Junction Temperature Assessment for LEDs & Lasers Operated in Pulsed Mode

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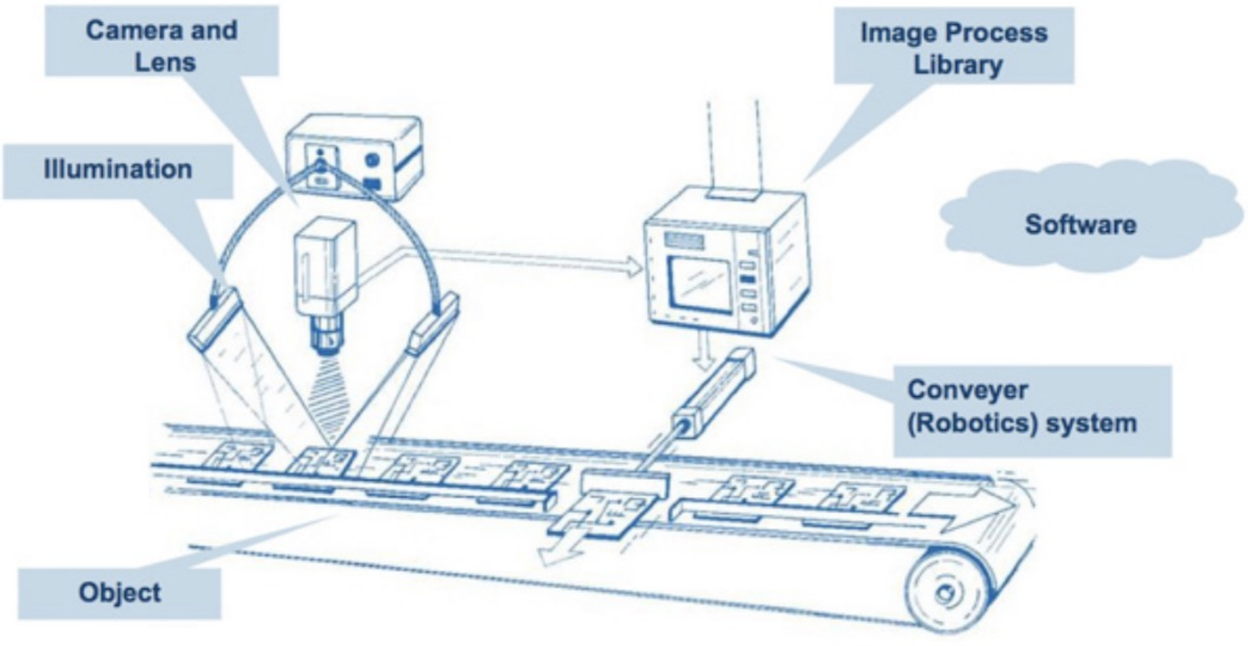
Outline

- Pulsed applications
- Why junction temperature is important
- DC vs Pulsed junction temperature
- JEDEC method overview
  - Variation 1 – heating and measurement current sources (classic ETM)
  - Variation 2 – single heating current source (modified ETM)
- Examples and data comparison

Lasers and LEDs are Often Driven With Pulsed Current

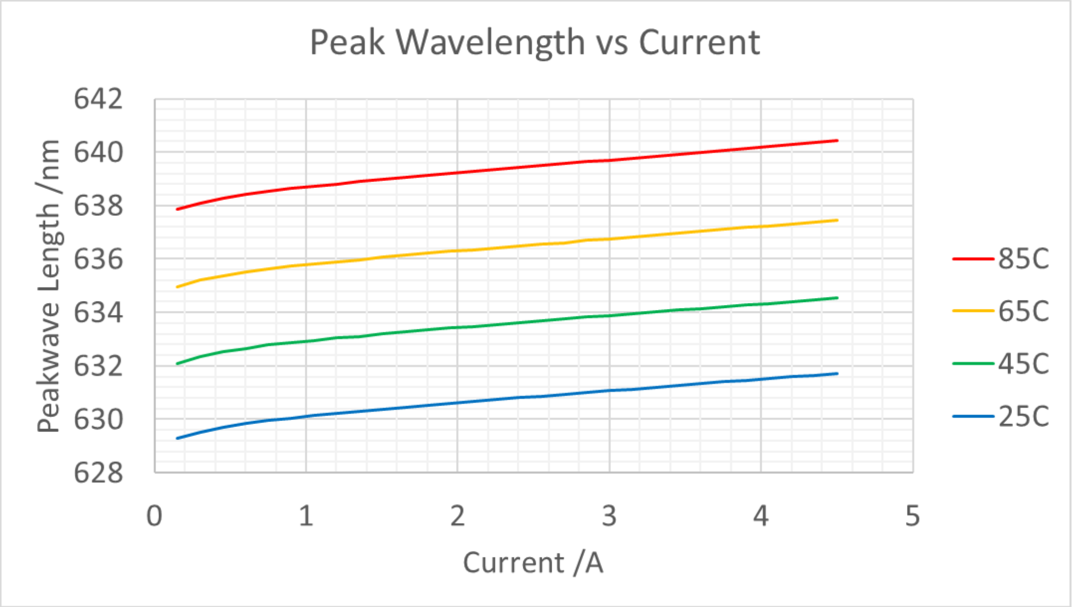
- Video projection
- Machine vision
- Laser cutting
- Binning measurements

- For some applications drive current may be >> $I_{nominal}$

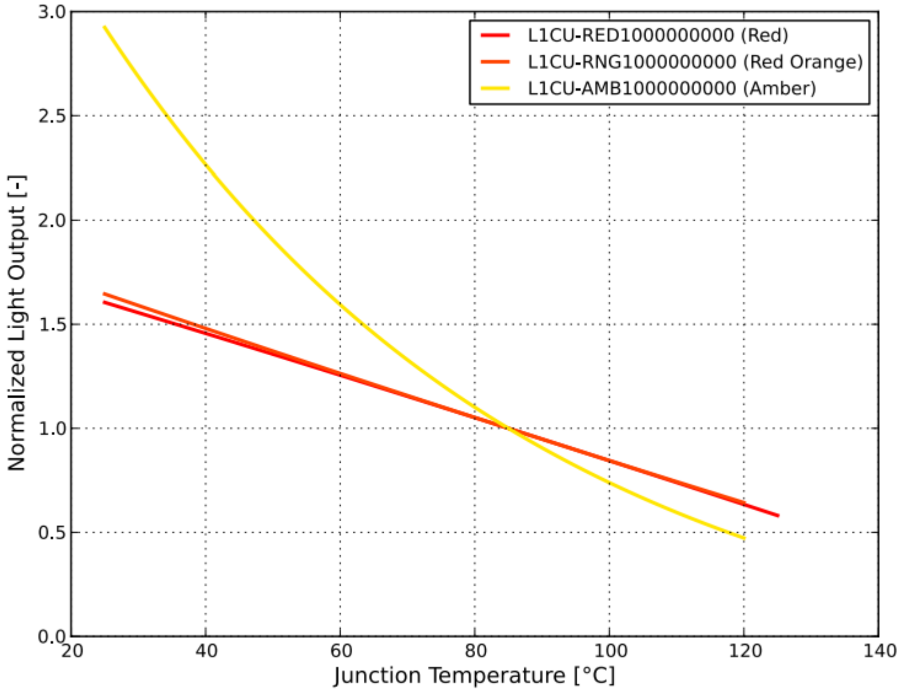


Typical machine vision setup
- Robotics Tomorrow

Key Device Parameters Can Change Dramatically With Junction Temperature



Red LED peak wavelength shifts higher as junction temperature increases



LED output decreases as junction temperature increases – most dramatically for amber LEDs

In DC Operation Junction Temperature May Be Calculated Using Thermal Resistance

Junction temperature =

$T_{SP} + P * R_{\Theta}$

Electrical and Thermal Characteristics

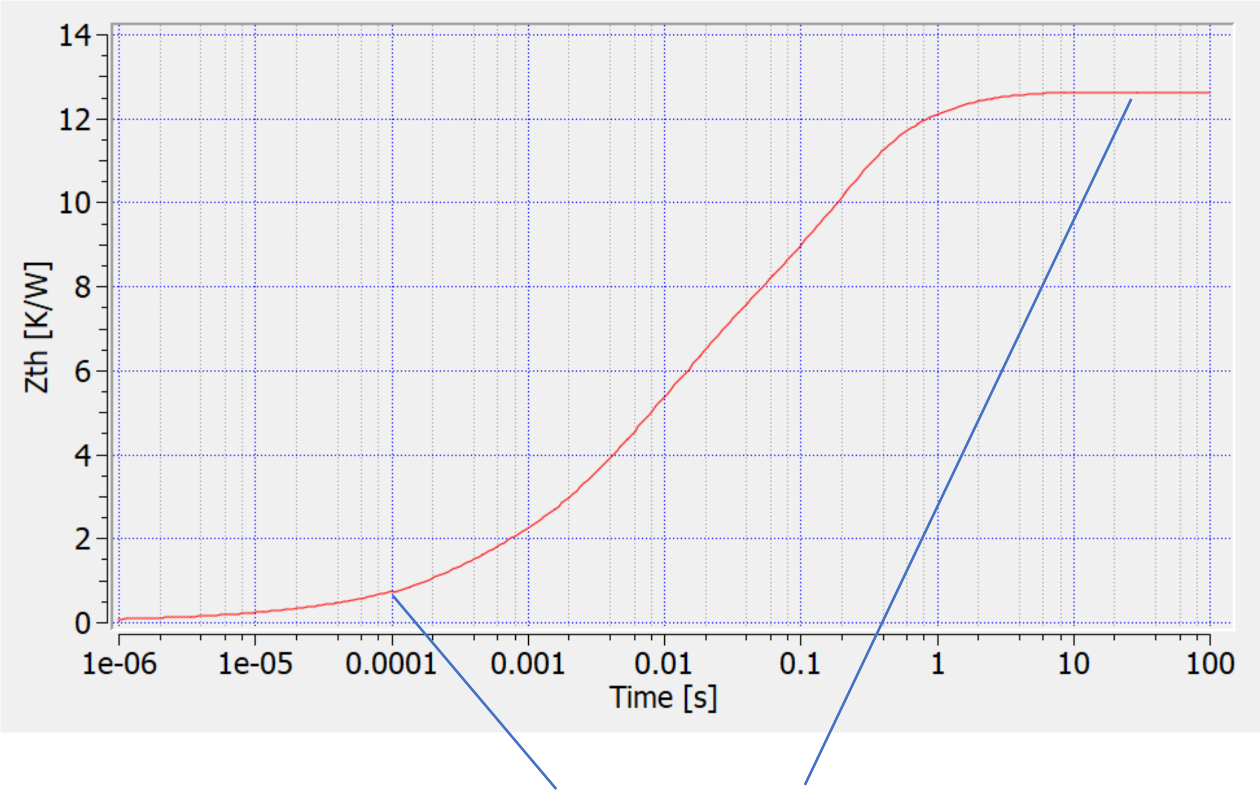
Table 3. Electrical and thermal characteristics for LUXEON CZ Color Line at 350mA, T_j=85°C.

COLOR	PART NUMBER	FORWARD VOLTAGE [1] (V_f)			TYPICAL TEMPERATURE COEFFICIENT OF FORWARD VOLTAGE [2] (mV/°C)	TYPICAL THERMAL RESISTANCE—JUNCTION TO SOLDER PAD (°C/W)
		MINIMUM	TYPICAL	MAXIMUM		
Far Red	L1CU-FRD1000000000	1.50	1.90	2.30	-1.7	3.5
Deep Red	L1CU-DRD1000000000	1.50	2.05	2.30	-1.7	3.5
Red	L1CU-RED1000000000	1.75	2.00	2.50	-1.6	3.5
Red-Orange	L1CU-RNG1000000000	1.75	2.05	2.50	-1.6	3.5
Amber	L1CU-AMB1000000000	1.75	2.05	2.50	-2.0	3.5
PC Amber	L1CU-PCA1000000000	2.50	2.75	3.50	-1.7	3.5
Mint	L1CU-MNT1000000000	2.50	2.75	3.50	-2.7	3.2
Lime	L1CU-LME1000000000	2.50	2.75	3.50	-2.7	3.2
Green	L1CU-GRN1000000000	2.50	3.05	3.50	-2.4	4.0
Cyan	L1CU-CYN1000000000	2.50	3.05	3.50	-2.4	4.0
Blue	L1CU-BLU1000000000	2.50	2.83	3.50	-2.6	4.0
Royal Blue	L1CU-RYL0000000000	2.50	2.75	3.50	-1.7	3.2
Violet	L1CU-VLT1000000000	2.50	2.83	3.50	-1.7	3.2
White	L1CU-xxx0000000000	2.50	2.75	3.50	-1.7	3.2

Notes for Table 3:
1. Lumileds maintains a tolerance of ±0.06V on forward voltage measurements.
2. Measured between 25°C and 85°C.

For Pulsed Operation, the Effective Thermal Resistance Varies With Time, Making it Difficult to Calculate T_J.

- For short pulses, at low duty cycle, the effective thermal resistance will be much lower than the DC thermal resistance

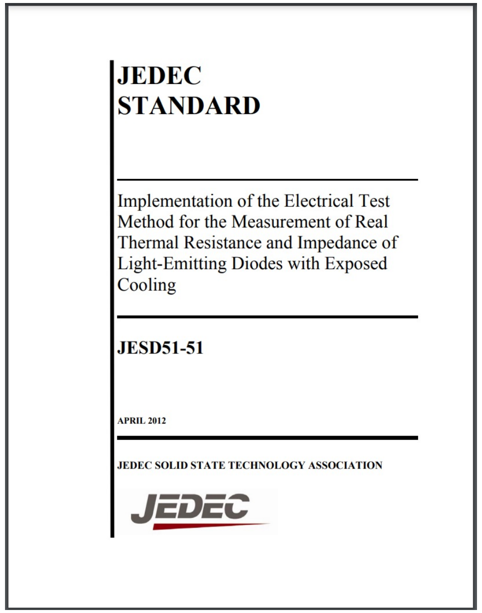


100 µs pulsed R_Θ= 1 C/W, DC R_Θ= 12.6 C/W

Junction Temperature Measurements Utilize the JEDEC Electrical Test Method (ETM)

- JEDEC method for determining junction temperature using the forward voltage of a diode

- JESD51-51 is the primary standard for these measurements



JEDEC STANDARD

Implementation of the Electrical Test Method for the Measurement of Real Thermal Resistance and Impedance of Light-Emitting Diodes with Exposed Cooling

JESD51-51

APRIL 2012

JEDEC SOLID STATE TECHNOLOGY ASSOCIATION

JEDEC

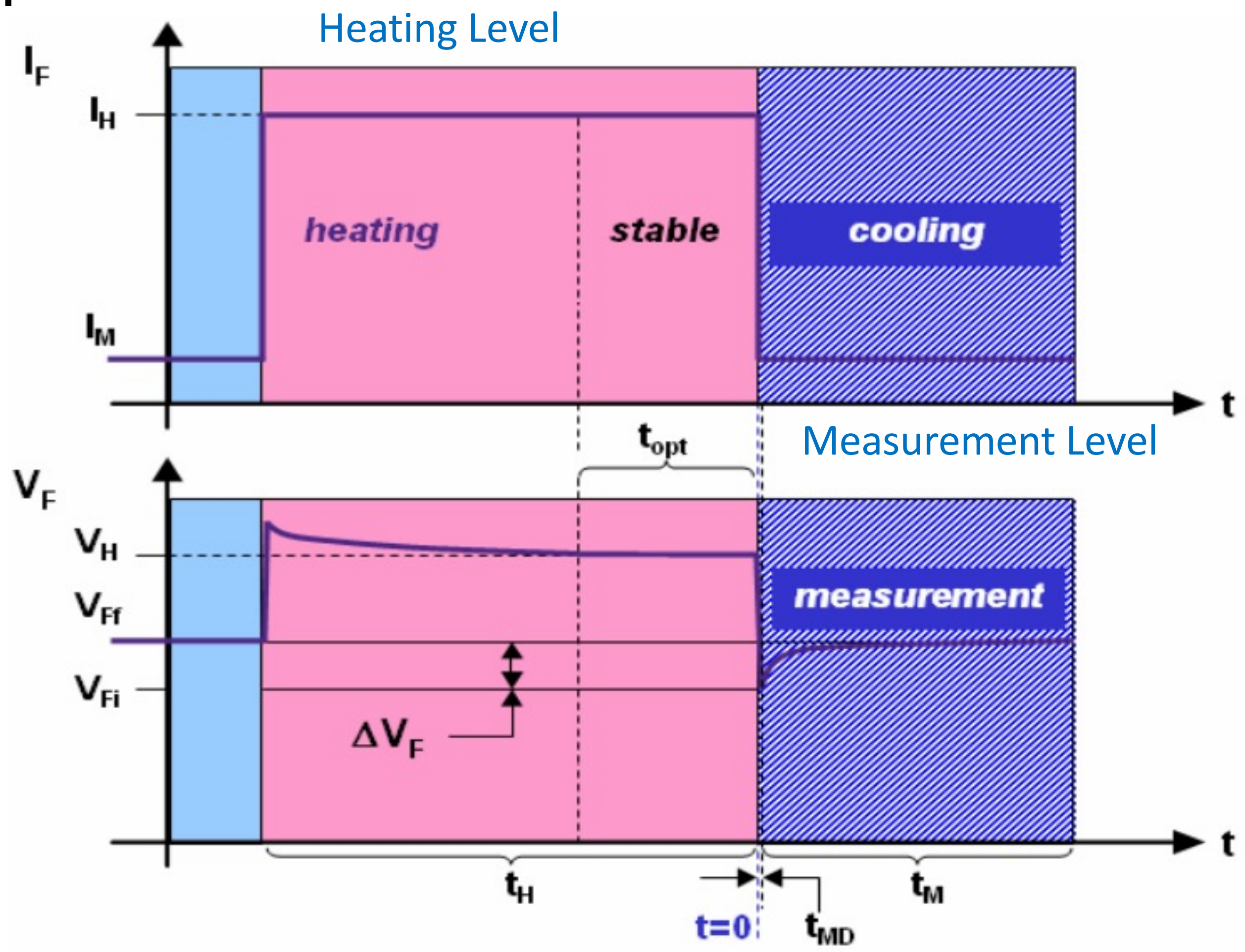
The ETM Infers Junction Temperature & Thermal Resistance Using a Semiconductor Diode's Forward Voltage (V_F) Temperature Characteristic

- A diode's V_F typically decreases by 1-3 mV for each 1˚C increase in T_J
- This temperature sensitivity factor is called S_{VF}
- The reciprocal of S_{VF} is called the K-factor
- S_{VF} is slightly different for each device
- Devices of the same design will have similar S_{VF} values
- S_{VF} can shift during initial operation, so it is a good idea to "burn-in" devices before performing measurements

T_J Is Typically Measured Using a Two-Level Current Waveform

- The DUT is first operated at the heating current level for the duration of the pulse, then the current is reduced to the measurement level and V_F is digitized

- The V_F before and after the pulse to calculate T_J



T_J Measurement Circuit - Two Current Sources and a Digitizer Are Required

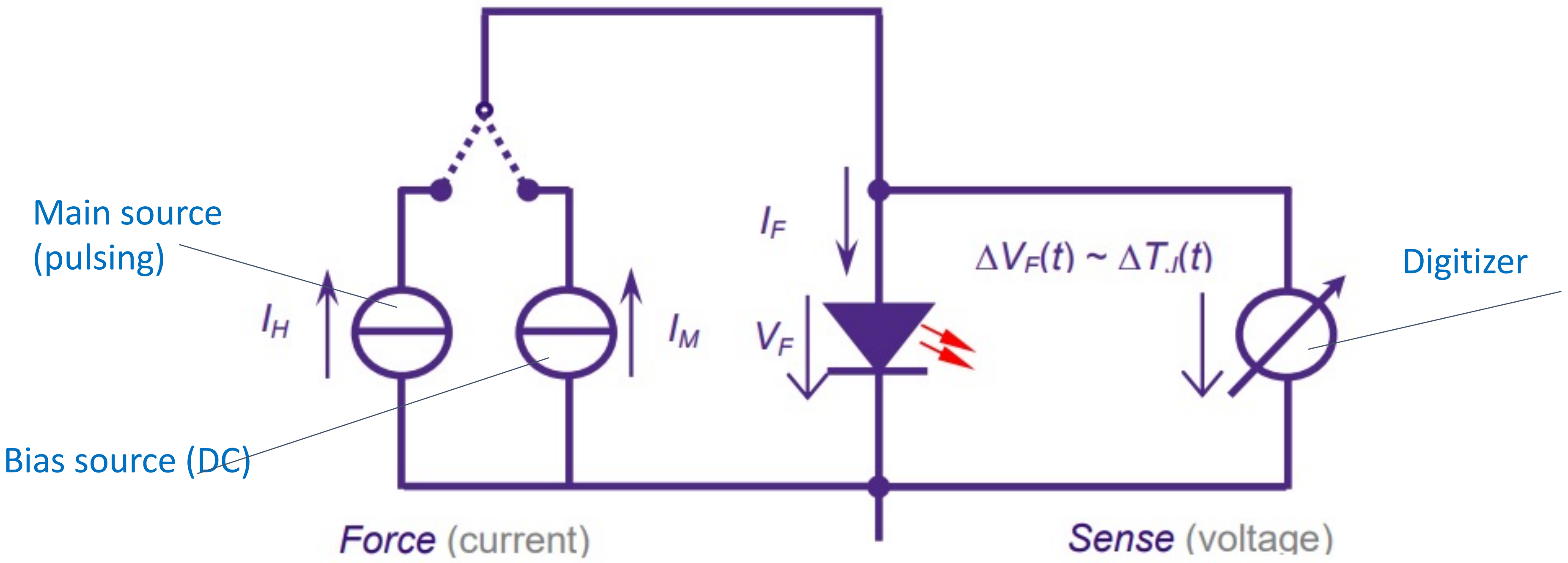
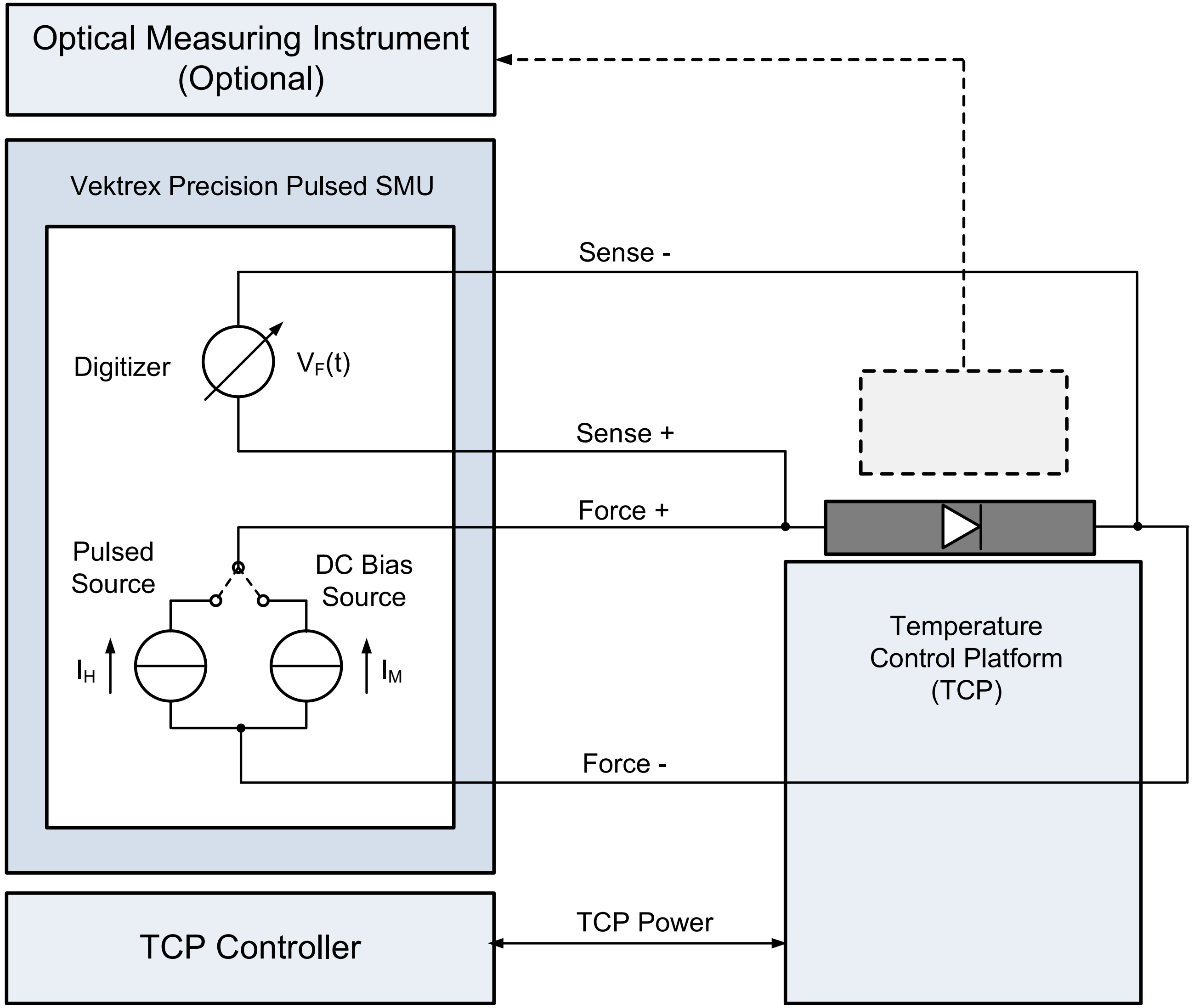
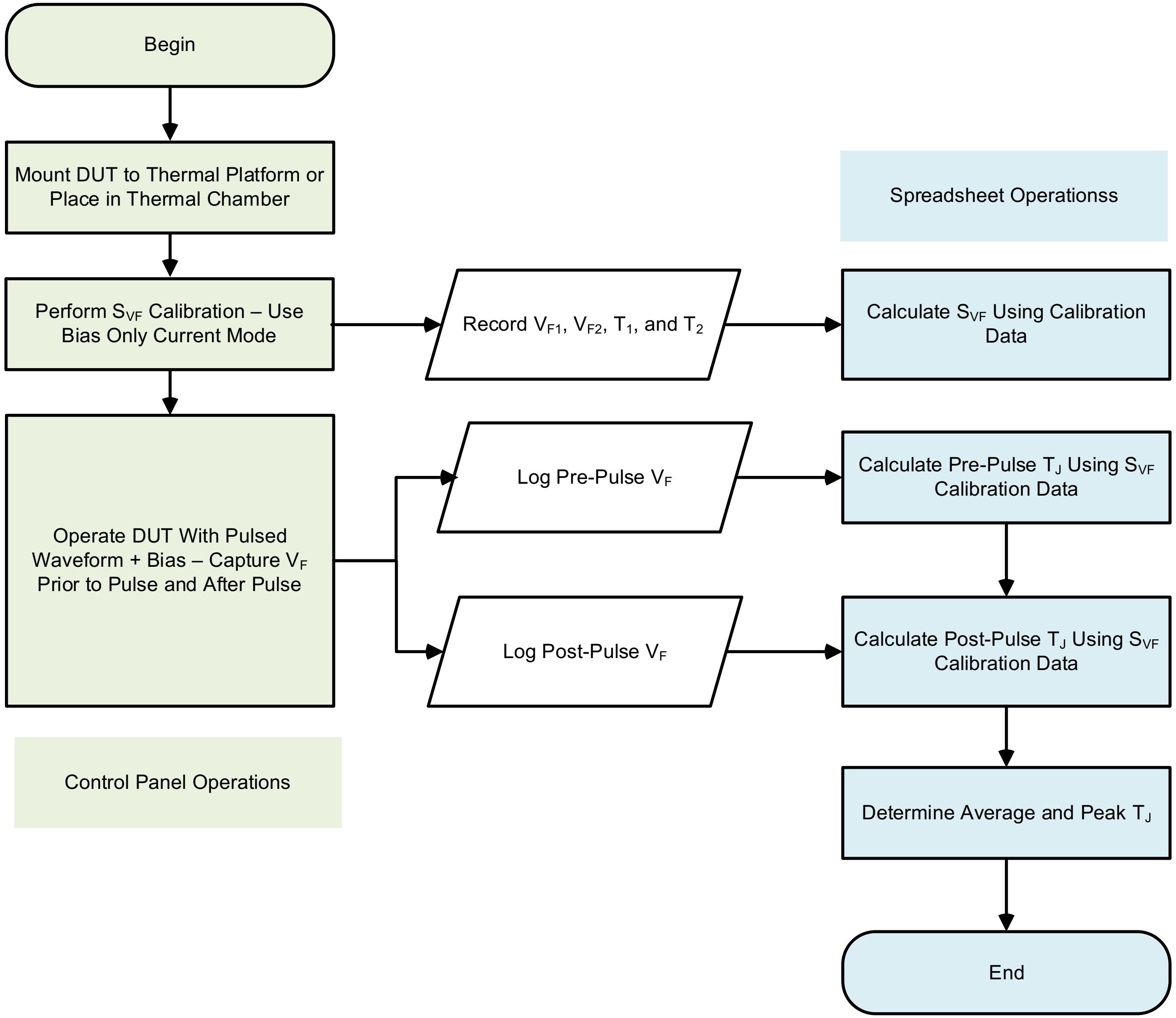


Figure 6 — Diode thermal measurement circuit
(see JESD51, MIL-STD-750D Method 3101.3)

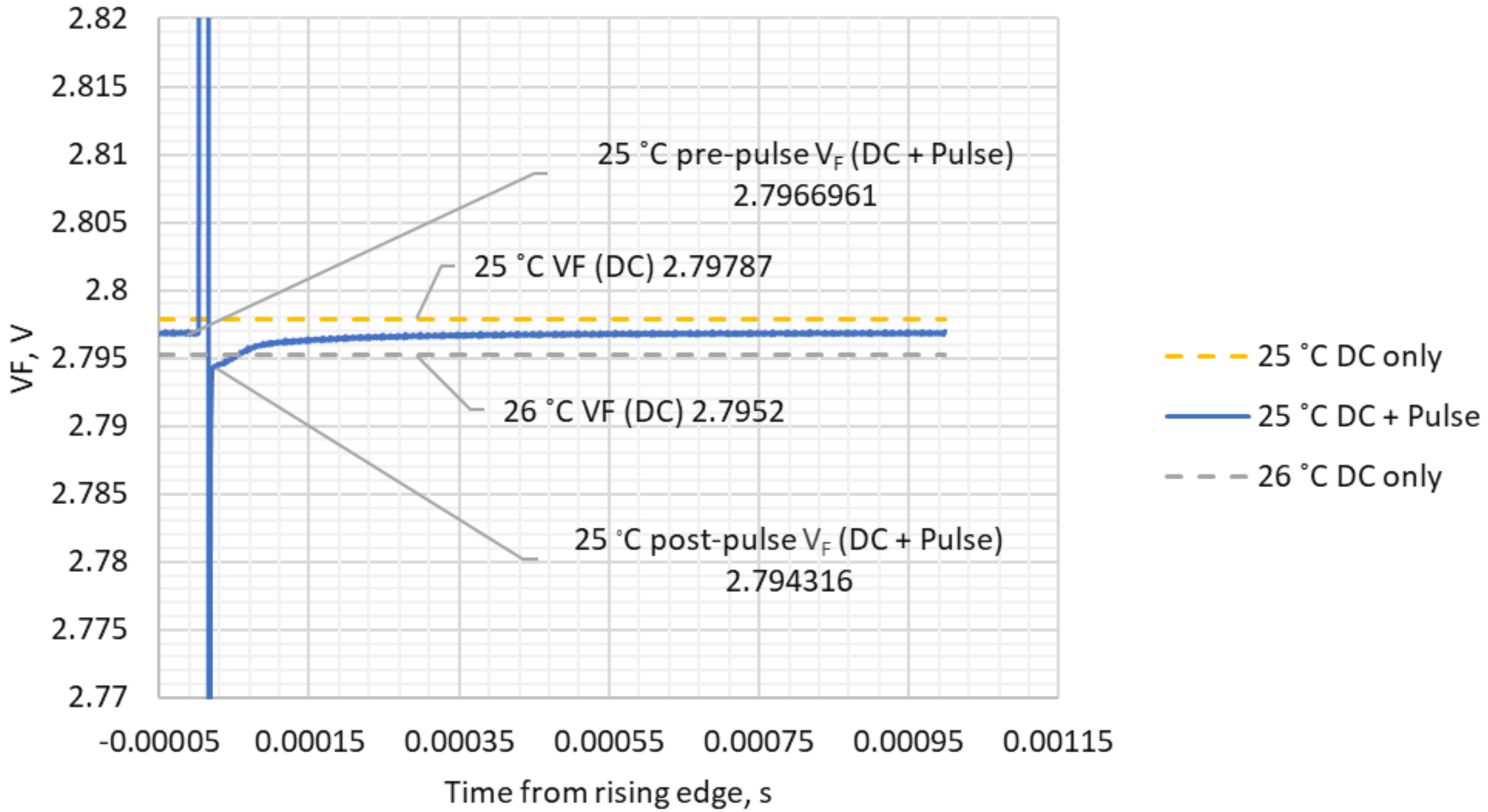
Junction Temperature Assessment System Block Diagram



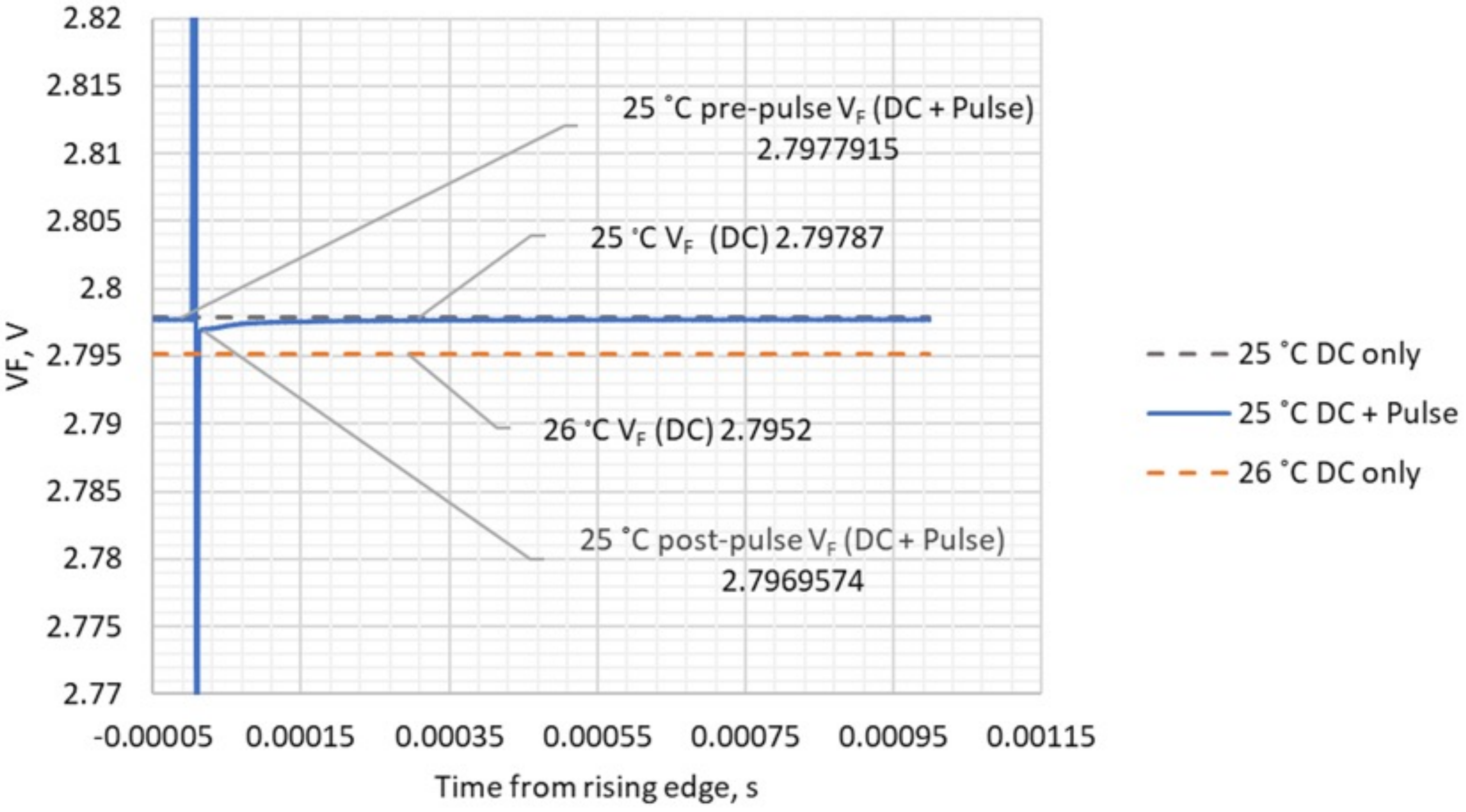
Method 1 Flow Chart



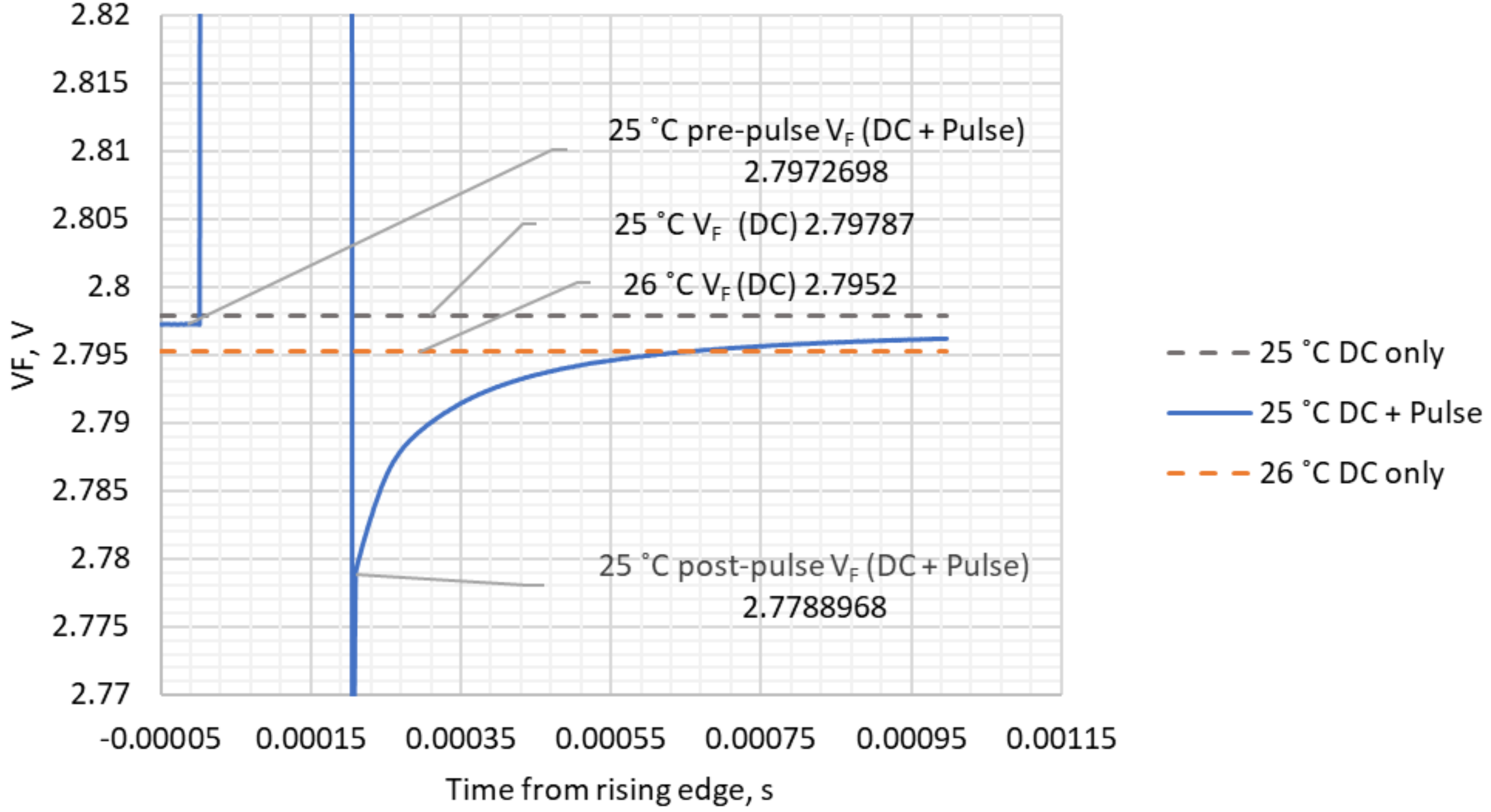
Method 1 Results – 10 μs Pulse, 1% Duty Cycle



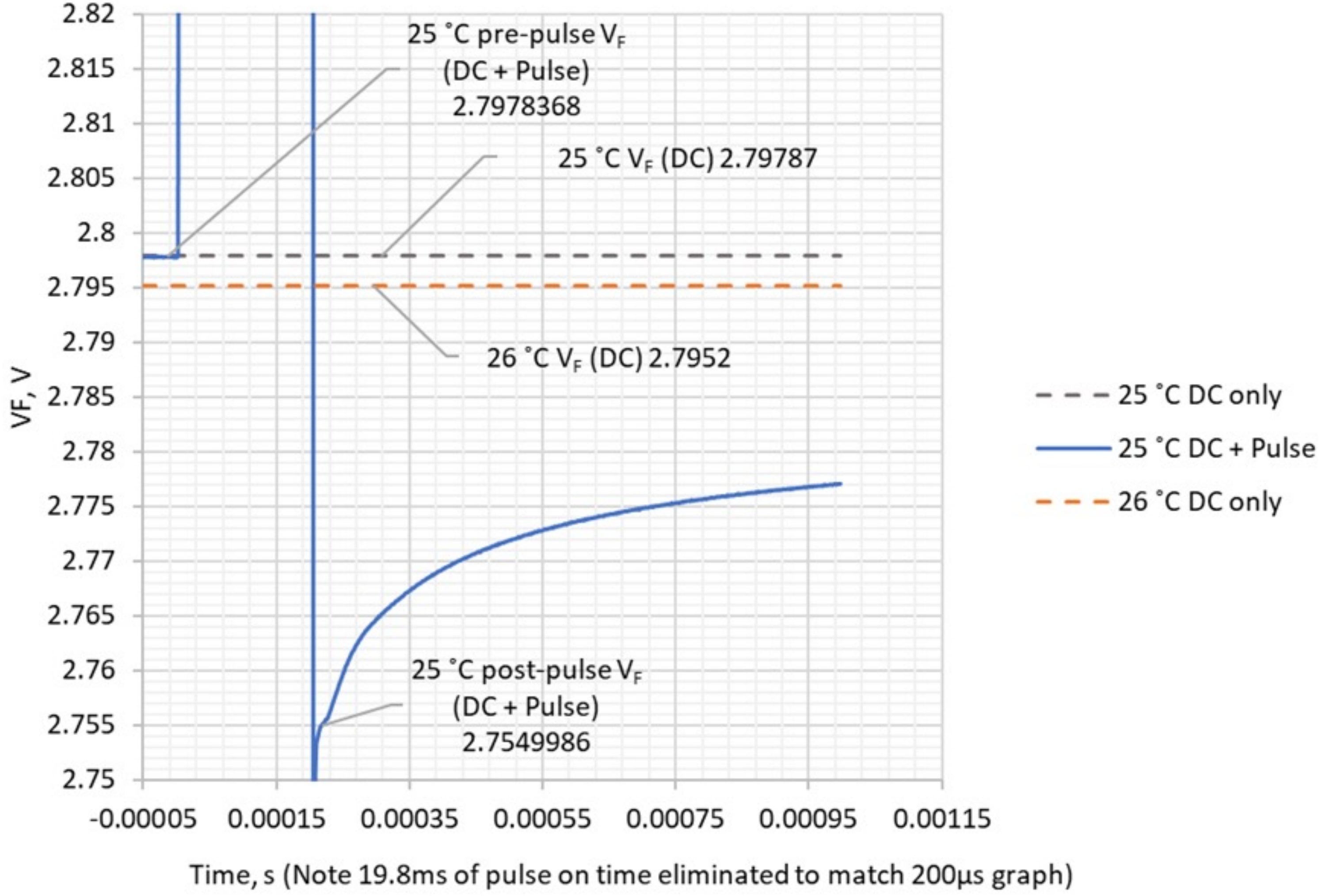
Method 1 Results – 2.5 µs Pulse, 1% Duty Cycle



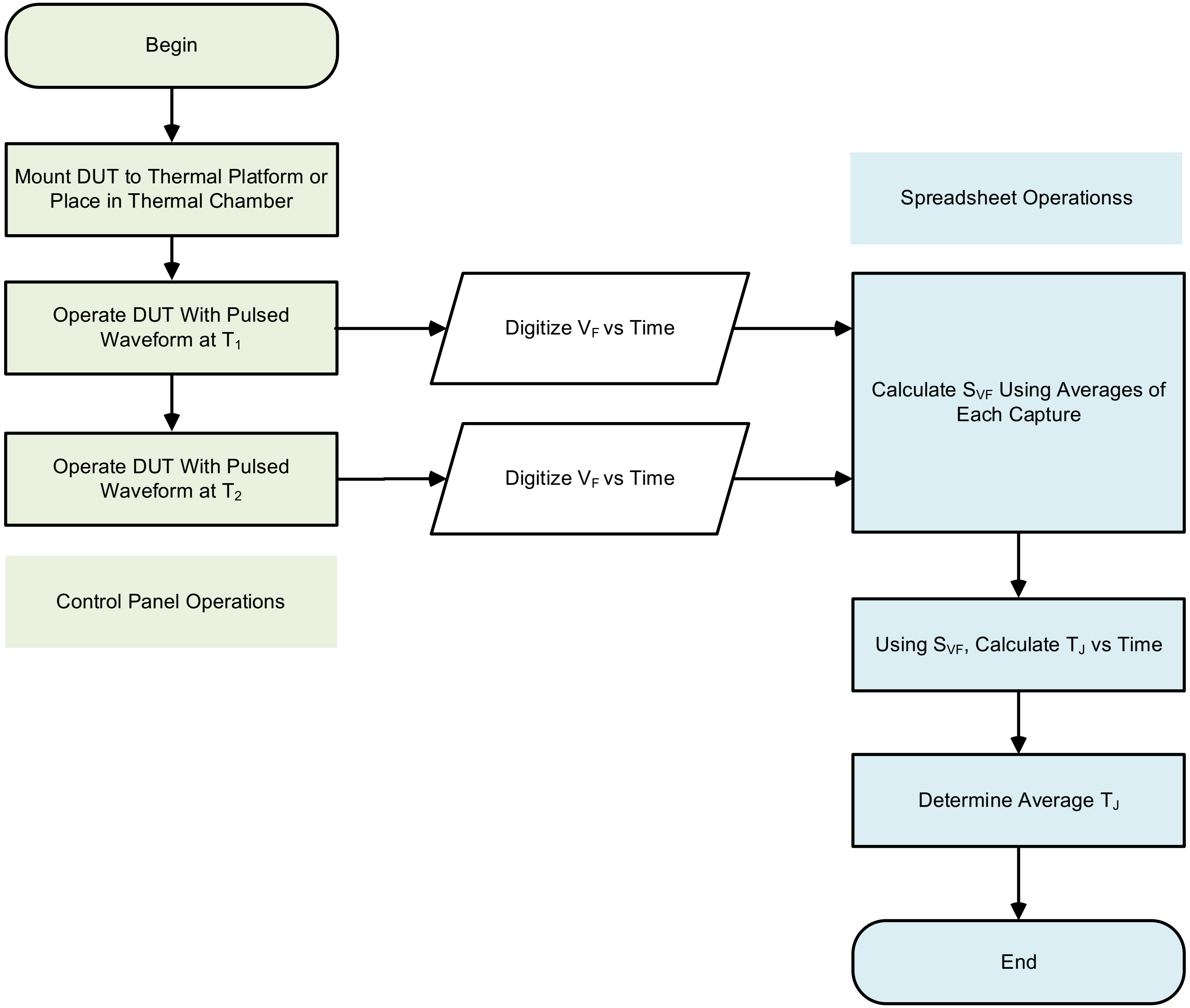
Method 1 Results – 200 µs Pulse, 1% Duty Cycle



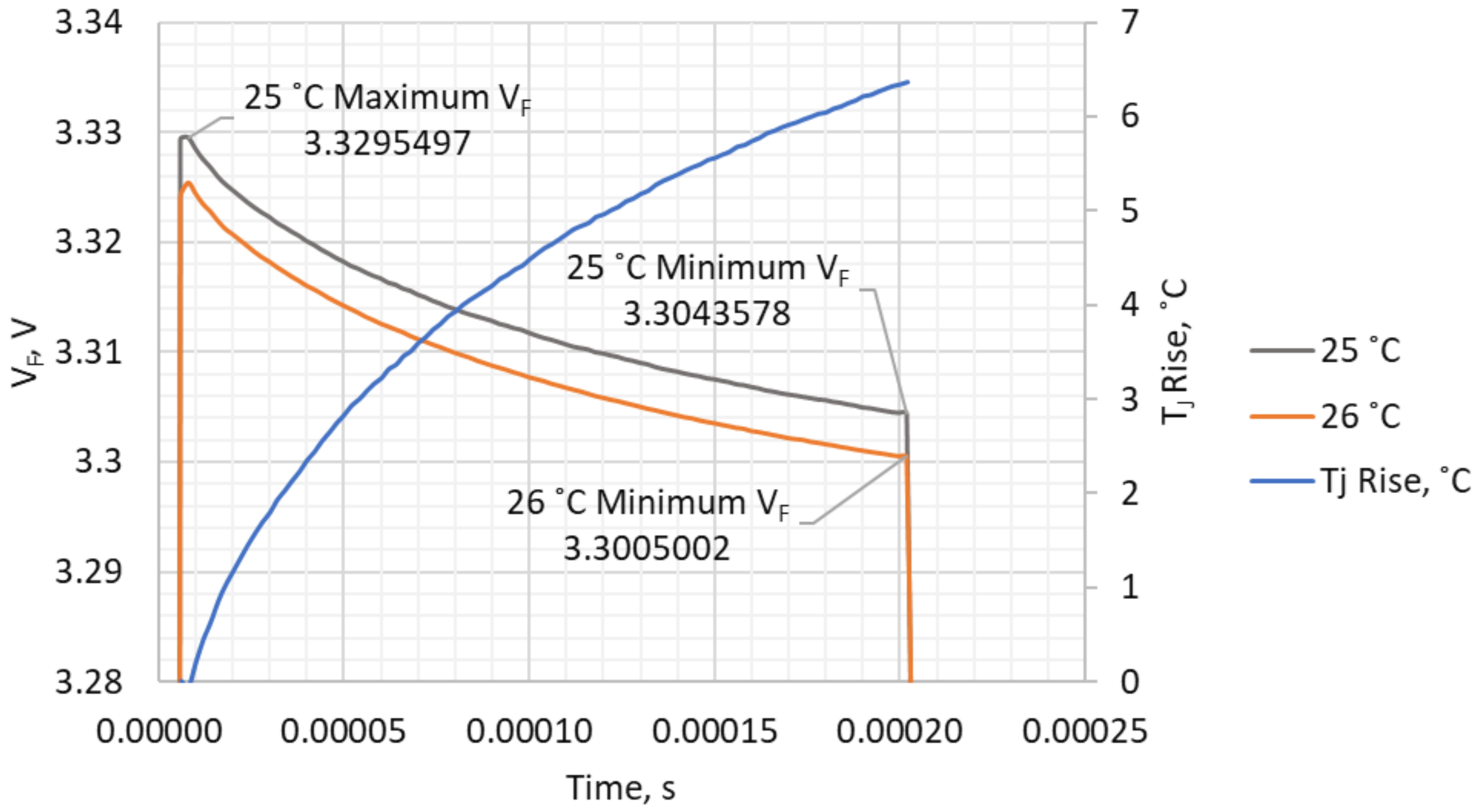
Method 1 Results – 20 ms, 1% Duty Cycle



Method 2 Flow Chart



Method 2 Results – 200 µs Pulse, 1% Duty (

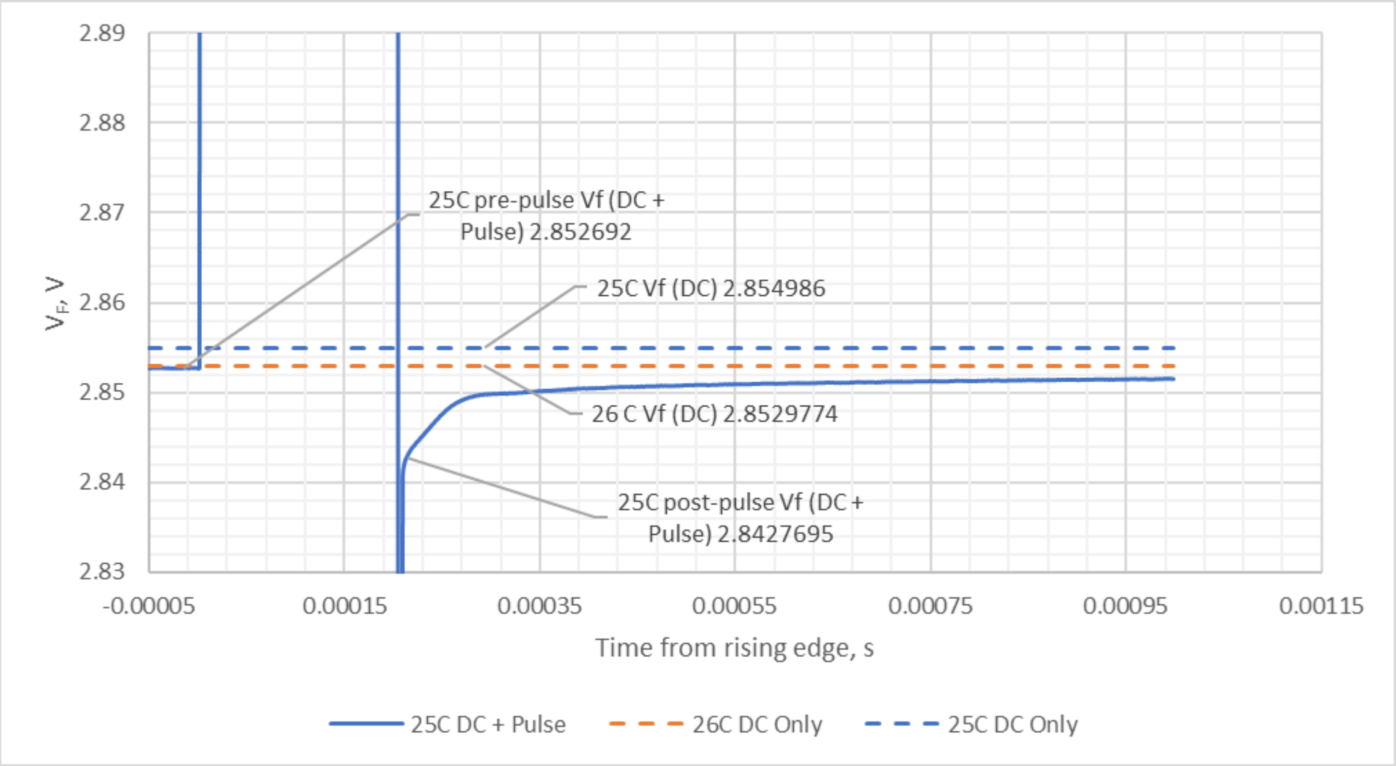


For Blue LED Method 1 and Method 2 Agree Well

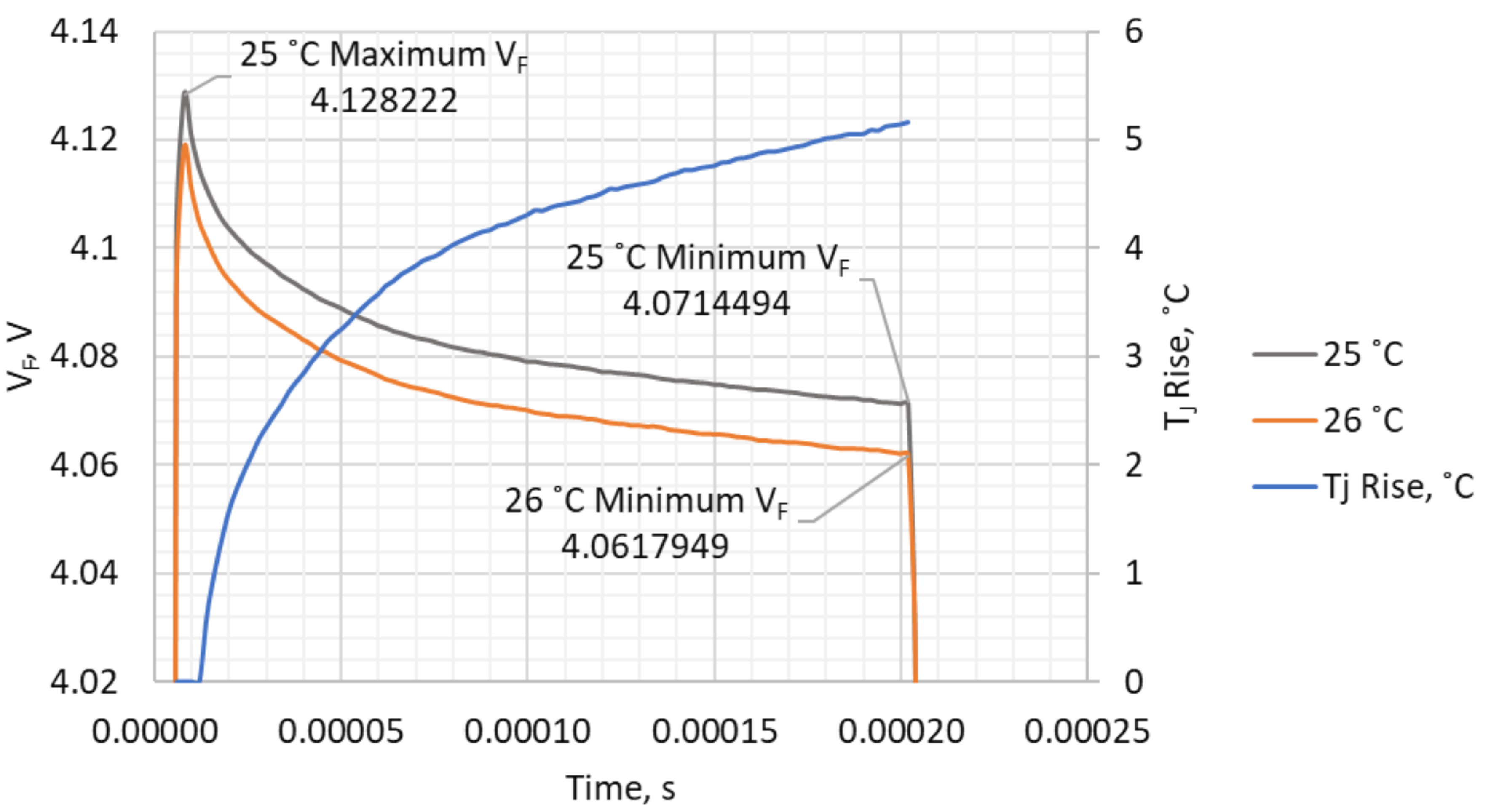
Pulse Width	25 °C V_F, V	26 °C V_F, V	S_{VF}, V/°C	Pre-pulse V_F, V	Post-pulse V_F, V	Pre-pulse T_J, °C	Post-pulse T_J, °C	T_J Rise During Pulse, °C	Average Transient T_J, °C
2.5 µs	2.79787	2.7952	-0.00267	2.7977915	2.7969574	25.03	25.34	0.31	25.18
10 µs	2.79787	2.7952	-0.00267	2.7966961	2.7943160	25.44	26.33	0.89	25.89
200 µs	2.79787	2.7952	-0.00267	2.7972698	2.7788968	25.22	32.10	6.88	28.67
20 ms	2.79787	2.7952	-0.00267	2.7978368	2.7549986	25.01	41.06	16.05	33.03

Pulse Width	25 °C Minimum V_F, V	26 °C Minimum V_F, V	S_{VF}, V/°C	Total T_J Rise During Pulse, °C	Average T_J Rise During Pulse, °C	Average Transient T_J, °C
200 µs	3.3005002	3.3043578	-0.00386	6.23	4.17	29.17

Laser Data – 1A, 200 µs, 1% Duty Cycle – Method 1



Laser Data – 1A, 200 µs, 1% Duty Cycle – Method 2



Laser Data Also Agrees Well – Again Method 1 Showed Slightly Lower Temps

Pulse Width	25 °C V_F, V	26 °C V_F, V	S_{VF}, V/°C	Pre-pulse V_F, V	Post-pulse V_F, V	Pre-pulse T_J, °C	Post-pulse T_J, °C	T_J Rise During Pulse, °C	Average Transient T_J, °C
200 µs	2.854986	2.8529774	0.002009	2.852692	2.8427695	26.15	31.08	4.94	28.61

Pulse Width	25 °C Minimum V_F, V	26 °C Minimum V_F, V	S_{VF}, V/°C	Total T_J Rise During Pulse, °C	Average T_J Rise During Pulse, °C	Average Transient T_J, °C
200 µs	4.0714494	4.0617949	-0.009588	5.12	4.004	29.004

Conclusions

- The methods work well
- Measurements are easy to perform using an SMU with bias and 18 bit digitization
- For more information see the Annex in the upcoming LM-85 standard
- I can share spreadsheets use to calculate these values, contact me at jhulett@vektrex.com

Thank you