

DEVELOPMENT OF DESIGN CRITERIA AND A QUALIFICATION TEST FOR BYPASS DIODES

JET PROPULSION LABORATORY

D. H. Otth

Objectives

- **Define specific design criteria for bypass diodes in PV applications to ensure acceptable field reliability**
- **Develop a qualification test for assessing conformance to design criteria**
  - **Diodes integral with module**
  - **Externally mounted diodes**
- **Use test procedure to assess diode and heat-sink adequacy in a variety of modules and refine the qualification test**

Design Criteria

DIODE JUNCTION TEMPERATURE ALLOWABLES

DIODE TYPE	MAXIMUM ALLOWABLE JUNCTION TEMPERATURE	DERATED TEMPERATURE FOR LONG-TERM RELIABILITY
p-n	175°C	125°C
Schottky	125°C	75°C
APPLICABLE FIELD CONDITIONS	100 mW/cm^2	100 mW/cm^2
	40°C	40°C
	1.5 I_{sc}	1.0 I_{sc}

Qualification Test Approach

- **Develop test to determine diode junction temperature in situ using readily available laboratory test instruments**
  - **Use diode forward-voltage drop versus temperature to sense junction temperature**
  - **Extrapolate temperature to 100 mW/cm^2, 40°C field thermal conditions from laboratory temperature using NOCT relationships**

Method for Assessing Design Conformance

(1) **Simulate field thermal conditions by heating module front surface with IR radiant heaters to obtain predicted module temperature rise above ambient for 100 mW/cm^2 irradiance**

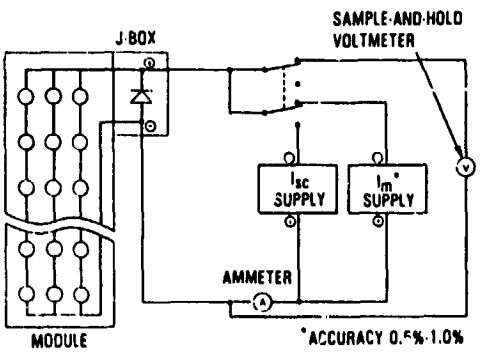
(2) **Apply test current 1.5 I_{sc} or 1.0 I_{sc} to diode until thermal equilibrium is reached**

(3) **Sense the diode junction temperature (T_j) by measuring forward voltage drop across junction at a fixed, known current level (I_m)**

Oven characterization tests used to obtain diode temperature vs voltage drop curve

(4) **Compute junction temperature under 40°C ambient conditions as T_j + 40°C minus the test environment ambient temperature (i.e., T_{room})**

Test Circuit for Measuring Bypass Diode Junction Temperature



Junction Temperature Assessments of Various Heat-Sinked Bypass Diodes for 100 mW/cm^2, 40°C Field Conditions

Module and Heat-Sink Design			Derated Temp $(T_j)_D$ (125°C Limit)		Max Operating Temp $(T_j)_{max}$ (175°C Limit)	
Module Type	P-n Diode Location	NOCT °C	1.0 I_{sc} A	$(T_j)_D$ °C	1.5 I_{sc} A	$(T_j)_{max}$ °C
A	Across Terminals, in Junction Box	46	2.27	83	3.40	105
B	Bracket in Junction Box	54	12.02	122	–	–
C	P-C Board in Junction Box	49	5.30	186	7.95	234
D	Module Frame	56	6.80	140	10.30	185
E	Bracket in Junction Box	47	5.3	130	7.95	169
F	Across Terminals, in Potted J-Box	51	1.44	57	2.16	79
G	Across Bus Bar Ends in Laminate Assembly	47	7.1	234	–	–
H	External Assembly Diode	–	1 X 60	91	1 X 90	128
		–	2 X 60	102	2 x 90	142

Conclusions

- Proposed qual test worked well with a wide variety of bypass diode mounting configurations
- Wide variability of performance obtained from module/diode test set
  - 3 devices: junction temperatures well below limits
  - 2 devices: close to limits, i.e., 1 marginally under and 1 marginally over
  - 3 devices: well beyond the limits
- Diodes meeting the 125°C derated limit at 1.0 I_{SC} easily passed the 175°C maximum operating temperature limit at 1.5 I_{SC}
  - Derated junction temperature limit of 125°C is the more stringent design criterion
- Properly heat-sinked diodes can easily meet the design criteria

Future Work

- **Continue to refine steps in test method to establish a detailed qualification test procedure**
- **Include bypass diode performance criteria and test procedure in Block VI module design and test specification**