Solar Cell Parameter Report

Single-diode parameters from a measured I–V curve, with temperature prediction

1 Comparison of samples

Sample	Iph	I0	Rs	Rsh	n	RMSE
RTC-France-Monocrystal	0.76079	3.1068e-07	0.036547	52.89	1.4773	7.7301e-04
Photowatt-PWP201-Polyc	1.0314	2.6381e-06	1.2356	821.64	1.3222	2.0530e-03

2 Sample: RTC-France-Monocrystalline-Silicon-Cell.txt

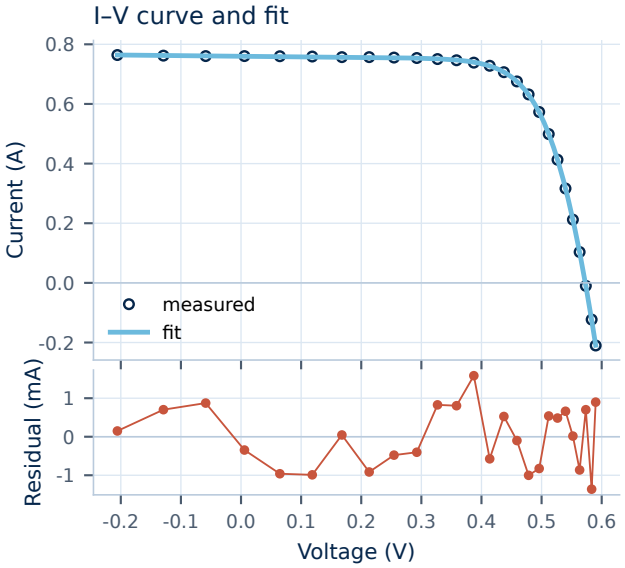
Source	Easwarakhanthan et al. (1986), Int. J. Solar Energy 4, 1-12; 1000 W/m2
Data	N = 26, V = -0.2057 … 0.59 V
Conditions	T = 33 °C, Ns = 1
Fit objective	RMSE of the current (least squares)

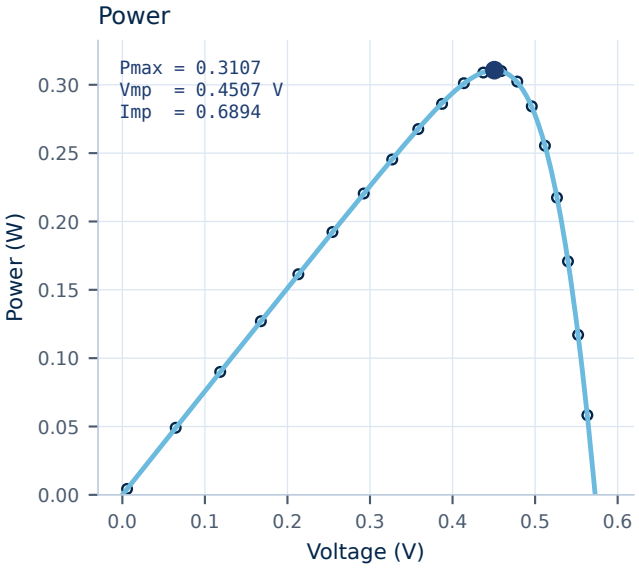
Extracted parameters

Quantity	Value ± standard error	Unit
Photocurrent Iph	0.76079 ± 3.2e-04	A
Saturation current I0	3.1068e-07 ± 3.3e-08	A
Series resistance Rs	0.036547 ± 4.9e-04	Ω
Shunt resistance Rsh	52.89 ± 4.0	Ω
Ideality factor n (per cell)	1.4773 ± 0.011	
Diode voltage n·Ns·kT/q	0.038973 ± 2.8e-04	V

Fit quality

RMSE = 7.7301e-04 A = 0.102 % Isc RMSRE = 4.717e-03 max|ΔI| = 1.585e-03 A

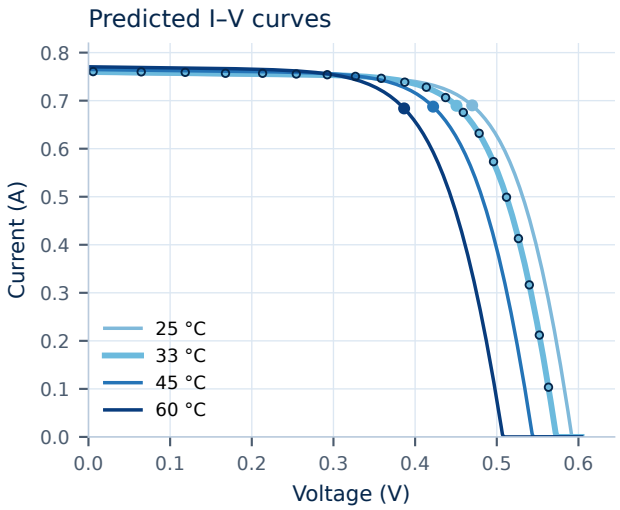


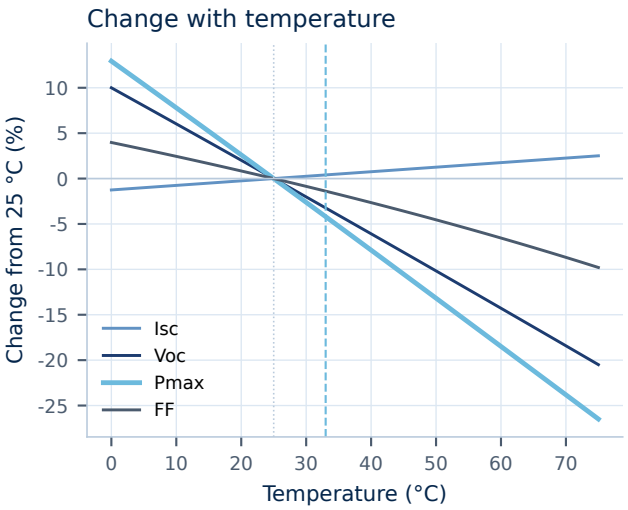


Figures of merit at the measurement temperature

Quantity	Measured	From the fit	Unit
Isc	0.7605	0.76026	A
Voc	0.57269	0.57278	V
Pmax	0.31005	0.31069	W
Vmp	0.459	0.45069	V
Imp	0.6755	0.68938	A
FF	0.7119	0.71348	

3 Temperature prediction





T	Isc	Voc (V)	Pmax	Vmp (V)	FF
25 °C	0.75722	0.59194	0.3243	0.46987	0.7235
33 °C	0.76026	0.57278	0.31069	0.45069	0.7135
45 °C	0.76482	0.54385	0.29016	0.42205	0.6976
60 °C	0.77052	0.50739	0.26433	0.38653	0.6761

Temperature coefficients at 25 °C

Quantity	per K	% per K
Isc	+3.8012e-04 A/K	+0.0502 %/K
Voc	-2.3885e-03 V/K	-0.4035 %/K
Pmax	-1.6955e-03 W/K	-0.5228 %/K
FF	-1.2265e-03 1/K	-0.1695 %/K

Assumptions

I0 at each temperature follows the band gap (Varshni) and n; Iph, Rs and Rsh change linearly with the coefficients below. The defaults are typical of silicon and can be changed in the tool.

I0(T) = I0·(T/Tm)^3·exp[q/(n·k)·(Eg(Tm)/Tm − Eg(T)/T)], material = Si
αIph = +0.05 %/K αRs = +0 %/K αRsh = +0 %/K

4 Comparison with published values

Bouali & Alamri (2024), Mathematics 13(1), 19, doi:10.3390/math13010019 - SDM, Obj2

Parameter	Published	This tool	Difference	Verdict
Iph	0.76079 A	0.76079 ± 3.2e-04 A	0.00 %	agrees ± unc.
IO	3.1069e-07 A	3.1068e-07 ± 3.3e-08 A	0.00 %	agrees ± unc.
Rs	0.036547 Ω	0.036547 ± 4.9e-04 Ω	0.00 %	agrees ± unc.
Rsh	52.89 Ω	52.89 ± 4.0 Ω	0.00 %	agrees ± unc.
n	1.4773	1.4773 ± 0.011	0.00 %	agrees ± unc.
RMSE	7.7299e-04 A	7.7301e-04 A	0.00 %	agrees

Previous version of this tool (V1, relative-error objective)

Parameter	Published	This tool	Difference	Verdict
Iph	0.76085 A	0.76079 ± 3.2e-04 A	-0.01 %	agrees ± unc.
IO	2.6244e-07 A	3.1068e-07 ± 3.3e-08 A	+18.38 %	agrees ± unc.
Rs	0.037146 Ω	0.036547 ± 4.9e-04 Ω	-1.61 %	agrees ± unc.
Rsh	49.27 Ω	52.89 ± 4.0 Ω	+7.35 %	agrees ± unc.
n	1.4605	1.4773 ± 0.011	+1.15 %	agrees ± unc.
RMSE	8.3271e-04 A	7.7301e-04 A	-7.17 %	differs

5 Processing steps

- 26 points read, V from -0.2057 to 0.59 V.
  N = 26, V = -0.2057 … 0.59 V
- A '?' in front of numbers was read as the minus sign (lost in an encoding change).
- Measured Isc is the current at V = 0 and Voc the voltage at I = 0, both by linear interpolation between the neighbouring points.
- Model: single diode, solved explicitly with the Lambert W function; n is per cell and the diode voltage is n·Ns·kT/q.
  Ns = 1, T = 33 °C, n·Ns·Vt = 0.038973 V
- Global search by differential evolution, then bounded least-squares refinement of the RMSE of the current.
  objective = rmse
- The strongest correlation between two fitted parameters (expected for I0 and n):
  corr(I0, n) = +0.9999
- Temperature prediction: I0 from the band gap (Varshni) and n; Iph, Rs and Rsh change linearly with the coefficients below (per kelvin). These are model assumptions, not measurements at other temperatures.
  material = Si, αIph = +0.05 %/K, αRs = +0 %/K, αRsh = +0 %/K

6 Warnings

No warnings.

7 Sample: Photowatt-PWP201-Polycrystalline-Module 2.txt

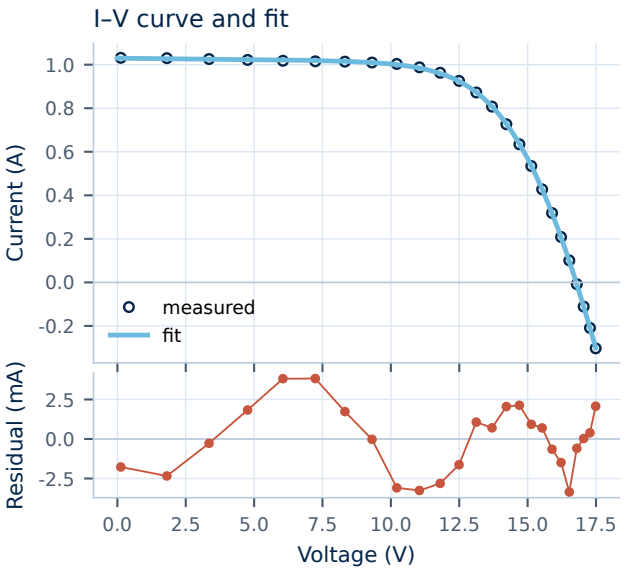
Source	Easwarakhanthan et al. (1986), Int. J. Solar Energy 4, 1-12; 1000 W/m2
Data	N = 25, V = 0.1248 … 17.49 V
Conditions	T = 45 °C, Ns = 36
Fit objective	RMSE of the current (least squares)

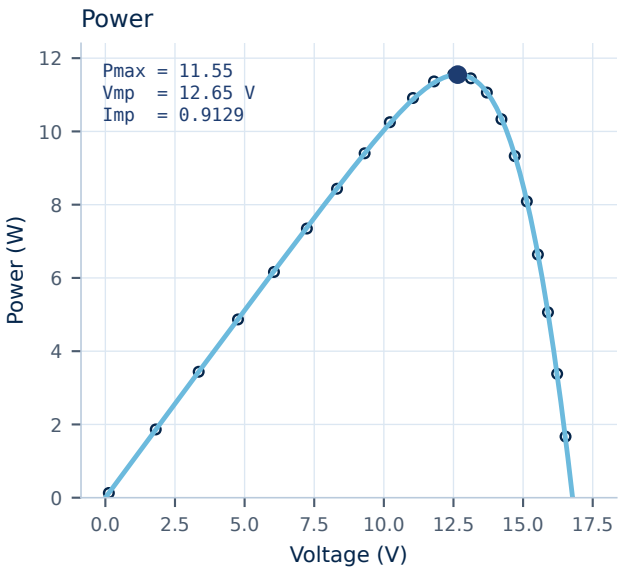
Extracted parameters

Quantity	Value ± standard error	Unit
Photocurrent Iph	1.0314 ± 0.0019	A
Saturation current I0	2.6381e-06 ± 5.9e-07	A
Series resistance Rs	1.2356 ± 0.027	Ω
Shunt resistance Rsh	821.64 ± 1.8e+02	Ω
Ideality factor n (per cell)	1.3222 ± 0.023	
n·Ns (module)	47.598 ± 0.83	
Diode voltage n·Ns·kT/q	1.305 ± 0.023	V

Fit quality

RMSE = 2.0530e-03 A = 0.199 % Isc RMSRE = 7.594e-03 max|ΔI| = 3.823e-03 A



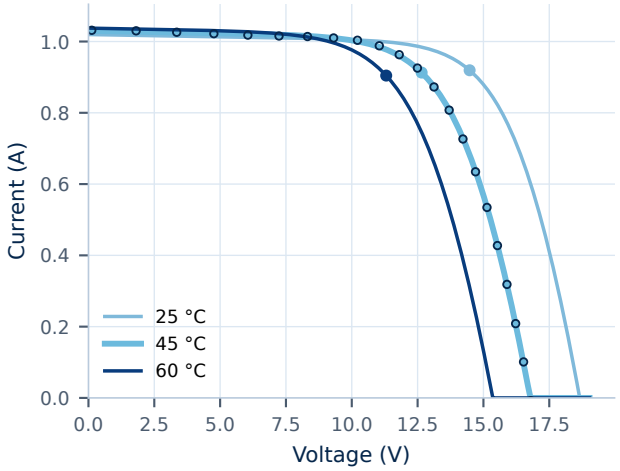


Figures of merit at the measurement temperature

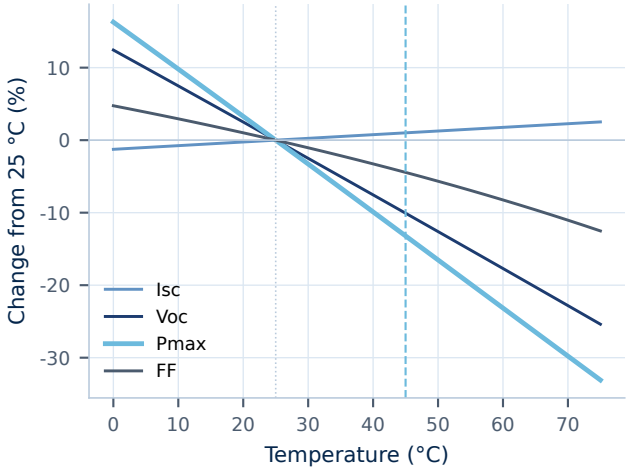
Quantity	Measured	From the fit	Unit
Isc	1.0316	1.0299	A
Voc	16.779	16.777	V
Pmax	11.562	11.551	W
Vmp	12.493	12.653	V
Imp	0.9255	0.91289	A
FF	0.66799	0.66851	

8 Temperature prediction

Predicted I–V curves



Change with temperature



T	Isc	Voc (V)	Pmax	Vmp (V)	FF
25 °C	1.0196	18.656	13.308	14.476	0.6996
45 °C	1.0299	16.777	11.551	12.653	0.6685
60 °C	1.0376	15.354	10.227	11.307	0.6419

Temperature coefficients at 25 °C

Quantity	per K	% per K
Isc	+5.1489e-04 A/K	+0.0505 %/K
Voc	-9.3448e-02 V/K	-0.5009 %/K
Pmax	-8.7432e-02 W/K	-0.6570 %/K
FF	-1.4454e-03 1/K	-0.2066 %/K

Assumptions

I0 at each temperature follows the band gap (Varshni) and n; Iph, Rs and Rsh change linearly with the coefficients below. The defaults are typical of silicon and can be changed in the tool.

`I0(T) = I0·(T/Tm)^3·exp[q/(n·k)·(Eg(Tm)/Tm − Eg(T)/T)],  material = Si`

`αIph = +0.05 %/K   αRs = +0 %/K   αRsh = +0 %/K`

9 Comparison with published values

Bouali & Alamri (2024), Mathematics 13(1), 19, doi:10.3390/math13010019 - SDM, Obj2

Parameter	Published	This tool	Difference	Verdict
Iph	1.0314 A	1.0314 ± 0.0019 A	0.00 %	agrees ± unc.
IO	2.6381e-06 A	2.6381e-06 ± 5.9e-07 A	0.00 %	agrees ± unc.
Rs	1.2356 Ω	1.2356 ± 0.027 Ω	0.00 %	agrees ± unc.
Rsh	821.64 Ω	821.64 ± 1.8e+02 Ω	0.00 %	agrees ± unc.
n	1.3222	1.3222 ± 0.023	0.00 %	agrees ± unc.
RMSE	0.0020528 A	0.002053 A	+0.01 %	agrees

The paper gives Rs and Rsh per cell (0.034323 and 22.8234 Ω, ×36 here) and n = 49.464 for the module; converted to n per cell with the same diode voltage n·Ns·kT/q.

Previous version of this tool (V1, relative-error objective)

Parameter	Published	This tool	Difference	Verdict
Iph	1.0297 A	1.0314 ± 0.0019 A	+0.17 %	agrees ± unc.
IO	4.6199e-06 A	2.6381e-06 ± 5.9e-07 A	-42.90 %	differs
Rs	1.1622 Ω	1.2356 ± 0.027 Ω	+6.32 %	differs
Rsh	1191 Ω	821.64 ± 1.8e+02 Ω	-31.01 %	differs
n	1.3821	1.3222 ± 0.023	-4.34 %	close
RMSE	0.0024167 A	0.002053 A	-15.05 %	differs

10 Processing steps

- 25 points read, V from 0.1248 to 17.49 V.
  `N = 25,  V = 0.1248 … 17.49 V`
- Measured Isc is the current at V = 0 and Voc the voltage at I = 0, both by linear interpolation between the neighbouring points.
- Model: single diode, solved explicitly with the Lambert W function; n is per cell and the diode voltage is n·Ns·kT/q.
  `Ns = 36,  T = 45 °C,  n·Ns·Vt = 1.305 V`
- Global search by differential evolution, then bounded least-squares refinement of the RMSE of the current.
  `objective = rmse`
- The data do not reach V = 0: the measured Isc is extrapolated from the two nearest points.
  `first point at 0.74 % of Voc`
- The strongest correlation between two fitted parameters (expected for I0 and n):
  `corr(n, I0) = +0.9999`
- Temperature prediction: I0 from the band gap (Varshni) and n; Iph, Rs and Rsh change linearly with the coefficients below (per kelvin). These are model assumptions, not measurements at other temperatures.
  `material = Si,  αIph = +0.05 %/K,  αRs = +0 %/K,  αRsh = +0 %/K`

11 Warnings

No warnings.

12 How to read the results

Iph

The current generated by light. It is close to Isc; a gap of more than a few percent points to a large Rs or a poor fit.

I0, n

The diode. n near 1 means diffusion, near 2 recombination. I0 and n are strongly correlated: compare them together, not one at a time.

Rs, Rsh

Rs lowers the slope near Voc and the fill factor; Rsh lowers the slope near Isc. A very large Rsh with a large error means the data show no leakage.

RMSE

The root-mean-square difference between the fitted and measured currents. Below about 0.2 % of Isc the single-diode model describes the curve well; look at the residual plot for a pattern.

Temperature

The curves at other temperatures come from the model and the stated assumptions, not from measurement. Voc and Pmax fall with temperature; Isc rises slightly.

Verdict: "agrees ± unc." when the difference is within twice the standard error of this tool; otherwise "agrees" up to 2 %, "close" up to 5 %, "differs" above.

This report was produced by the Phy-Lab Solar Cell Parameter Extractor. More tools at phy-lab.com.