

ENGINEERING PRACTICE STUDY

PROJECT NUMBER: 5961-2016-028

TITLE:

MIL-STD-750-4, TEST METHOD 4026:
PROPOSED REVISION TO CLARIFY THE TESTING
PROCEDURES AND REFORMAT CONTENT

30 NOVEMBER 2016

FINAL REPORT

STUDY CONDUCTED BY

DLA LAND AND MARITIME
DOCUMENT STANDARDIZATION DIVISION (VA)
ACTIVE DEVICE BRANCH (VAC)

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ATTCH 3

I. OBJECTIVES: The objective of this Engineering Practice Study (EPS) was to obtain concurrence or comments from the military services, device manufacturers, laboratories, and user community concerning the proposed revision to test method 4026 of MIL-STD-750-4 (see attachments 1 and 2).

II. BACKGROUND: Test method 4026 of MIL-STD-750-4 had not been thoroughly reviewed for updating for a number of years. The current revision, 4026.4 (attachment 3), was last updated with the issuance of change 1 to MIL-STD-750D on 29 February 2000 and the changes made at that time were only editorial in nature.

The initial draft of this EPS was coordinated to the FSC 5961 community and DLA Land and Maritime had requested that those activities that have an interest in test method 4026 to review the proposed revision. This proposed revision includes both format and technical content changes.

III. RESULTS: Comments were received and compiled concerning the proposed revision. The comments and the proposed disposition were coordinated with all commentors. The preparing activity, in cooperation with a small working group of technical experts, reviewed and assigned a recommended disposition to all comments. That recommended disposition was coordinated to all commentors and there were no objections to the assigned disposition.

IV. CONCLUSIONS: The format and technical changes to test method 4026, as documented in attachment 1, should be proposed for incorporation into the next standardization document change action to MIL-STD-750-4.

V. RECOMMENDATIONS: DLA Land and Maritime – VAC recommends that after this EPS final report has been reviewed and accepted by the activities that submitted responses, a formal initial draft of MIL-STD-750-4 should be coordinated with using attachment 1 as the draft of test method 4026.5.

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Changes made in the initial draft of the EP Study: Text highlighted in yellow has been added.

Changes made to the final report draft: Text highlighted in green has been added. Additions/changes to figures are in red.

METHOD 4026.5

FORWARD RECOVERY TIME AND PEAK FORWARD RECOVERY VOLTAGE

1. Purpose. The purpose of this test method is to measure the forward recovery time and peak forward recovery voltage of the semiconductor device undergoing testing.

2. Applicability. A device under test (DUT) reveals an excessive transient forward voltage when it is switched rapidly into the forward conductance region. The amplitude and time duration of this voltage peak can be measured by observing the voltage waveform across the DUT when a forward current pulse of the specified amplitude, rise time, and pulse width, are applied to the DUT.

3. Definitions, symbols, and terms. The following definitions, symbols, and terms shall apply to this test method.

3.1 Symbols. The following symbols shall apply to this test method:

I_F Forward current (dc).

R_F Forward resistance (Ω). For this test method, the value of $R_F = V_F / I_F$ at the specified I_F .

t_{fr} Forward recovery time (s).

t_p Pulse time (s).

t_r Rise time (s).

V_F Forward voltage (see 4.2.3).

V_{FR} Forward recovery voltage (instantaneous total value).

V_{FRM} Peak forward recovery voltage (dc).

3.2 Forward recovery time. The forward recovery time is the time interval between the instant when the forward current rises from a specified value, usually 10 percent of I_F , and the time when the forward voltage falls below a specified V_{FR} .

3.3 Peak forward recovery voltage. The peak forward recovery voltage is the maximum instantaneous value across the DUT resulting from the application of a specified forward current pulse. Peak forward recovery voltage is sometimes identified as $V_{F(PK)}$, $V_{FM(DYN)}$, V_{FM} , and V_{peak} . V_{FRM} is the preferred symbol.

4. General requirements.

4.1 Apparatus. The apparatus used to determine the forward recovery time and peak forward recovery voltage shall be capable of demonstrating device conformance to the minimum requirements of the applicable specification sheet. The apparatus required for this test shall include the following, as applicable.

- a. The test circuit shown on figure 4026-1. The test circuit should be configured to minimize lead length where lead inductance might cause ringing in the test circuit.
- b. Pulse generator. The pulse generator shall be capable of generating the specified forward current pulse.
- c. Response detector (oscilloscope). The input impedance of the response detector shall be $Z \geq 100 R_F$.
- d. Resistor R_P . The value of resistor R_P shall be chosen to optimize the impedance match between pulse generator and test circuit, thereby minimizing the ringing in the test circuit.
- e. Source resistance R_S . The value of resistor $R_S \geq 20 R_F$.

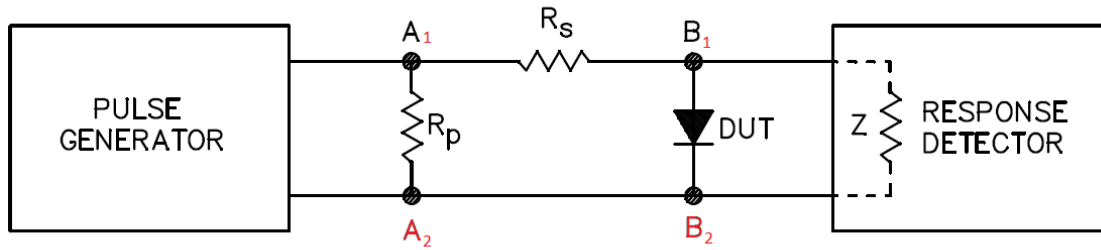
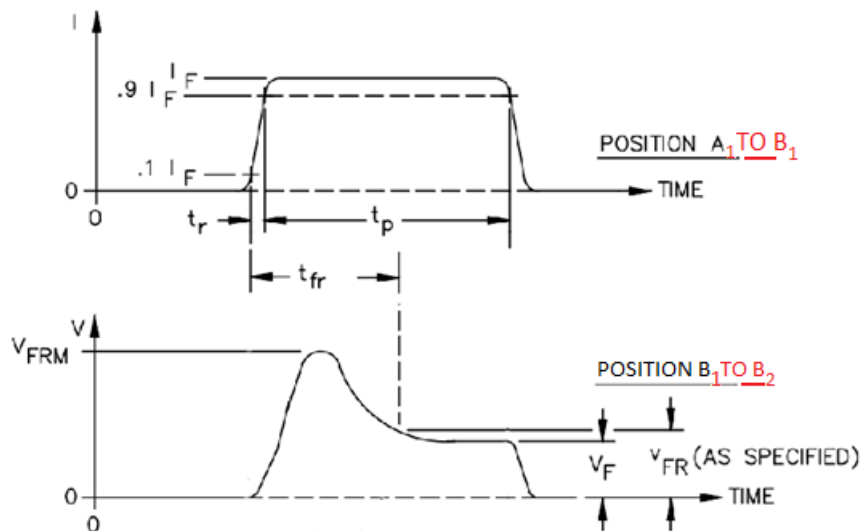


FIGURE 4026–1. Test circuit for forward recovery time and peak forward recovery voltage.

4.2 Procedure. The DUT shall be subjected to the specified forward current pulse. The pulse generator shall be adjusted to achieve the specified amplitude, pulse time, and rise time. The resulting forward current pulse through the DUT (position A on figure 4026–2) and voltage waveform across the DUT (position B on figure 4026–2) shall be graphically monitored with amplitude displayed versus time. The desired forward recovery time and peak forward recovery voltage characteristics shall be obtained from the response detector.

4.2.1 Current pulse characteristics for peak forward recovery voltage. The peak forward recovery voltage of the DUT shall be determined using the following forward current pulse characteristics:

- Forward current I_F amplitude shall be as specified (see 6.a).
- Rise time t_r shall be 10 ns or as specified (see 6.b).
- Pulse time t_p shall be greater than or equal to 10 times the specified forward recovery time t_{fr} .
- Pulse frequency shall be such that a reduction in frequency shall result in no change in forward recovery characteristics.



NOTE: Positions refer to those locations identified on the test circuit of figure 4026–1.

FIGURE 4026–2. Input forward current pulse (top) and output voltage (bottom) waveforms.

4.2.2 Determination of v_{FR} for forward recovery time. When v_{FR} is specified (see 6.c), the forward recovery time of the DUT shall terminate when the voltage drop reaches the v_{FR} voltage (see figure 4026–2). When v_{FR} is not specified, the forward recovery time of the DUT shall terminate as follows:

- a. If V_{FRM} exceeds 10 volts, then v_{FR} shall be 3 times V_F .
- b. If V_{FRM} is greater than or equal to 1.3 volts and less than 10 volts, then v_{FR} shall be 1.1 times V_F .
- c. If V_{FRM} is less than 1.3 volts, then v_{FR} shall be equal to $0.5 (V_{FRM} - V_F) + V_F$.

4.2.3 Determination of V_F for t_{fr} measurement. Unless otherwise specified, V_F shall be measured at 3 times the t_{fr} specified by the performance specification sheet.

5. Measurements. The following measurement shall be made:

- a. The forward recovery time (t_{fr}). The following details shall apply:
 1. The forward recovery time shall be measured as the time interval from $0.1 I_F$ (see waveform at position A on figure 4026–2) to the time that the forward voltage recovers to a specified v_{FR} (see voltage waveform at position B on figure 4026–2 and 6.c).
 2. For DUTs where V_{FRM} is less than v_{FR} , the t_{fr} shall be measured at V_{FRM} .
- b. The peak forward recovery voltage (V_{FRM}).

5.1 Example of measuring t_{fr} . For an example DUT, the t_{fr} is specified to be 15 ns maximum by the performance specification sheet. The test operator measures the V_F at 45 ns, 3 times 15 ns as specified in 4.2.3. It has also been determined that V_{FRM} at 45 ns is greater than or equal to 1.3 volts and less than 10 volts. Using the determination factor of 4.2.2.b, the test operator would then multiply the measured value of V_F by 1.1 (110 percent) to arrive at the value of v_{FR} . The test operator then would turn the second cursor on the response detector back to the calculated value of v_{FR} value to measure the actual t_{fr} of the DUT.

6. Summary. The following conditions shall be specified in the applicable performance specification sheet or acquisition document:

- a. Amplitude of the forward current pulse (I_F) (see 4.2.1.a).
- b. Rise time (t_r) of the forward current pulse, if other than 10 nanoseconds (see 4.2.1.b).
- c. Forward recovery voltage (v_{FR}) chosen to terminate the forward recovery time measurement (see 4.2.2).

EP Study initial draft changes: Text highlighted in yellow has been added and red text w/strike-out and highlighted in blue will be deleted.

EP Study final report changes: Text highlighted in green has been added and white text w/strike-out highlighted in red will be deleted.

METHOD 4026.45

~~FORWARD RECOVERY VOLTAGE AND TIME~~

FORWARD RECOVERY TIME AND PEAK FORWARD RECOVERY VOLTAGE

1. Purpose. The purpose of this test method is intended to measure the forward recovery time and peak forward recovery voltage and recovery time of the semiconductor device undergoing testing.

2. Applicability. A device under test (DUT) reveals an excessive transient forward voltage when it is switched rapidly into the forward conductance region. The amplitude and time duration of this voltage peak can be measured by observing the voltage waveform across the device DUT when a flat-top-pulse forward current pulse of the specified amplitude, rise time, and pulse width, and frequency are applied to the device DUT.

3. Definitions, symbols, and terms. The following definitions, symbols, and terms shall apply to this test method.

3.1 Symbols. The following symbols shall apply to this test method:

I_F Forward current (dc).

R_F Forward resistance (Ω). For this test method, the value of $R_F = V_F / I_F$ at the specified I_F .

t_{fr} Forward recovery time (s).

t_p Pulse time (s).

t_r Rise time (s).

V_F Forward voltage (see 4.2.3).

V_{FR} Forward recovery voltage (instantaneous total value).

V_{FRM} Peak forward recovery voltage (dc).

3.2 Forward recovery time. The forward recovery time is the time interval between the instant when the forward current rises from a specified value, usually 10 percent of I_F , and the time when the forward voltage falls below a specified V_{FR} .

3.3 Peak forward recovery voltage. The peak forward recovery voltage is the maximum instantaneous value across the DUT resulting from the application of a specified forward current pulse. Peak forward recovery voltage is sometimes identified as $V_{F(PK)}$, $V_{FM(DYN)}$, V_{FM} , and V_{peak} . V_{FRM} is the preferred symbol.

~~4. Test circuit. See figure 4026-1.~~

4. General requirements.

4.1 Apparatus. The apparatus used to determine the forward recovery time and peak forward recovery voltage shall be capable of demonstrating device conformance to the minimum requirements of the applicable specification sheet. The apparatus required for this test shall include the following, as applicable.

- The forward transient test circuit shown on figure 4026-1. ~~is used in conjunction with a pulse generator and an output sensing device. Care~~ The test circuit should be configured to minimize lead length where lead inductance might cause ringing in the test circuit.
- Pulse generator. The pulse generator shall be capable of generating the specified forward current pulse.
- Response detector (oscilloscope). The input impedance of the response detector shall be $Z \geq 100 R_F$.
- Resistor R_P . The value of resistor R_P shall be chosen to optimize the impedance match between pulse generator and test circuit, thereby minimizing the ringing in the test circuit.
- Source resistance R_S . The value of resistor $R_S \geq 20 R_F$.

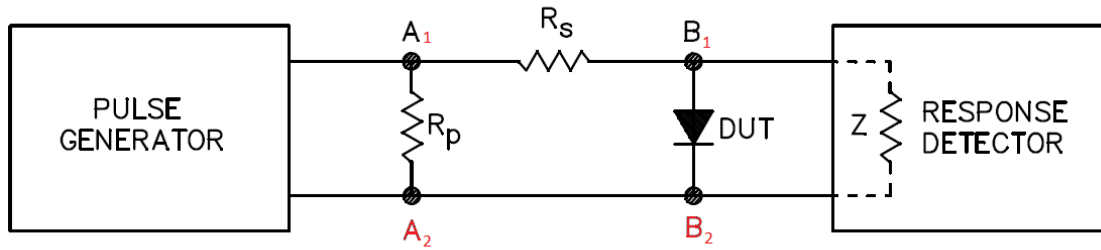


FIGURE 4026-1. Test circuit for forward recovery time and peak forward recovery voltage.

4.2 ~~3~~ Procedure. ~~The test shall be performed using the following:~~ The DUT shall be subjected to the specified forward current pulse. The pulse generator shall be adjusted to achieve the specified amplitude, pulse time, and rise time. The resulting forward current pulse through the DUT (position A on figure 4026-2) and voltage waveform across the DUT (position B on figure 4026-2) shall be graphically monitored with amplitude displayed versus time. The desired forward recovery time and peak forward recovery voltage characteristics shall be obtained from the response detector.

4.2.1 Current pulse characteristics for peak forward recovery voltage. The peak forward recovery voltage of the DUT shall be determined using the following forward current pulse characteristics:

~~3.1 Conditions:~~

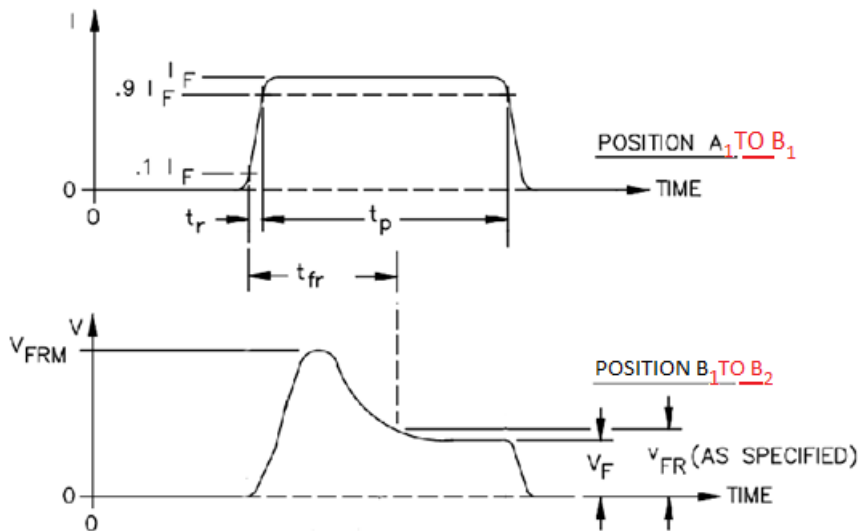
~~a. Pulse input A:~~

- a. ~~(1)~~ Forward current I_F amplitude shall be as specified (see 6.a).
- b. ~~(2)~~ Rise time t_r shall be 10 ns or as specified (see 6.b).
- c. ~~(3)~~ Pulse time width t_1 t_p shall be greater than or equal to 10 times the specified response time forward recovery time t_{fr} .

~~(4) Generator resistance $R_s \geq 20 R_F$ ($R_F = V_F/I_F$ at specified I_F).~~

- d. ~~(5)~~ Pulse frequency shall be such that a reduction in frequency shall result in no change in forward recovery characteristics.

~~b. Response detector input impedance, $Z \geq 100 R_F$.~~



NOTE: Positions refer to those locations identified on the test circuit of figure 4026-1.

FIGURE 4026-2. Input forward current pulse (position A top) and output voltage (position B bottom) waveforms.

4.2.2 Determination of v_{FR} for forward recovery time. When v_{FR} is specified (see 6.c), the forward recovery time of the DUT shall terminate when the voltage drop reaches the v_{FR} voltage (see figure 4026–2). When v_{FR} is not specified, the forward recovery time of the DUT shall terminate as follows:

- a. If V_{FRM} exceeds 10 volts, then v_{FR} shall be 3 times V_F .
- b. If V_{FRM} is greater than or equal to 1.3 volts and less than 10 volts, then v_{FR} shall be 1.1 times V_F .
- c. If V_{FRM} is less than 1.3 volts, then v_{FR} shall be equal to $0.5 (V_{FRM} - V_F) + V_F$.

4.2.3 Determination of V_F for t_{fr} measurement. Unless otherwise specified, V_F shall be measured at 3 times the t_{fr} specified by the performance specification sheet.

5. Measurements. The following measurement shall be made:

- a. The forward recovery time (t_{fr}). The following details shall apply:
 1. The forward recovery time shall be measured as the time interval from $0.1 I_F$ (see waveform at position A on figure 4026–2) to the time that the forward voltage recovers to a specified v_{FR} (see voltage waveform at position B on figure 4026–2 and 6.c).
 2. For DUTs where V_{FRM} is less than v_{FR} , the t_{fr} shall be measured at V_{FRM} .
- b. The peak forward recovery voltage (V_{FRM}).

5.1 Example of measuring t_{fr} . For an example DUT, the t_{fr} is specified to be 15 ns maximum by the performance specification sheet. The test operator measures the V_F at 45 ns, 3 times 15 ns as specified in 4.2.3. It has also been determined that V_{FRM} at 45 ns is greater than or equal to 1.3 volts and less than 10 volts. Using the determination factor of 4.2.2.b, the test operator would then multiply the measured value of V_F by 1.1 (110 percent) to arrive at the value of v_{FR} . The test operator then would turn the second cursor on the response detector back to the calculated value of v_{FR} value to measure the actual t_{fr} of the DUT.

6. 4. Summary. The following conditions shall be specified in the applicable performance specification sheet or acquisition document:

- a. Amplitude of the forward current pulse (I_F) of input waveform A (see 4.2.1.a 3-1).
- b. Rise time (t_r) of the forward current pulse, if other than 10 nanoseconds (see 4.2.1.b 3-1).
- c. Forward recovery voltage v_{FR} (V_{FR}) chosen to terminate the forward recovery time measurement (see figure 4026-1) (see 4.2.2).

~~d. The following measurements should be made: Forward recovery time (t_{fr}) (measured from the time of 0.1 seconds I_F to the time that forward voltage recovers to a specified V_{FR}) (see figure 4026-1).~~

~~e. The Peak forward voltage V_{PEAK} (see figure 4026-1). This symbol is interchangeable with V_{FRM} .~~

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w/CHANGE 1

METHOD 4026.4

FORWARD RECOVERY VOLTAGE AND TIME

1. Purpose. The purpose of this test method is intended to measure the forward voltage and recovery time of the semiconductor device. A device reveals an excessive transient forward voltage when it is switched rapidly into the forward conductance region. The amplitude and time duration of this voltage peak can be measured by observing the voltage waveform across the device when a flat-top pulse of the specified amplitude, rise time, pulse width, and frequency are applied to the device.

2. Test circuit. See figure 4026-1.

- a. The forward transient test circuit shown on figure 4026-1 is used in conjunction with a pulse generator and an output sensing device. Care should be taken to minimize lead length where lead inductance might cause ringing in the test circuit.
- b. The value of resistor R_p shall be chosen to optimize the impedance match between pulse generator and test circuit, thereby minimizing the ringing in the test circuit.

3. Procedure. The test shall be performed using the following:

3.1 Conditions:

- a. Pulse input A:
 - (1) I_F amplitude: As specified.
 - (2) Rise time = 10 ns or as specified.
 - (3) Pulse width $t_1 \geq 10X$ specified response time.
 - (4) Generator resistance $R_S \geq 20 R_F$ ($R_F = V_F/I_F$ at specified I_F).
 - (5) Pulse frequency shall be such that a reduction in frequency shall result in no change in forward recovery characteristics.
- b. Response detector input impedance, $Z \geq 100 R_F$.

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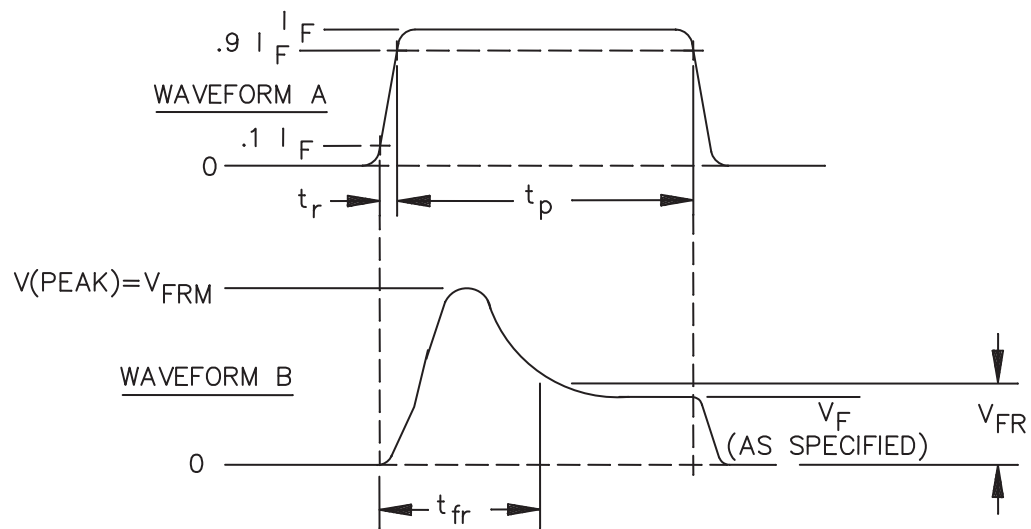
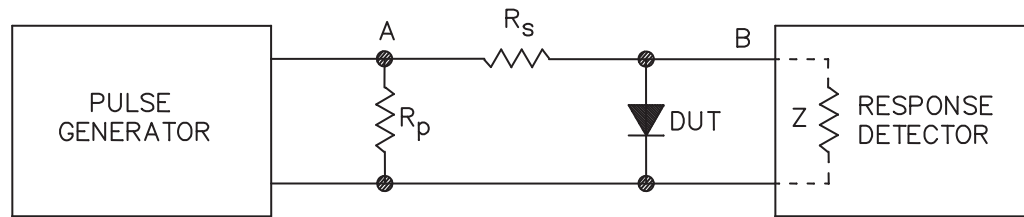


FIGURE 4026-1. Test circuit for forward recovery voltage and time.

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4. Summary. The following conditions shall be specified in the applicable performance specification sheet or acquisition document:

- a. I_F of input waveform A (see 3.1).
- b. Rise time if other than 10 nanoseconds (see 3.1).
- c. Forward recovery voltage V_{FR} chosen to terminate the forward recovery time measurement (see figure 4026-1).
- d. The following measurements should be made: Forward recovery time (t_{fr}) (measured from the time of 0.1 seconds I_F to the time that forward voltage recovers to a specified V_{FR}) (see figure 4026-1).
- e. The peak forward voltage $V_{(PEAK)}$ (see figure 4026-1). This symbol is interchangeable with V_{FRM} .