VOLTAGE REGULATOR DIODES

Silicon diodes in subminiature all glass DO-7 envelope for use as low current voltage stabilizers or voltage references.
The series consists of 24 types with nominal zener voltages ranging from 3.3 V to 30 V with a tolerance of ±5%.

QUICK REFERENCE DATA

Zener voltage range		nom.	3.3 to 30	V
Zener voltage tolerance			±5	%
Repetitive peak zener current	I_{ZRM}	max.	250	mA
Total power dissipation up to T_{amb} = 50 °C	P_{tot}	max.	400	mW
Non repetitive peak reverse power T_j = 150 °C; t = 100 μs	P_{ZSM}	max.	15	W
Junction temperature	T_j	max.	175	°C
Thermal resistance from junction to ambient in free air	$R_{th\ j\text{-}a}$	=	0.31	°C/mW

MECHANICAL DATA Dimensions in mm

DO-7

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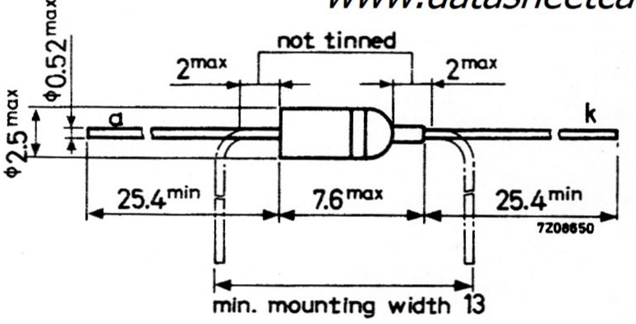

The band indicates the cathode side

RATINGS Limiting values in accordance with the Absolute Maximum System (IEC134)

Currents

Forward current (d.c.)	I_F	max.	250	mA
Repetitive peak forward current	I_{FRM}	max.	250	mA
Repetitive peak zener current	I_{ZRM}	max.	250	mA

Power dissipation

Total power dissipation up to $T_{amb} = 50\ ^oC$	P_{tot}	max.	400	mW
Non repetitive peak reverse power $T_j = 150\ ^oC$; $t = 100\ \mu s$	P_{ZSM}	max.	15	W

Temperatures

Storage temperature	T_{stg}		-65 to +175	^oC
Junction temperature	T_j	max.	175	^oC

THERMAL RESISTANCE

From junction to ambient in free air	$R_{th\ j\text{-}a}$	=	0.31	$^oC/mW$

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CHARACTERISTICS T_j = 25 °C unless otherwise specified

Forward voltage

I_F = 10 mA [1]) V_F < 0.9 V

BZY88-...	Zener voltage V_Z at I_Z = 1 mA				Temperature coefficient S_Z at I_Z = 1 mA				Differential resistance r_Z at I_Z = 1 mA			
	min.	nom.	max.		min.	typ.	max.		min.	typ.	max.	
C3V3	2.4	2.75	3.0	V	−4.5	−1.9	−0.5	mV/°C	380	410	440	Ω
C3V6	2.7	3.0	3.3	V	−4.5	−2.05	−0.5	mV/°C	380	410	430	Ω
C3V9	3.0	3.3	3.6	V	−3.5	−2.4	−0.5	mV/°C	380	410	430	Ω
C4V3	3.3	3.6	3.9	V	−2.7	−2.25	−0.5	mV/°C	340	410	430	Ω
C4V7	3.7	4.1	4.3	V	−2.5	−2.0	−0.3	mV/°C	360	390	420	Ω
C5V1	4.3	4.65	5.0	V	−2.1	−1.9	−0.3	mV/°C	300	340	370	Ω
C5V6	4.8	5.3	5.7	V	−1.8	−1.4	0	mV/°C	160	310	350	Ω
C6V2	5.7	5.9	6.5	V	0	+1.6	+3.0	mV/°C	10	100	250	Ω
C6V8	6.3	6.7	6.9	V	+2	+3.2	+3.7	mV/°C	5.0	15	70	Ω
C7V5	7.0	7.45	7.8	V	+3	+4.2	+5.9	mV/°C	4.0	8.6	20	Ω
C8V2	7.8	8.1	8.5	V	+4.3	+5.0	+6.0	mV/°C	4.0	10	20	Ω
C9V1	8.55	9.0	9.5	V	+4.5	+6.0	+7.0	mV/°C	7.0	12	24	Ω
C10	9.3	9.9	10.5	V	+6.0	+6.6	+7.0	mV/°C	5.0	20	50	Ω
C11	10.3	10.9	11.5	V	+7.1	+8.3	+9.0	mV/°C	5.0	25	70	Ω
C12	11.3	11.9	12.5	V	+7.6	+8.7	+9.2	mV/°C	10	25	80	Ω
C13	12.3	12.9	13.0	V	+9.1	+10.1	+11.1	mV/°C	10	25	90	Ω
C15	13.8	14.9	15.5	V	+11	+12.5	+13	mV/°C	19	35	95	Ω
C16	15.3	15.8	16.9	V	+12	+13	+14	mV/°C	20	45	100	Ω
C18	16.7	17.8	18.9	V	+14	+15	+16.5	mV/°C	20	50	120	Ω
C20	18.7	19.8	21.0	V	+16	+17	+18.5	mV/°C	20	60	140	Ω
C22	20.6	21.8	23.1	V	+17	+19	+21	mV/°C	25	70	150	Ω
C24	22.5	23.8	25.7	V	+19	+21	+23	mV/°C	30	85	200	Ω
C27	24.7	26.6	28.5	V	+21	+22.5	+25	mV/°C	35	90	300	Ω
C30	27.5	29.5	31.5	V	+22	+24	+29	mV/°C	50	180	350	Ω

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[1]) T_{amb} = 25 °C

CHARACTERISTICS (continued) T_j = 25 °C unless otherwise specified

BZY88-...	Zener voltage V_Z at I_Z = 5 mA 1)				Temperature coefficient S_Z at I_Z = 5 mA				Differential resistance r_Z at I_Z = 5 mA			
	min.	nom.	max.		min.	typ.	max.		min.	typ.	max.	
C3V3	3.1	3.3	3.5	V	−4.0	−2.3	−0.5	mV/°C	70	83.5	110	Ω
C3V6	3.4	3.6	3.8	V	−3.5	−2.0	−0.5	mV/°C	65	76	105	Ω
C3V9	3.7	3.9	4.1	V	−2.5	−2.05	−0.5	mV/°C	60	76	100	Ω
C4V3	4.0	4.3	4.5	V	−2.5	−1.8	−0.5	mV/°C	55	70	90	Ω
C4V7	4.4	4.7	5.0	V	−2.0	−1.55	0	mV/°C	49	62	85	Ω
C5V1	4.8	5.1	5.4	V	−1.75	−1.2	0	mV/°C	34	46	75	Ω
C5V6	5.3	5.6	6.0	V	−1.5	−0.2	+1.0	mV/°C	10	22	55	Ω
C6V2	5.8	6.2	6.6	V	+0.5	+2.0	+3.5	mV/°C	1.0	7.0	27	Ω
C6V8	6.4	6.8	7.2	V	+2.3	+3.2	+3.8	mV/°C	0.5	3.0	15	Ω
C7V5	7.1	7.5	7.9	V	+3.1	+4.2	+5.9	mV/°C	0.5	3.0	15	Ω
C8V2	7.8	8.2	8.7	V	+4.2	+5.0	+6.0	mV/°C	0.9	3.5	20	Ω
C9V1	8.6	9.1	9.6	V	+4.8	+6.0	+7.0	mV/°C	1.0	4.75	25	Ω
C10	9.4	10	10.6	V	+6.0	+7.0	+7.5	mV/°C	2.0	5.0	25	Ω
C11	10.4	11	11.6	V	+7.0	+8.7	+9.1	mV/°C	3.0	7.0	25	Ω
C12	11.4	12	12.6	V	+8.5	+9.0	+9.6	mV/°C	4.0	8.0	35	Ω
C13	12.4	13	14.1	V	+10	+10.5	+11.5	mV/°C	4.0	10	35	Ω
C15	13.9	15	15.6	V	+12	+12.5	+14	mV/°C	4.0	15	35	Ω
C16	15.4	16	17.1	V	+12	+13	+14	mV/°C	5.0	20	40	Ω
C18	16.9	18	19.1	V	+14	+15	+18	mV/°C	7.0	25	45	Ω
C20	18.9	20	21.2	V	+16	+17	+19	mV/°C	10	30	50	Ω
C22	20.8	22	23.3	V	+17	+19	+21	mV/°C	15	35	60	Ω
C24	22.7	24	25.9	V	+20	+21	+24	mV/°C	20	40	75	Ω
C27	25.1	27	28.9	V	+22	+23.5	+27	mV/°C	25	50	85	Ω
C30	28	30	32	V	+25	+26	+29	mV/°C	30	60	95	Ω

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1) T_{amb} = 25 °C

CHARACTERISTICS (continued) T_j = 25 °C unless otherwise specified

BZY88-...	Zener voltage V_Z at I_Z = 20 mA [1]				Temperature coefficient S_Z at I_Z = 20 mA				Differential resistance r_Z at I_Z = 20 mA			
	min.	nom.	max.		min.	typ.	max.		min.	typ.	max.	
C3V3	3.5	4	4.2	V	−3.3	−2.4	−0.5	mV/°C	16.0	19.5	22	Ω
C3V6	3.9	4.2	4.4	V	−2.5	−1.55	−0.5	mV/°C	16	18	20	Ω
C3V9	4.2	4.45	4.65	V	−2.4	−1.55	−0.5	mV/°C	14	16	18	Ω
C4V3	4.45	4.7	4.95	V	−2.0	−1.5	−0.5	mV/°C	13	15	17	Ω
C4V7	4.9	5.1	5.3	V	−1.5	−0.85	0	mV/°C	12	15	17	Ω
C5V1	5.1	5.35	5.7	V	−1.5	−0.8	0	mV/°C	4.0	7.0	11	Ω
C5V6	5.45	5.75	6.1	V	−1.0	+1.0	+3.0	mV/°C	1.5	4.0	8.0	Ω
C6V2	5.95	6.4	6.7	V	+1.0	+2.2	+4.0	mV/°C	0.8	1.4	3.1	Ω
C6V8	6.6	6.9	7.25	V	+2.8	+3.2	+3.8	mV/°C	0.7	1.3	3.0	Ω
C7V5	7.2	7.65	7.95	V	+2.5	+4.2	+5.9	mV/°C	0.5	1.6	5.0	Ω
C8V2	7.9	8.4	8.75	V	+4.0	+5.0	+6.0	mV/°C	0.9	1.8	6.0	Ω
C9V1	8.7	9.4	9.7	V	+5.0	+6.0	+7.0	mV/°C	1.0	1.85	7.0	Ω
C10	9.5	10.1	10.8	V	+7.0	+7.3	+7.5	mV/°C	1.0	2.0	8.0	Ω
C11	10.5	11.1	11.8	V	+8.5	+9.1	+9.5	mV/°C	1.0	3.0	10	Ω
C12	11.6	12.2	12.8	V	+8.9	+9.6	+10.3	mV/°C	2.0	3.5	25	Ω
C13	12.6	13.2	14.3	V	+11	+11.5	+12.5	mV/°C	2.0	4.5	25	Ω
C15	14.1	15.3	15.9	V	+12	+13.5	+14.5	mV/°C	2.0	6.0	25	Ω
C16	15.6	16.3	17.4	V	+13	+14	+15	mV/°C	5.0	10	30	Ω
C18	17.2	18.4	19.6	V	+15	+16	+18	mV/°C	5.0	12	30	Ω
C20	19.3	20.5	21.9	V	+17.5	+18.5	+20.5	mV/°C	5.0	15	35	Ω
C22	21.3	22.6	24.1	V	+19	+20.5	+22.5	mV/°C	10	18	35	Ω
C24	23.3	24.7	26.7	V	+20	+23	+25	mV/°C	10	20	40	Ω
C27	25.8	28.1	30.1	V	+23	+25.5	+28	mV/°C	10	25	45	Ω
C30	29.0	31.3	33.4	V	+25	+28	+32	mV/°C	10	35	50	Ω

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[1] T_{amb} = 25 °C

CHARACTERISTICS (continued) T_j = 25 °C unless otherwise specified

BZY88-...	Diode capacitance C_d at V_R = 3 V (typ.)	Reverse current I_R at V_R =	typ.	max.	
C3V3	395 pF	1 V	0.54	3.0	μA
C3V6	370 pF	1 V	0.25	3.0	μA
C3V9	335 pF	1 V	0.11	3.0	μA
C4V3	270 pF	1 V	0.1	3.0	μA
C4V7	290 pF	2 V	0.25	3.0	μA
C5V1	275 pF	2 V	0.15	1.0	μA
C5V6	260 pF	2 V	0.6	1.0	μA
C6V2	240 pF	2 V	0.1	1.0	μA
C6V8	220 pF	3 V	0.025	1.0	μA
C7V5	190 pF	3 V	15	500	nA
C8V2	150 pF	3 V	11	400	nA
C9V1	140 pF	5 V	8	400	nA
C10	110 pF	7 V	–	2.5	μA
C11	90 pF	7 V	–	2.5	μA
C12	80 pF	8 V	–	2.5	μA
C13	65 pF	9 V	–	2.5	μA
C15	60 pF	10 V	–	2.5	μA
C16	55 pF	10 V	–	2.5	μA
C18	50 pF	13 V	–	2.5	μA
C20	45 pF	14 V	–	2.5	μA
C22	43 pF	15 V	–	2.5	μA
C24	42 pF	17 V	–	2.5	μA
C27	40 pF	19 V	–	2.5	μA
C30	35 pF	21 V	–	2.5	μA

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OPERATING NOTES

1. Dissipation and heatsink considerations

a. Steady-state conditions

The maximum allowable steady-state dissipation $P_{S\,max}$ is given by the relationship

$$P_{S\,max} = \frac{T_{j\,max} - T_{amb}}{R_{th\,j\text{-}a}}$$

where $T_{j\,max}$ is the maximum permissible operating junction temperature,
T_{amb} is the ambient temperature,
$R_{th\,j\text{-}a}$ is the total thermal resistance from junction to ambient

b. Pulse conditions (see fig. below)

The maximum allowable additional pulse power $P_{m\,max}$ is given by the formula

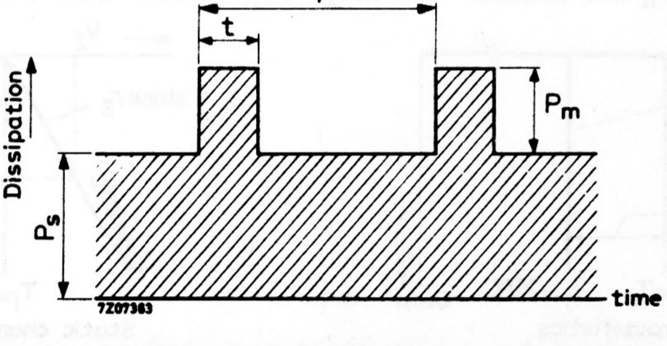
$$P_{m\,max} = \frac{(T_{j\,max} - T_{amb}) - (P_S \cdot R_{th\,j\text{-}a})}{Z_{th}}$$

where P_S is the steady-state dissipation, excluding that in the pulses,

Z_{th} is the effective transient thermal resistance of the device from junction to ambient. It is a function of the pulse duration t and duty cycle δ (see page 9, lower figure).

δ is the duty cycle and is equal to the pulse duration t divided by the period duration T.

The steady-state power P_S when biased in the zener direction at a given zener current can be found from page 13, upper figure. With the additional pulsed power dissipation $P_{m\,max}$ calculated from the above expression, the total repetitive peak zener power dissipation $P_{ZRM} = P_S + P_{m\,max}$. From page 13, upper figure the corresponding maximum repetitive peak zener current at P_{ZRM} can now be read. This repetitive peak zener current is subject to the absolute maximum rating. For pulse durations longer than the temperature stabilization time of the diode t_{stab}, the maximum allowable repetitive peak dissipation P_{ZRM} is equal to the maximum steady-state power $P_{S\,max}$. The temperature stabilization time for the BZY88 series is 100 s (see page 9, lower figure).



OPERATING NOTES (continued)

Example

The following example illustrates how to calculate the maximum permissible repetitive peak zener current of a BZY88-C7V5 zener diode mounted in free air at a maximum ambient temperature of 60 °C. The steady-state zener current is 10 mA, the duty cycle $\delta = 0.1$ and the pulse duration t = 1 ms.

The steady-state dissipation P_S at a zener current of 10 mA (from page 13, upper figure) = 76 mW.
The thermal resistance from junction to ambient $R_{th\ j\text{-}a} = 0.31\ ^{o}C/mW$.
The thermal impedance Z_{th} with a duty cycle $\delta = 0.1$ and a pulse duration t = 1 ms (from page 9, lower figure).

$$Z_{th} = 41.5\ ^{o}C/W$$

The maximum additional pulse power dissipation

$$P_{m\ max} = \frac{(T_{j\ max} - T_{amb}) - P_S \cdot R_{th\ j\text{-}a}}{Z_{th}}$$

If $P_S = 76$ mW, $Z_{th} = 41.5\ ^{o}C/W$,

$$P_{m\ max} = \frac{(175-60) - (0.076 \times 310)}{41.5} = 2.2\ W$$

therefore, the total repetitive peak power dissiaption,

$$P_{ZRM} = 0.076 + 2.2 = 2.28\ W$$

From page 13, upper figure, the corresponding repetitive peak zener current is 250 mA. This is within the rating of the BZY88-C7V5 and is therefore permissible.

2. Zener characteristics

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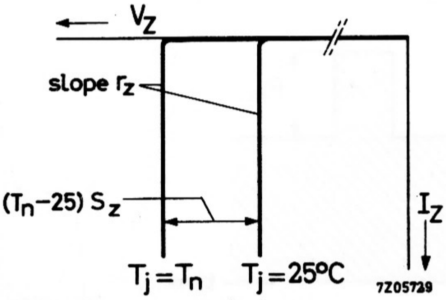
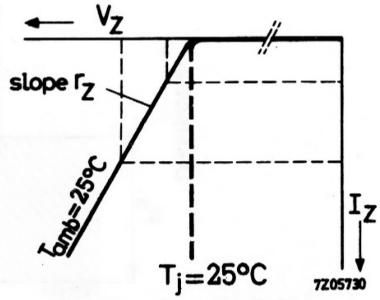
The basic characteristic of a zener diode is the dynamic zener characteristic, that is, the variation of zener voltage when a current pulse is applied in the reverse direction. The slope of this characteristic is r_Z. Typical dynamic characteristics at $T_j = 25$ and 150 °C are given on pages 10 and 11 for each type of diode. Because of the temperature sensitivity of the zener characteristics, the dynamic characteristics at any other operating temperature will be displaced from those at $T_j = 25\ ^{o}C$ by a voltage corresponding to $S_Z \times (T_n - 25)\ ^{o}C$, where S_Z is the temperature coefficient of the diode and T_n is a nominal operating temperature. This is illustrated below.



Dynamic characteristics



Static characteristic

OPERATING NOTES (continued)

The static characteristic of the diode is obtained by connecting the steady-state zener voltages at various direct zener currents and may, therefore, be used to determine the operating point at any zener current. This is shown above. The slope of the static characteristic will depend on

(1) the differential resistance, r_Z

(2) the rise in junction temperature due to internal dissipation and the thermal resistance from junction to ambient, $V_Z.I_Z.R_{th\ j\text{-}a}$

(3) the temperature coefficient of the diode, S_Z

From the above, the static slope resistance r_Z is found to be

$$r_Z = r_z + V_Z.R_{th\ j\text{-}a}.S_Z$$

where r_z is the differential resistance, V_Z is the steady-state zener voltage and is equal to

$$\frac{V_Z'}{1-I_Z.R_{th\ j\text{-}a}.S_Z}$$

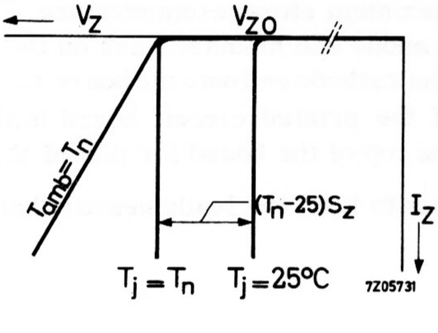
V_Z' being the zener voltage at $T_j = T_n$ at the working current I_Z.

The position of this static characteristic in relation to the dynamic characteristic at $T_j = 25\ ^oC$ is dependent on the ambient temperature and the temperature coefficient, the low-current voltage being displaced by

$$S_Z \times (T_n - 25)\ ^oC$$

from the low current voltage, V_{ZO} on the dynamic characteristic at $T_j = 25\ ^oC$ (See figure below)

Example for positive S_Z



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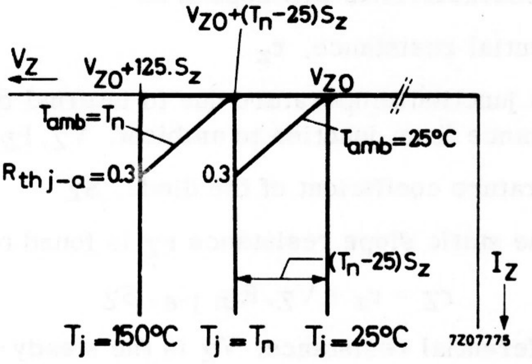
OPERATING NOTES (continued)

Next figure shows typical dynamic characteristics at T_j = 25, 150 and a nominal temperature, T_n °C. It also shows static characteristics at ambient temperatures of 25 and T_n °C.



Example for positive S_Z

Typical static characteristics for each type of diode are given on page 12. These curves were obtained with the device mounted in free air at an ambient temperature of 25 °C.

The slope resistance for pulse operation can be calculated by incorporating the thermal impedance Z_{th} into the formula for r_Z. Curves of Z_{th} plotted against pulse duration and duty cycle are given in the lower figure on page 9.

3. When using a soldering iron, the diode may be soldered directly into a circuit, but heat conducted to the junction should be kept to a minimum by use of a thermal shunt.

4. Diodes may be dip soldered at a solder temperature of 245 °C for a maximum soldering time of 5 seconds. The case temperature during dip soldering must not at any time exceed the maximum storage temperature. These recommendations apply to a diode with the anode end mounted flush on the board with punched-through holes. For mounting the cathode end onto the board the diode must be spaced 5 mm from the underside of the printed circuit board in the case of punched-through holes or 5 mm from the top of the board for plated-through holes.

5. Care should be taken not to bend the leads nearer than 1.5 mm from the seals.

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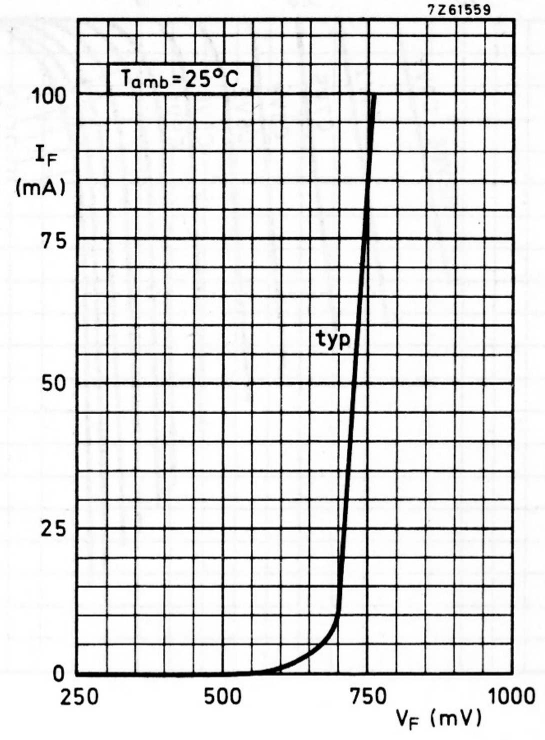

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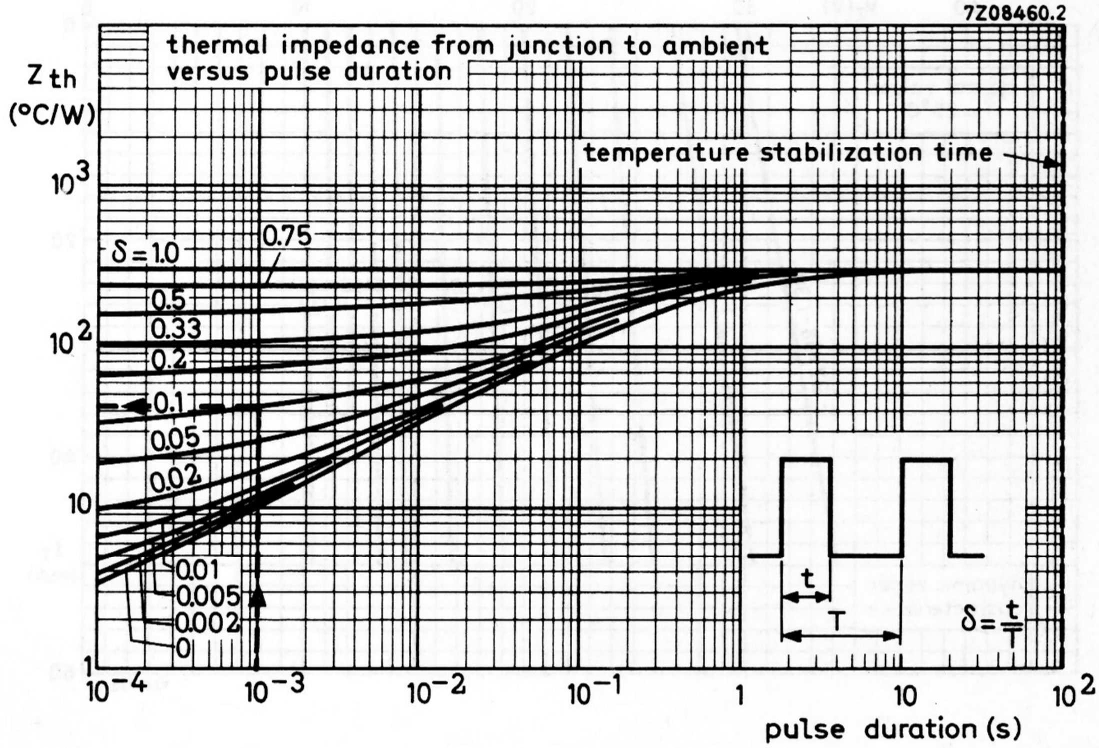

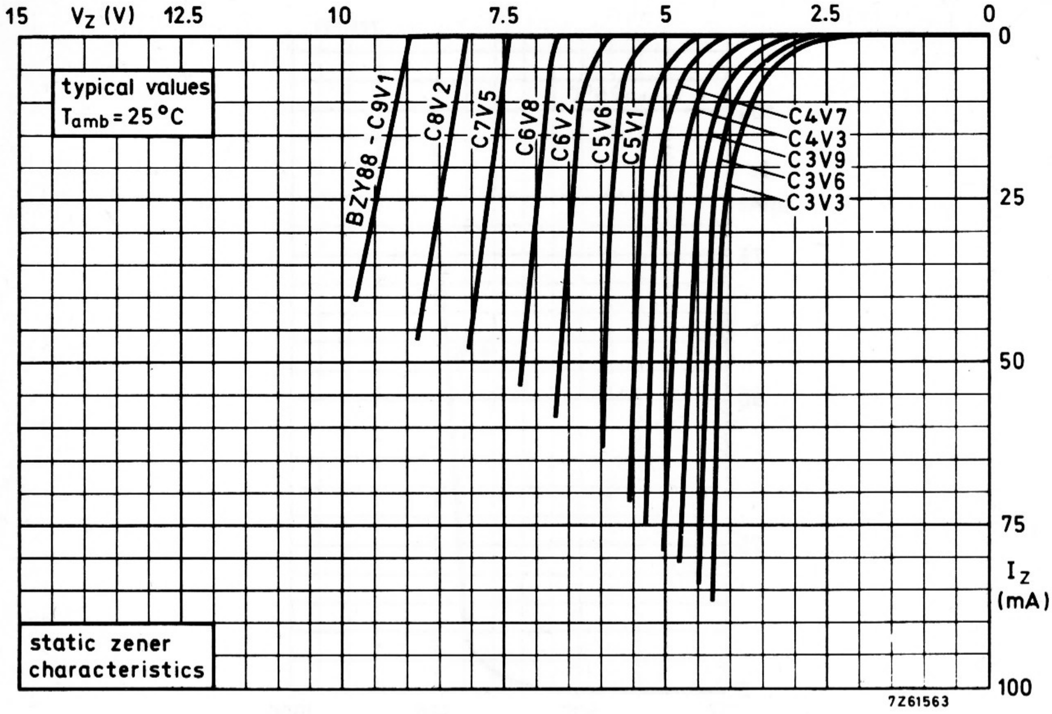

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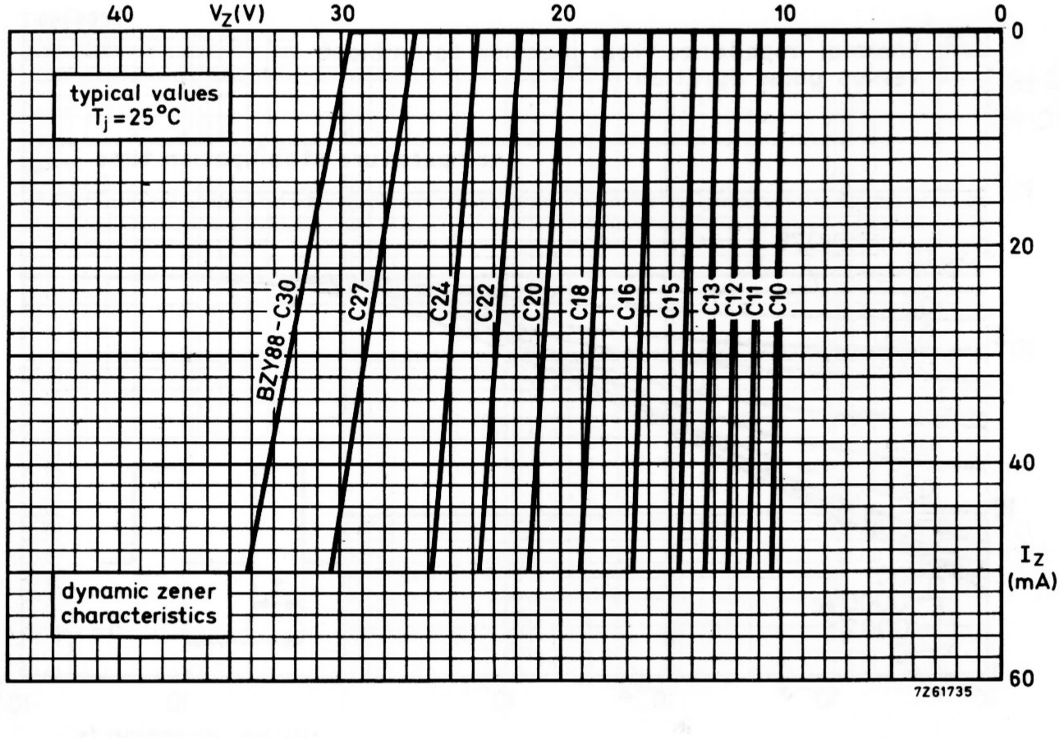

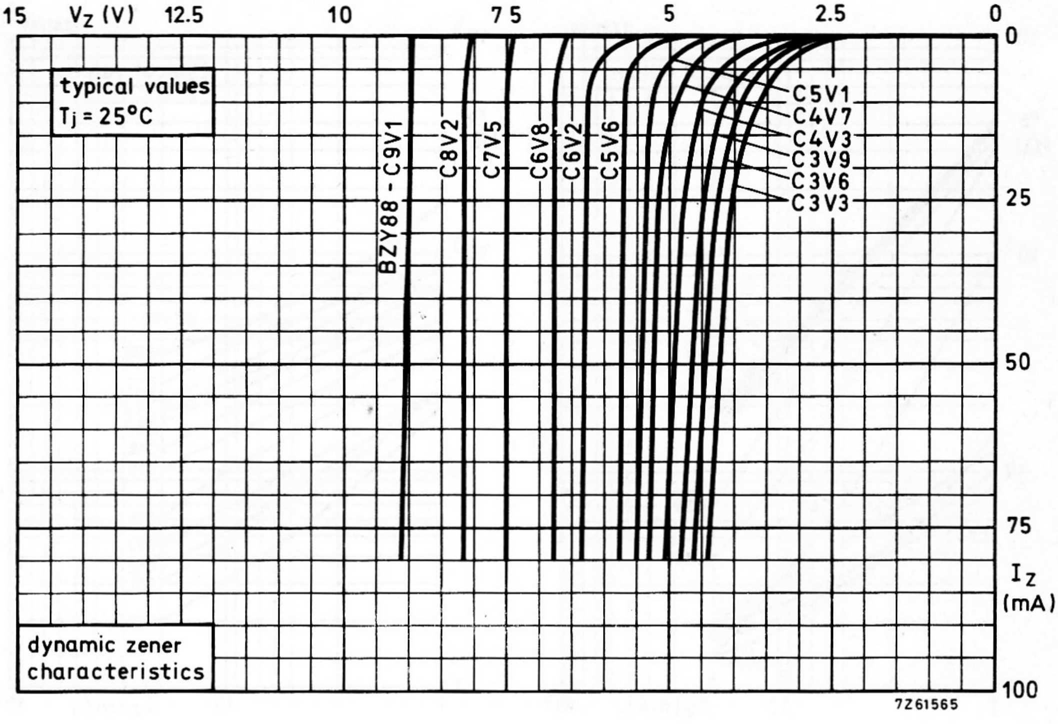

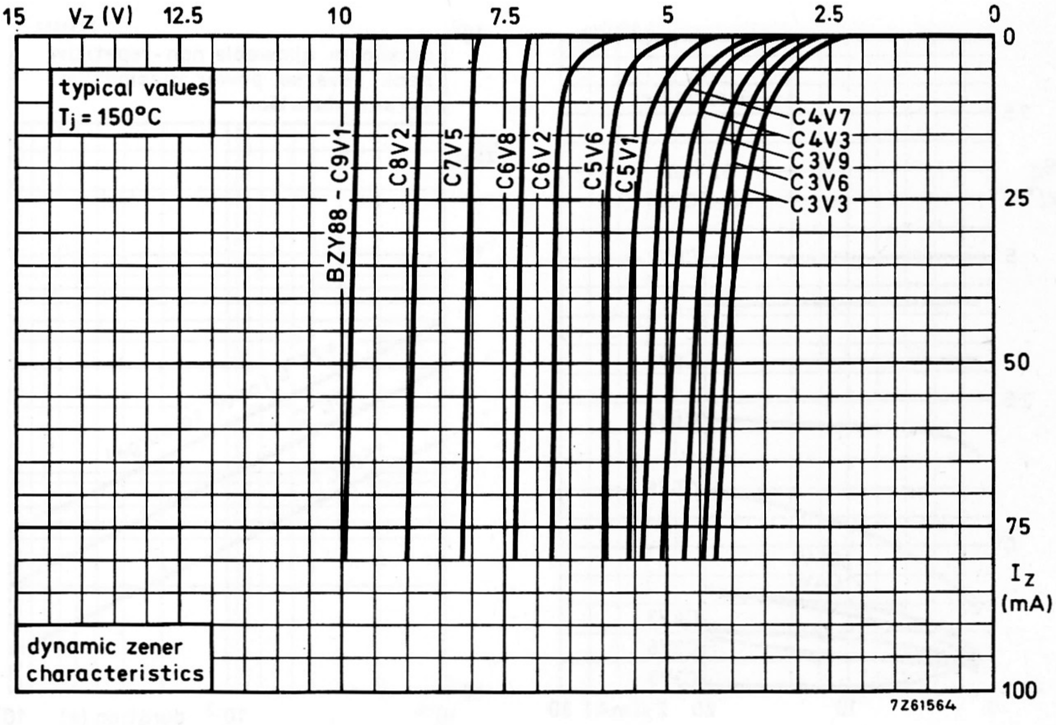

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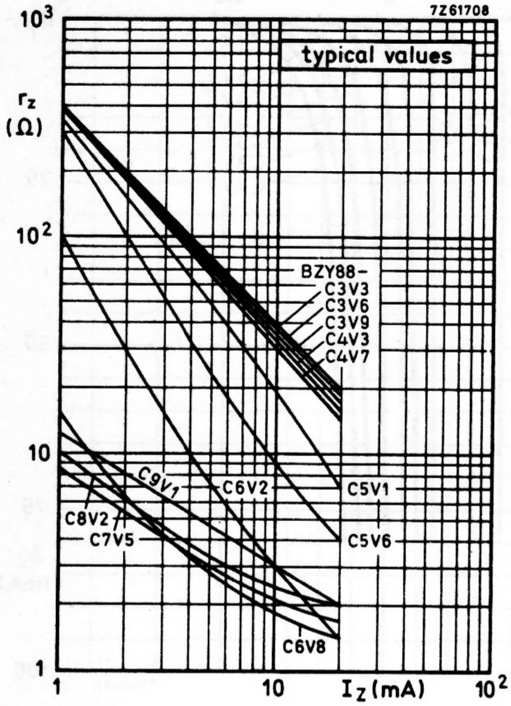

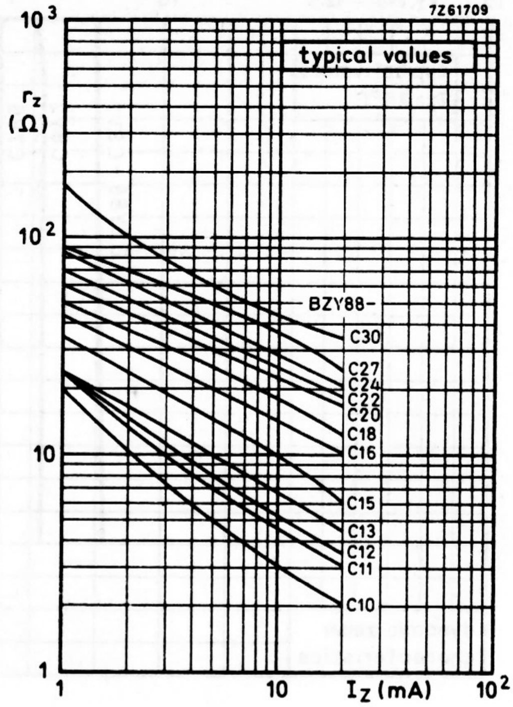

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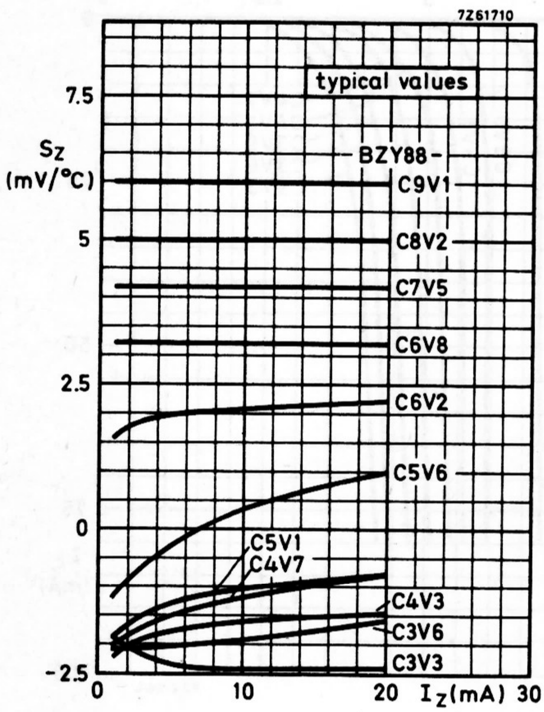

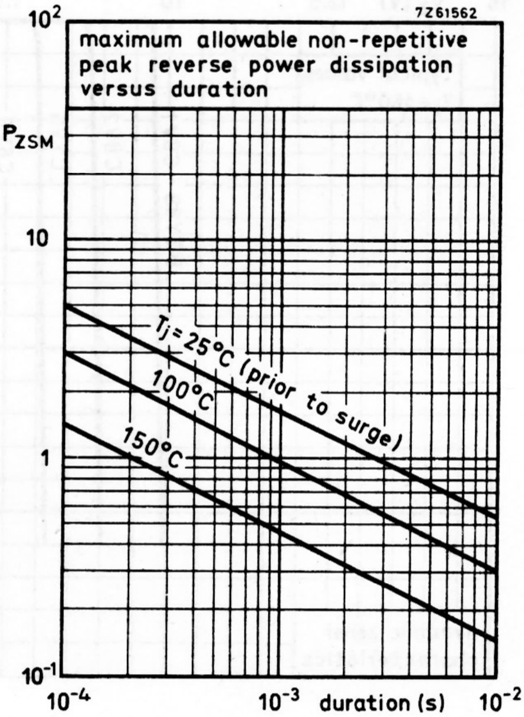

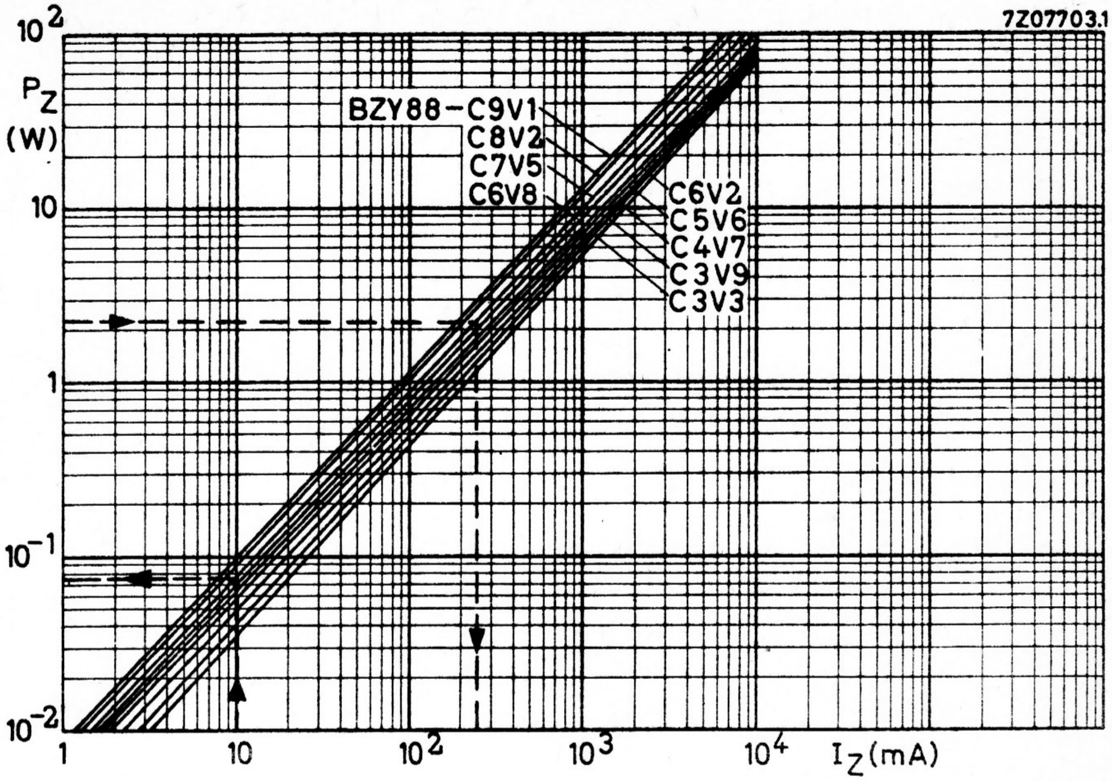

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