels (square-law detection) approximately given by the reciprocal of the slope of the diode characteristic at the operating point. At higher RF levels (linear peak detection) it is determined by the current spikes flowing through the diode. In so far, **R**G nearly equals the diode resistances as shown in Figs. 5. The tuned circuit presents an AF short.

I determined the equivalent circuit of a pair of high-impedance Telefunken phones (4 k ohms at DC) at 1 kHz by using a measuring bridge and obtained the quantities given in Fig. 2. **R**EA is caused by the electro-acoustical transducing process. The AF source has to provide the real power for **R**EA as well as, necessarily, for the DC coil resistance, and foremost the reactive power for the phone coils (2.5 H) that are to move the membranes. In order to obtain the maximum of power transfer the magnitude (amount) of the overall phones′ impedance **Z**AF (16 k ohms for my phones) must match the AF source. Again I preferred to experimentally find the optimum AF load: I connected in turn 14 phones and speakers of different impedance to the set, partly connecting two of them in series or parallel, which in total provided 20 load impedance values between 80 ohms and 75 k ohms in magnitude. From the AF voltage measured across these load impedances I determined the AF power. The coupling to the RF signal generator was readjusted to retain RF matching each time the AF load was changed. Fig. 6 shows the obtained results when using a) a diode 1SS16 at low RF power (1 µW) and b) with a 1N914 at higher power (1 mW). The optimum AF load impedance turned out to be, resp., 1.2 and 3 k ohms. In order to simplify matters the diode was in this experiment fixed to the 1/3 tap at the tuned circuit. This meant a compromise as regards match-ing and generally did not produce quite the maximum of achievable AF power. The dashed curves of higher AF power in Fig. 6 were obtained when the diode was connected to the top of the tuning coil (as discussed above).