Version 6.1

FitAll

nonlinear regression analysis

Solar Cell Functions Guide

Published by

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Contents

Introduction

This ***FitAll***™ **Solar Cell Functions Guide** describes the functions contained in the **Solar Cell Functions Library** and has an appendix that explains how to get help from ***MTR*** **Software**.

Function Reference Overview

This section describes each of the functions in ***FitAll***'s **Solar Cell Functions Library**.

In most cases, a graph of the function is shown. These graphs were created using "typical" parameter and constant values.

The actual appearance of a function depends on the parameter and constant values and may look quite different from the illustrations shown.

Equation

Gives the equation and its variations. The variations are listed in order of increasing complexity.

Constants

Lists the constants, K, that are used in the function. The default values for the constants also are given.

Parameters

Lists the parameters, P, that are used in the function.

Multi-Fits

Describes the Multi-Fit functionality of "Multi-Fit enabled" functions.

Sample Applications

Gives examples of some situations in which the function is known to be used.

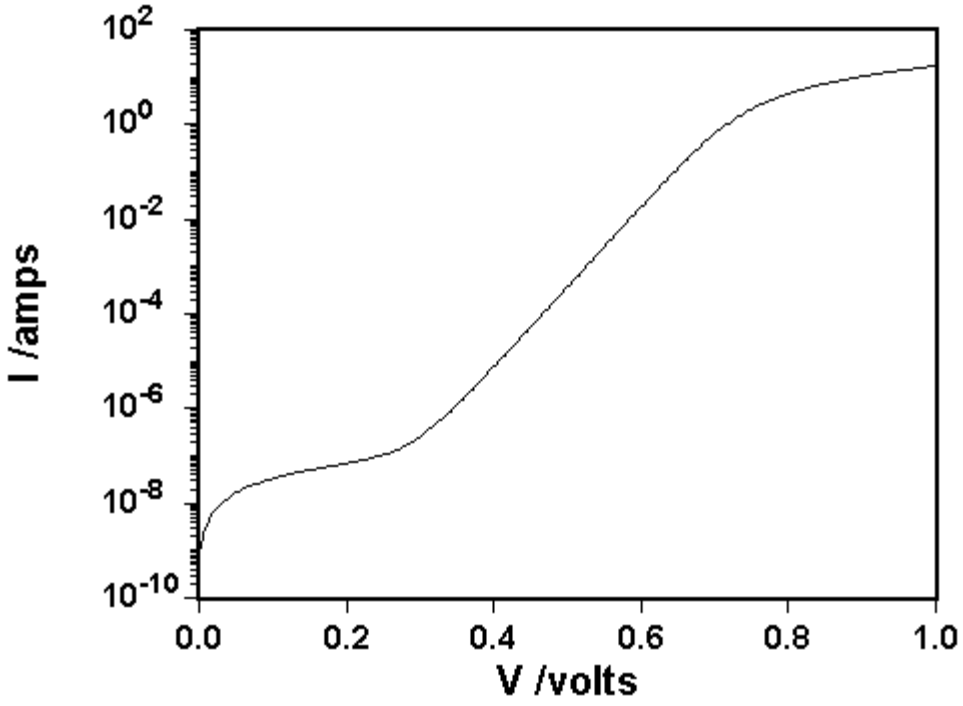
Remarks

Provides general comments and hints, and lists any known limitations or restrictions that should be observed when using the function.

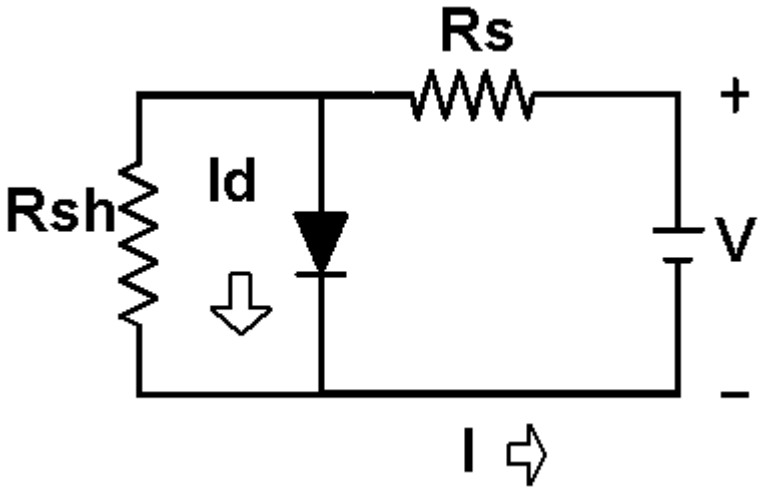
Also see

Provides links or references to other related functions.

Ftn 0501: Dark Current-Voltage: Ideal



Equivalent Circuit



Equation

There are two variations of this function:

- $$Y = P2 * \left\{ e^{\left[\frac{K1*X}{(273.15+K2)} \right]} - 1 \right\} + \frac{X}{P1}$$
- $$Y = P2 * \left\{ e^{\left[\frac{K1*(X-Y*P3)}{(273.15+K2)} \right]} - 1 \right\} + \frac{(X - Y * P3)}{P1}$$

in which:

- Y is the measured response, the current in amperes.
- X is the independent variable, the voltage in volts.

Constants

Constant	Name	Comments
K1	q/k	Elementary charge, q = 1.602177E-19 Coulomb, divided by Boltzmann's constant, k = 1.380662E-23 J/^{o}K Default value is 1.160441151E4 C^{o}K/J
K2	t	Temperature in ^{o}C Default value is 25 ^{o}C.

Parameters

Parameter	Name	Comments
P1	Rsh	Shunt resistance.
P2	Io	Diode saturation current for recombination mechanisms with ideality factor equal to one.
P3	Rs	Series resistance. When doing a fit that includes Rs as a parameter, it is often advantageous to limit it to values greater than or equal to zero. These are the only physically meaningful values of Rs.

Sample Applications

- Characterizing the current-voltage behaviour of semiconductor diodes.
- Characterizing the dark current - voltage behaviour of solar cells.

Remarks

Because of the extreme non linearity of the function, ***FitAll*** may arrive at one of several possible solutions. Manual adjustment of the initial estimates will most likely be necessary.

In most cases the current, Y, data will span a wide range of values, for example, three or four orders of magnitude. Because of this it is strongly advised that you weight the data using a weighting factor of $1/(SigmaY)^2$ or $1/(0.1Y)^2$. When you plot the fit, plot Log[Y] vs. X so that you will be able to see the deviations at low Y-values as well as at high Y-values.

This is an implicit function; that is, its value depends on itself. The dependent variable, Y, appears on both sides of the equation. ***FitAll*** uses an iterative method to evaluate this function. Function evaluations are more time consuming than normal and the regression analysis is correspondingly slower.

Often, the best fitting strategy is to first fit your data using the first form of this function, then re-do the fit using the second form and the parameters obtained in the first fit as the starting point for the second.

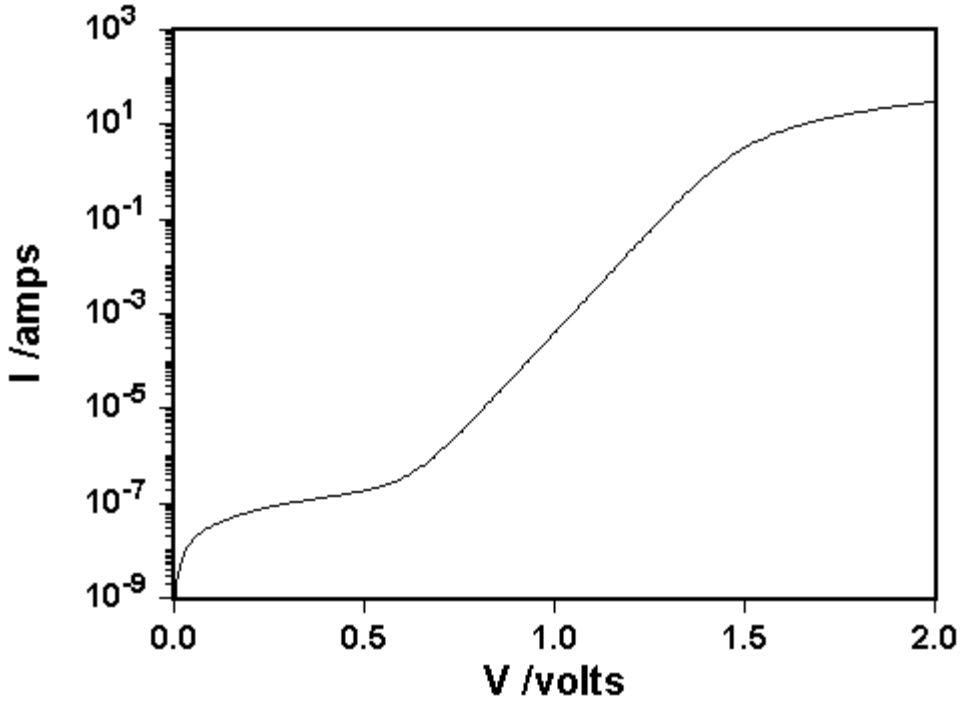
All currents and voltages are assumed to be greater than or equal to zero.

When automatic initial estimates are made, ***FitAll*** assumes that the data are sorted on column number 1, that is, the X-values.

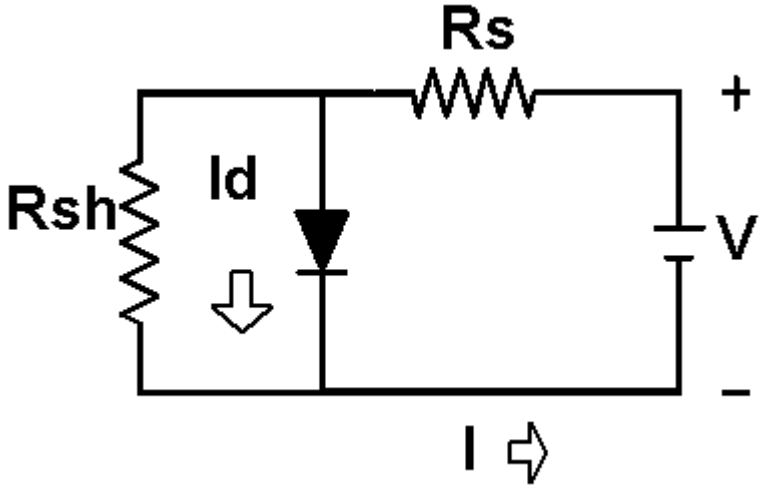
Also See

Function 0502 7, which is the same as this function except that it includes the parameter "n" that is a "diode ideality factor". This function assumes that the diode is an ideal diode.

Ftn 0502: Dark Current-Voltage: Non-Ideal



Equivalent Circuit



Equation

There are two variations of this function:

- $$Y = P2 * \left\{ e^{\left[\frac{K1*X}{((273.15+K2)*P3)} \right]} - 1 \right\} + \frac{X}{P1}$$
- $$Y = P2 * \left\{ e^{\left[\frac{K1*(X - Y*P4)}{((273.15+K2)*P3)} \right]} - 1 \right\} + \frac{(X - Y*P4)}{P1}$$

in which:

- Y is the measured response, the current in amperes.
- X is the independent variable, the voltage in volts.

Constants

Constant	Name	Comments
K1	q/k	Elementary charge, q = 1.602177E-19 Coulomb, divided by Boltzmann's constant, k = 1.380662E-23 J/ºK Default value is 1.160441151E4 CºK/J
K2	t	Temperature in ºC Default value is 25 ºC.

Parameters

Parameter	Name	Comments
P1	Rsh	Shunt resistance.
P2	Io	Diode saturation current for recombination mechanisms with ideality factor equal to one.
P3	Nr	Ideality factor, equal to one for an ideal semiconductor diode (See function 0501 4). When doing a fit it is often advantageous to limit the value of Nr to the range 1 to 5.
P4	Rs	Series resistance.

Parameter	Name	Comments
		When doing a fit that includes Rs as a parameter, it is often advantageous to limit it to values greater than or equal to zero. These are the only physically meaningful values of Rs.

Sample Applications

- Characterizing the current-voltage behaviour of semiconductor diodes.
- Characterizing the dark current - voltage behaviour of solar cells.

Remarks

Because of the extreme non linearity of the function, ***FitAll*** may arrive at one of several possible solutions. Manual adjustment of the initial estimates will most likely be necessary.

In most cases the current, Y, data will span a wide range of values, for example, three or four orders of magnitude. Because of this it is strongly advised that you weight the data using a weighting factor of $1/(SigmaY)^2$ or $1/(01.Y)^2$. When you plot the fit, plot Log[Y] vs. X so that you will be able to see the deviations at low Y-values as well as at high Y-values.

This function is an implicit function; that is, its value depends on itself. The dependent variable, Y, appears on both sides of the equation. ***FitAll*** uses an iterative method to evaluate this function. Function evaluations are more time consuming than normal and the regression analysis is correspondingly slower.

Often, the best fitting strategy is to first fit your data using the first form of this function, then re-do the fit using the second form and the parameters obtained in the first fit as the starting point for the second.

All currents and voltages are assumed to be greater than or equal to zero.

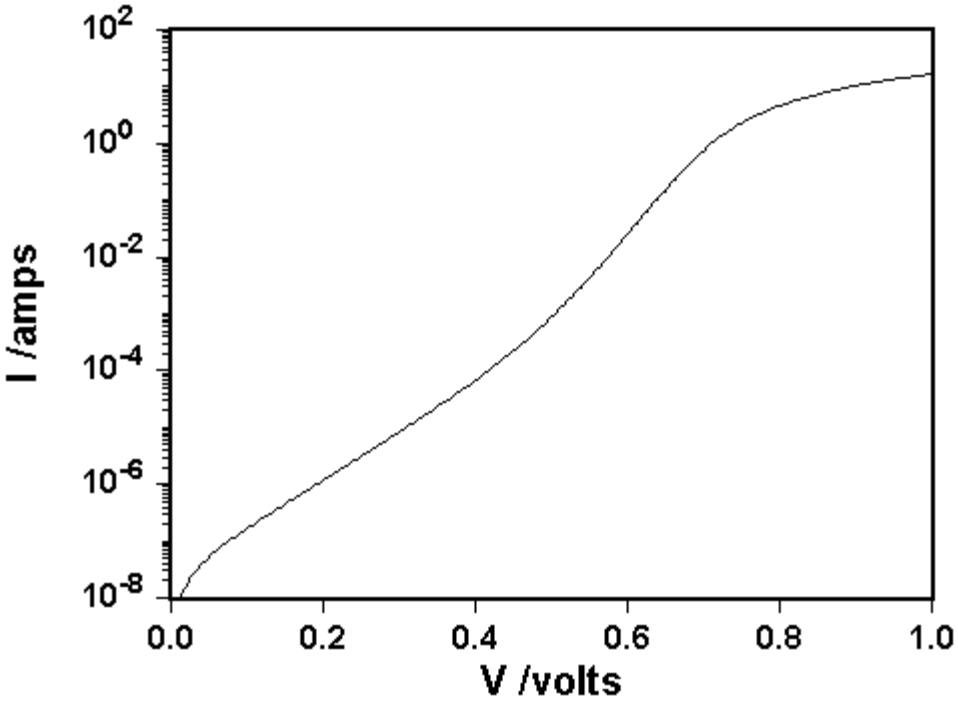
When automatic initial estimates are made, ***FitAll*** assumes that the data are sorted on column number 1, that is, the X-values.

Also See

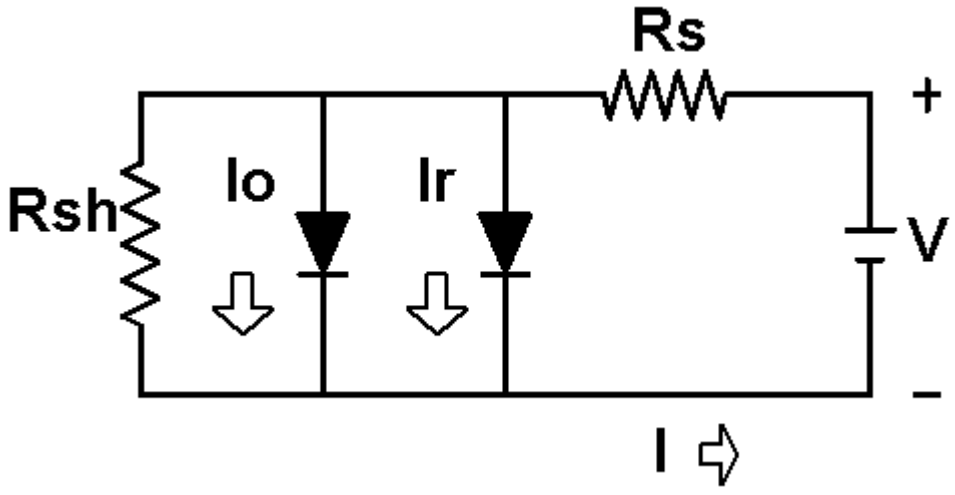
Function 0501 4, which is the same as this function except that it assumes that the diode is an ideal diode; that is, that the diode ideality factor equals 1 (one).

Function 0512 34, which is the same as this function except that the definitions of the dependent and independent variables are switched. That is, the meanings of X and Y are interchanged.

Ftn 0503: Dark Current-Voltage: Sum of Ideal and Non-Ideal:



Equivalent Circuit



Equation

There are two variations of this function:

- $$Y = P2 * \left\{ e^{\left[\frac{K1 * X}{(273.15 + K2)} \right]} - 1 \right\} + P3 * \left\{ e^{\left[\frac{K1 * X}{(273.15 + K2) * P4} \right]} - 1 \right\} + \frac{X}{P1}$$

- $$Y = P2 * \left\{ e^{\left[\frac{K1 * (X - Y * P5)}{(273.15 * K2)} \right]} - 1 \right\} + P3 * \left\{ e^{\left[\frac{K1 * (X - Y * P5)}{((273.15 + K2) * P4)} \right]} - 1 \right\} + \frac{(X - Y * P5)}{P1}.$$

in which:

- Y is the measured response, the current in amperes.
- X is the independent variable, the voltage in volts.

Constants

Constant	Name	Comments
K1	q/k	Elementary charge, q = 1.602177E-19 Coulomb, divided by Boltzmann's constant, k = 1.380662E-23 J/ºK Default value is 1.160441151E4 CºK/J
K2	t	Temperature in ºC Default value is 25 ºC.

Parameters

Parameter	Name	Comments
P1	Rsh	Shunt resistance.
P2	Io	Diode saturation current for recombination mechanisms with ideality factor equal to one.
P3	Ir	Diode saturation current for recombination mechanisms with ideality factor not equal to one.
P4	Nr	Ideality factor, equal to one for an ideal semiconductor diode (see function 0501 4).
P5	Rs	Series resistance.

Parameter	Name	Comments
		When doing a fit that includes Rs as a parameter, it is often advantageous to limit it to values greater than or equal to zero. These are the only physically meaningful values of Rs.

Sample Applications

- Characterizing the current-voltage behaviour of semiconductor diodes.
- Characterizing the dark current - voltage behaviour of solar cells.

Remarks

Because of the extreme non linearity of the function, ***FitAll*** may arrive at one of several possible solutions. Manual adjustment of the initial estimates will most likely be necessary.

In most cases the current, Y, data will span a wide range of values, for example, three or four orders of magnitude. Because of this it is strongly advised that you weight the data using a weighting factor of $1/(SigmaY)^2$ or $1/(0.1Y)^2$. When you plot the fit, plot Log[Y] vs. X so that you will be able to see the deviations at low Y-values as well as at high Y-values.

This is an implicit function; that is, its value depends on itself. The dependent variable, Y, appears on both sides of the equation. ***FitAll*** uses an iterative method to evaluate this function. Function evaluations are more time consuming than normal and the regression analysis is correspondingly slower.

Often, the best fitting strategy is to first fit your data using the first variation of the function, then re-do the fit using the second variation and the parameters obtained in the first fit as the starting point for the second.

All currents and voltages are assumed to be greater than or equal to zero.

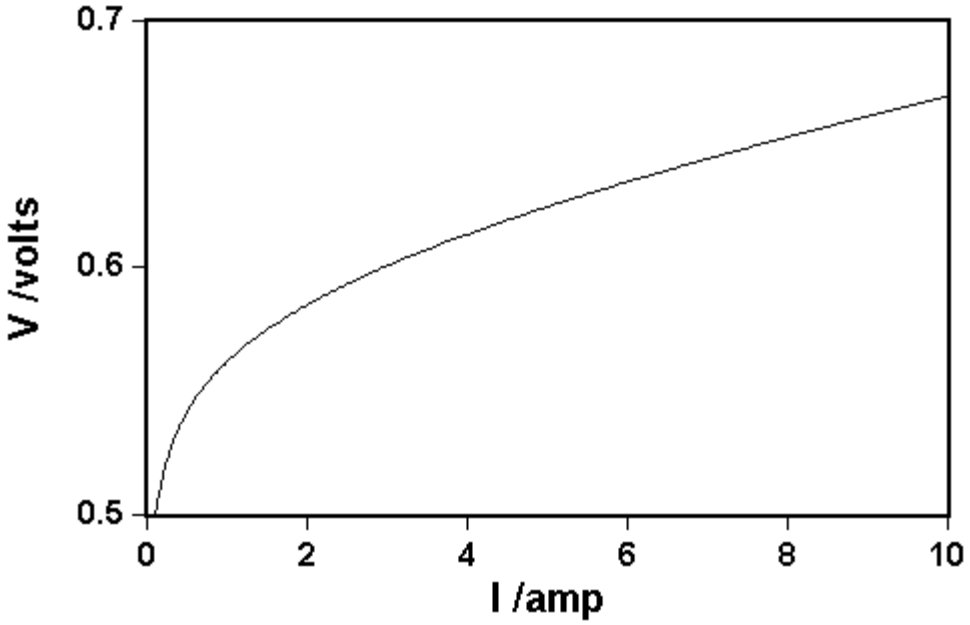
When automatic initial estimates are made, ***FitAll*** assumes that the data are sorted on column number 1, that is, the X-values.

Also See

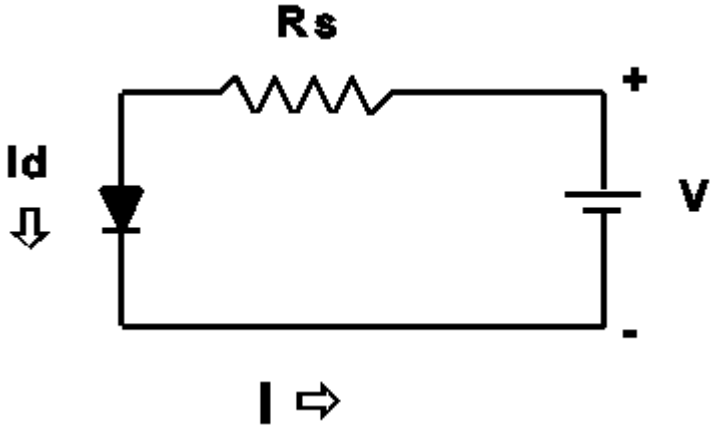
Function 0507 21 is the same as this function except that the definitions of the dependent and independent variables are switched. That is, the meanings of X and Y are interchanged.

Function 0517 42 is the same as this function except that the definitions of the dependent and independent variables are switched. That is, the meanings of X and Y are interchanged. Also, both diodes are assumed to be non-ideal diodes.

Ftn 0504: Dark I-V: Model 1: High I-range



Equivalent Circuit



Equation

$$Y = \frac{K3 * (273.15 + K2)}{K1} * \mathrm{Ln}\left|\frac{(X + P1)}{P1}\right| + X * P2$$

in which:

- Y is the measured response -- the voltage in volts.

- X is the independent variable -- the current in amperes.

Constants

Constant	Name	Comments
K1	q/k	Elementary charge, q=1.602177E-19 Coulomb, divided by Boltzmann's constant, k = 1.380662E-23 J/ºK. Default value is 1.160441151E4 CºK/J.
K2	t	Temperature in ºC. Default value is 25.0 ºC.
K3	n	Ideality factor for the diode. For an ideal diode, n = 1. For a non-ideal diode, n > 1.

Parameters

Parameter	Name	Comments
P1	Id	Saturation current for the diode, in amperes
P2	Rs	Series resistance in ohms. Rs >= 0.

Sample Applications

- Characterizing the current-voltage behaviour of semiconductor diodes.
- Characterizing the dark current-voltage behaviour of solar cells.

Remarks

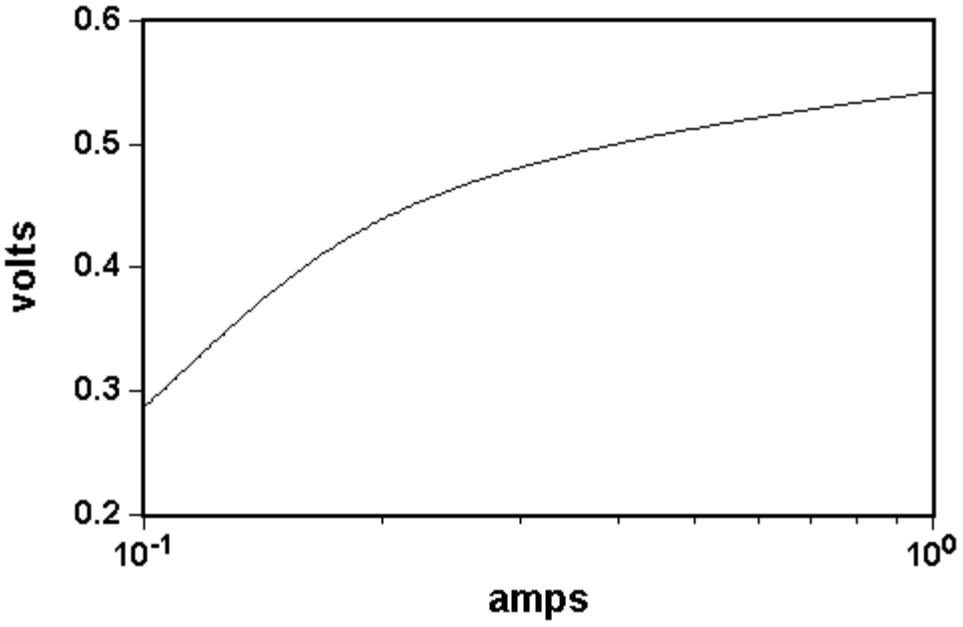
When automatic initial estimates are made, ***FitAll*** assumes that the data are sorted on column number 1, that is, the X-values.

All currents and voltages are assumed to be greater than or equal to zero.

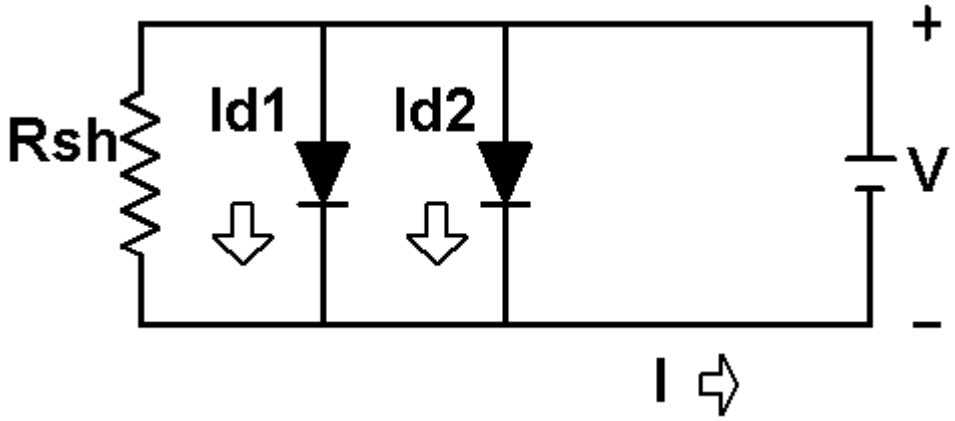
Also See

Function 0514 37, which is the same as this function except that the diode ideality factor, constant K3, is treated as a parameter rather than an adjustable constant.

Ftn 0505: Dark I-V: Model 2: Mid I-range



Equivalent Circuit



Equation

$$Y = P1 * \left(X - P2 * \left\{ e^{\left[\frac{K1 * Y}{(273.15 + K2)} \right]} - 1 \right\} - P3 * \left\{ e^{\left[\frac{K1 * Y}{(P4 * (273.15 + K2))} \right]} - 1 \right\} \right)$$

in which:

- Y is the measured response -- the voltage in volts.
- X is the independent variable -- the current in amperes.

Constants

Constant	Name	Comments
K1	q/k	Elementary charge, q=1.602177E-19 Coulomb, divided by Boltzmann's constant, k = 1.380662E-23 J/ºK. Default value is 1.160441151E4 CºK/J.
K2	t	Temperature in ºC. Default value is 25.0 ºC.

Parameters

Parameter	Name	Comments
P1	Rsh	Shunt resistance in ohms.
P2	Id1	Saturation current for ideal diode 1, in amperes
P3	Id2	Saturation current for non-ideal diode 2, in amperes
P4	n2	Ideality factor for diode 2. For an ideal diode, n = 1. For a non-ideal diode, n > 1.

Sample Applications

- Characterizing the current-voltage behaviour of semiconductor diodes.
- Characterizing the dark current-voltage behaviour of solar cells.

Remarks

Because of the exponential nature of this function and the magnitude of the constants, some of the values generated can be very large (or very small) -- in fact, large enough to exceed the numeric range of your computer. If this happens, one or more error messages will appear and the calculations will be terminated.

This is an implicit function; that is, the dependent variable, Y, appears on both sides of the equation. ***FitAll*** uses an iterative method to evaluate this function. Function evaluations are more time consuming than normal and the regression analysis is correspondingly slower.

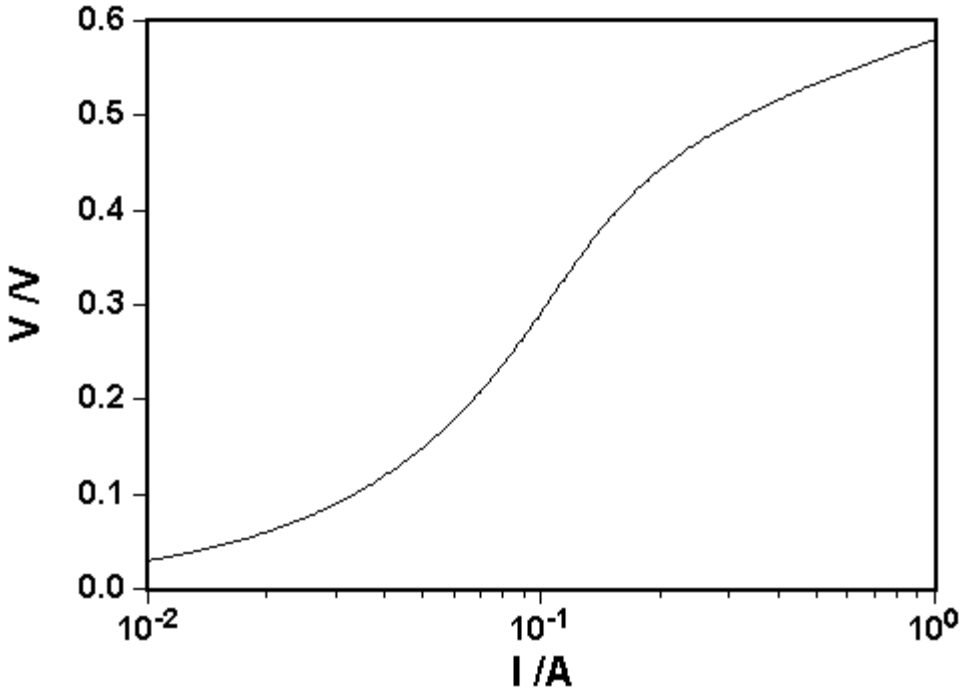
All currents and voltages are assumed to be greater than or equal to zero.

When automatic initial estimates are made, ***FitAll*** assumes that the data are sorted on column number 1, that is, the X-values.

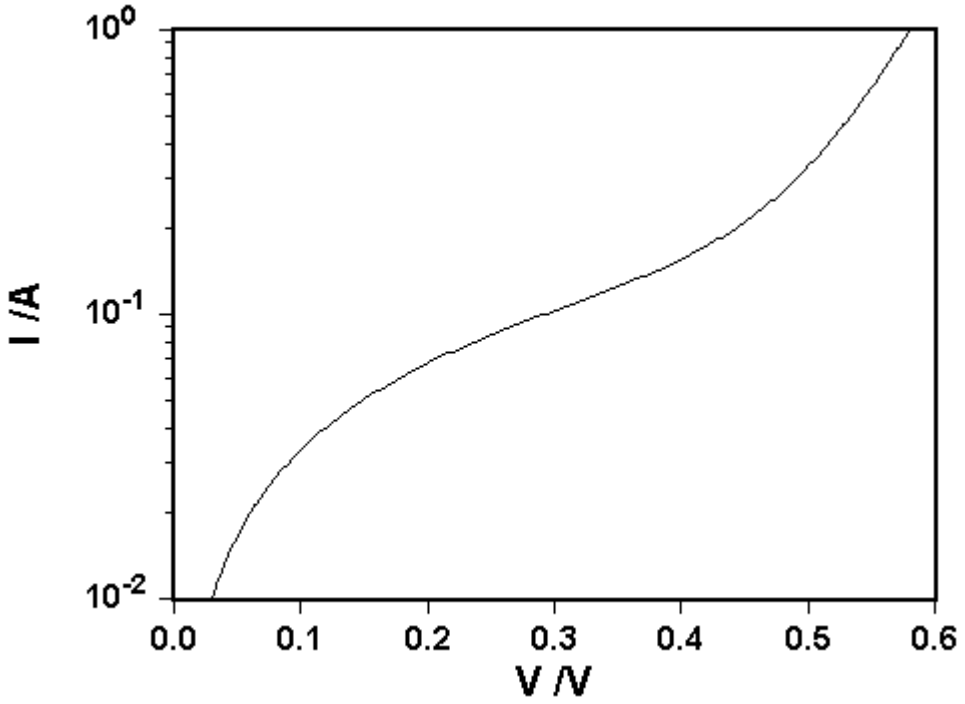
Also See

Function 0515 39, which is the same as this function except that diode 1 is treated as a non-ideal diode that may have a value greater than 1.0.

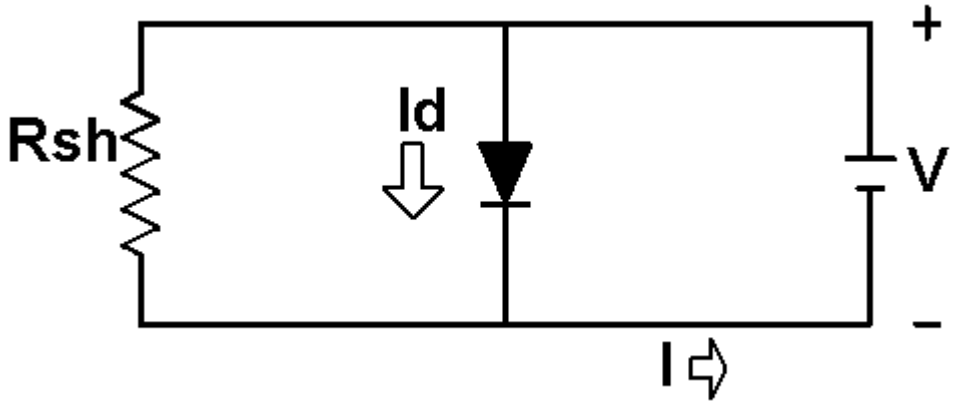
Ftn 0506: Dark I-V: Model 3: Low I-range



OR



Equivalent Circuit



Equation

$$Y = P1 * \left(X - P2 * \left\{ e^{\left[\frac{K1 * Y}{\left(P3 * \left(273.15 + K2 \right) \right)} \right]} - 1 \right\} \right)$$

in which:

- Y is the measured response -- the voltage in volts.
- X is the independent variable -- the current in amperes.

Constants

Constant	Name	Comments
K1	q/k	Elementary charge, q=1.602177E-19 Coulomb, divided by Boltzmann's constant, k = 1.380662E-23 J/ºK. Default value is 1.160441151E4 CºK/J.
K2	t	Temperature in ºC. Default value is 25.0 ºC.

Parameters

Parameter	Name	Comments
P1	Rsh	Shunt resistance in ohms.
P2	Id	Saturation current for diode 1, in amperes
P3	n	Ideality factor for diode 2. For an ideal diode, n = 1. For a non-ideal diode, n > 1.

Sample Applications

- Characterizing the current-voltage behaviour of semiconductor diodes.
- Characterizing the dark current-voltage behaviour of solar cells.

Remarks

Because of the exponential nature of this function and the magnitude of the constants, some of the values generated can be very large (or very small) -- in fact, large enough to exceed the numeric range of your computer. If this happens, one or more error messages will appear and the calculations will be terminated.

This is an implicit function; that is, the dependent variable, Y, appears on both sides of the equation. ***FitAll*** uses an iterative method to evaluate this function. Function evaluations are more time consuming than normal and the regression analysis is correspondingly slower.

All currents and voltages are assumed to be greater than or equal to zero.

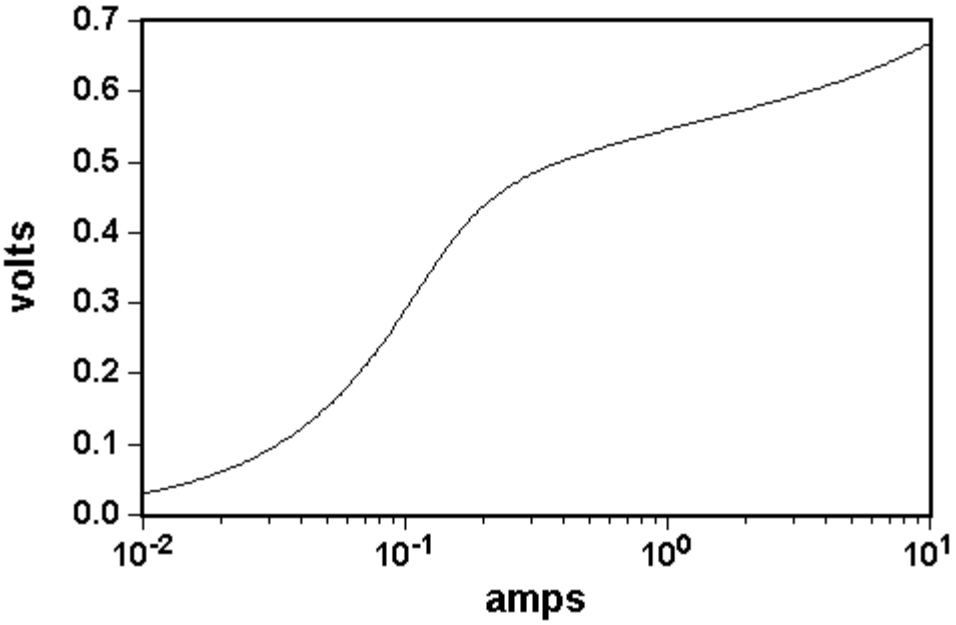
When automatic initial estimates are made, ***FitAll*** assumes that the data are sorted on column number 1, that is, the X-values.

Also See

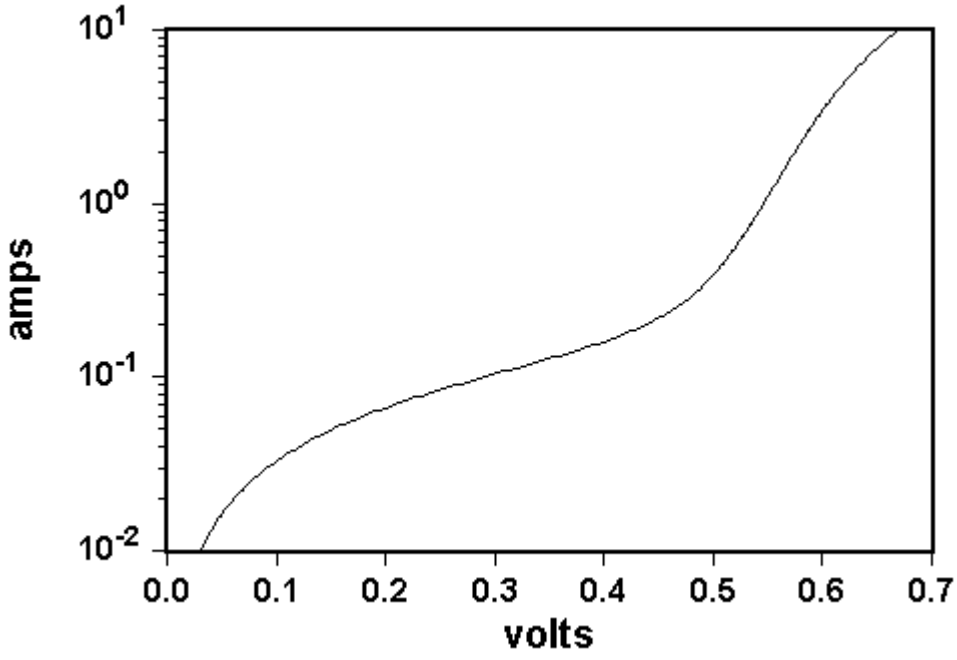
Function 0502 7.

Function 0512 34.

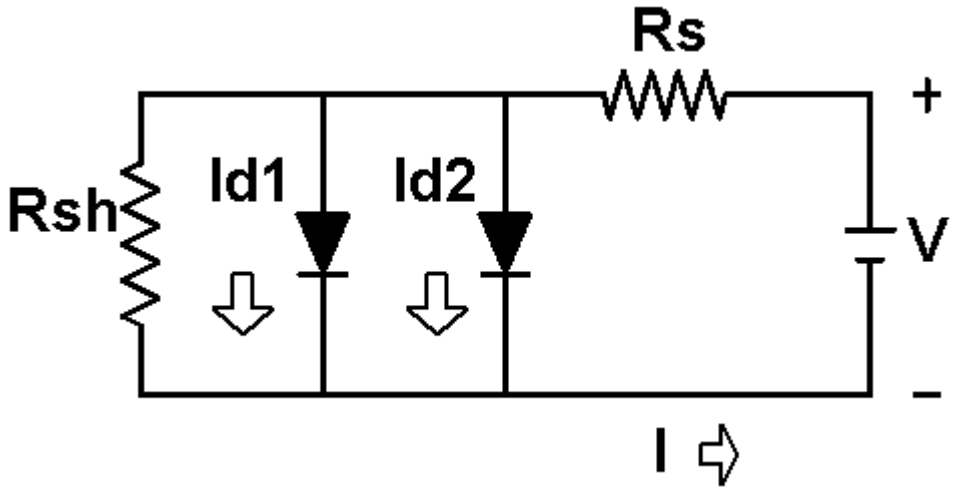
Ftn 0507: Dark I-V: Model 4: Full I-range



OR



Equivalent Circuit



Equation

$$Y = P1 * \left(X - P2 * \left\{ e^{\left[\frac{K1 * (Y - X * P5)}{(273.15 + K2)} \right]} - 1 \right\} - P3 * \left\{ e^{\left[\frac{K1 * (Y - X * P5)}{(P4 * (273.15 + K2))} \right]} - 1 \right\} \right) + X * P5$$

in which:

- Y is the measured response -- the voltage in volts.
- X is the independent variable -- the current in amperes.

Constants

Constant	Name	Comments
K1	q/k	Elementary charge, q=1.602177E-19 Coulomb, divided by Boltzmann's constant, k = 1.380662E-23 J/ºK. Default value is 1.160441151E4 CºK/J.
K2	t	Temperature in ºC. Default value is 25.0 ºC.

Parameters

Parameter	Name	Comments
P1	Rsh	Shunt resistance in ohms.
P2	Id1	Saturation current for diode 1, in amperes
P3	Id2	Saturation current for diode 2, in amperes.
P4	n2	Ideality factor for diode 2. For an ideal diode, n = 1. For a non-ideal diode, n > 1.
P5	Rs	Series resistance in ohms.

Sample Applications

- Characterizing the current-voltage behaviour of semiconductor diodes.
- Characterizing the dark current-voltage behaviour of solar cells.

Remarks

Because of the exponential nature of this function and the magnitude of the constants, some of the values generated can be very large (or very small) -- in fact, large enough to exceed the numeric range of your computer. If this happens, one or more error messages will appear and the calculations will be terminated.

This is an implicit function; that is, the dependent variable, Y, appears on both sides of the equation. ***FitAll*** uses an iterative method to evaluate this function. Function evaluations are more time consuming than normal and the regression analysis is correspondingly slower.

All currents and voltages are assumed to be greater than or equal to zero.

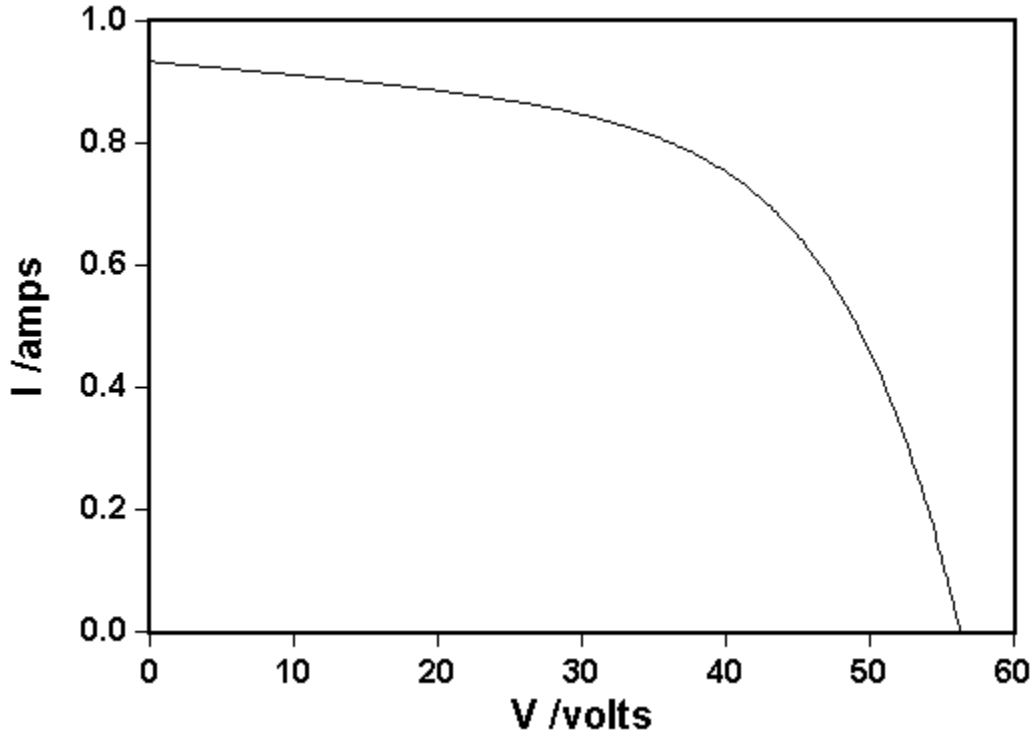
When automatic initial estimates are made, ***FitAll*** assumes that the data are sorted on column number 1, that is, the X-values.

Also See

Function 0503 10, which is the same as this function except that the definitions of the dependent and independent variables are switched. That is, the meanings of X and Y are interchanged.

Function 0517 42, which is the same as this function except that both diodes are assumed to be non-ideal diodes; that is, their ideality factors, n, are greater than or equal to 1.

Ftn 0508: Light I-V: 2 Parameters & 6-Constants



Equation

$$Y = K4*(A) + \left[(K4*P2 - K3)*(A) + K3 - X - Y*P2\right]* \left[\frac{K6 - K4*(B)}{(K4*P2 - K3)*(B) + K3 - K5 - K6*P2}\right]$$

with

$$A = \frac{e^{k_o*K3} - e^{k_o(X+Y*P2)}}{e^{k_o*K3} - e^{k_o*K4*P2}},$$

$$B = \frac{e^{k_o*K3} - e^{k_o*(K5+K6*P2)}}{e^{k_o*K3} - e^{k_o*K4*P2}},$$

and

$$k_o = \frac{K1}{P1*(273.15 + K2)}$$

in which

- Y is the cell operating current, I, in amperes.
- X is the cell operating voltage, V, in volts.

Constants

Constant	Name	Comments
K1	q/k	Elementary charge,q = 1.602177E-19 Coulomb, divided by Boltzmann's constant, k = 1.380662E-23 J/ºK. Default value is 1.160441151E4 CºK/J.
K2	t	Temperature (in ºC). Default value is 25.0 ºC.
K3	Voc	Voltage at Open Circuit (in volts).
K4	Isc	Current at Short Circuit (in amperes).
K5	Vmp	Voltage at Maximum Power (in volts).
K6	Imp	Current at Maximum Power (in amps).

Parameters

Parameter	Name	Comments
P1	n	Cell diode factor. For an ideal diode n = 1. For a non-ideal diode n > 1.
P2	Rs	Series resistance (in ohms). (Rs >= 0).

Sample Applications

- Characterizing the light current-voltage behaviour of solar cells.
- Characterizing the current-voltage behaviour of semiconductor diodes.

Remarks

This is an implicit function. That is, the dependent variable, Y, appears on both sides of the equation. ***FitAll*** uses an iterative method to evaluate this function. Function evaluations are more time consuming than normal and the regression analysis is correspondingly slower.

FitAll is not able to make reliable initial estimates.

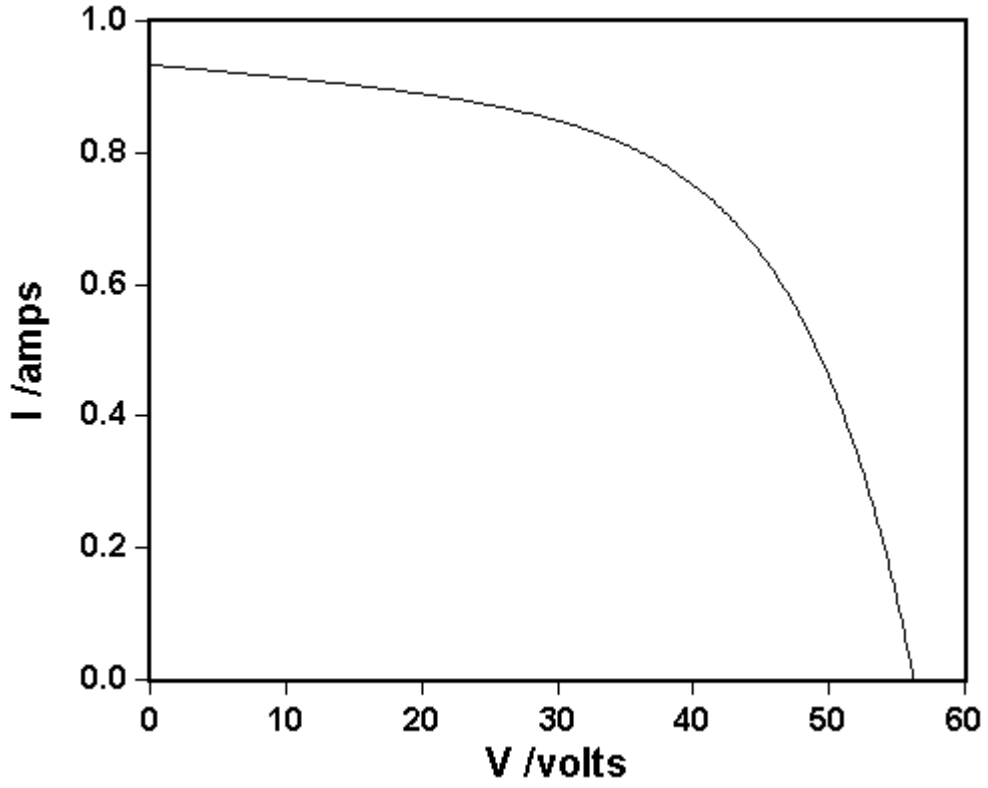
It is essential that you assign reasonable initial parameter values before doing the regression analysis.

All currents and voltages are assumed to be greater than or equal to zero.

Also See

Function 0510 29, which is the same as this function except that the constants K3 to K6 are treated as parameters. This may be useful to correct for small experimental errors that may arise as result of instrumental calibration errors.

Ftn 0509: Light I-V: 2 Parameters & 4-Constants with Rs=0



Equation

$$Y = K4*(A) + [(-K3)*(A) + K3 - X]/P2$$

with

$$A = \frac{e^{k_o*K3} - e^{k_o*X}}{e^{k_o*K3} - 1}$$

and

$$k_o = \frac{K1}{P1*(273.15 + K2)}$$

in which

- Y is the cell operating current, I, in amperes.
- X is the cell operating voltage, V, in volts.

Constants

Constant	Name	Comments
K1	q/k	Elementary charge, q = 1.602177E-19 Coulomb, divided by Boltzmann's constant, k = 1.380662E-23 J/ºK. Default value is 1.160441151E4 CºK/J.
K2	t	Temperature (in ºC). Default value is 25.0 ºC.
K3	Voc	Voltage at Open Circuit (in volts).
K4	Isc	Current at Short Circuit (in amperes).

Parameters

Parameter	Name	Comments
P1	n	Cell diode factor. For an ideal diode n = 1. For a non-ideal diode n > 1.
P2	Rsh	Cell shunt resistance (in ohms). (Rsh >= 0).

Sample Applications

- Characterizing the light current-voltage behaviour of solar cells.
- Characterizing the current-voltage behaviour of semiconductor diodes.

Remarks

FitAll is not able to make reliable initial estimates.

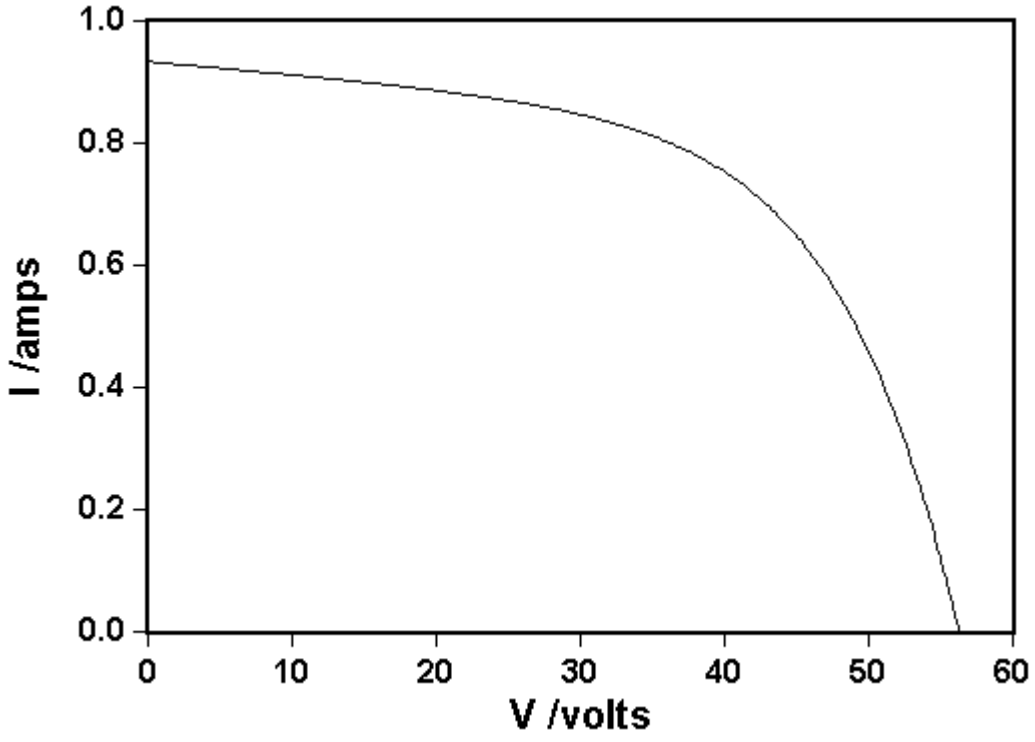
It is essential that you assign reasonable initial parameter values before doing the regression analysis.

All currents and voltages are assumed to be greater than or equal to zero.

Also See

Function 0511 32, which is the same as this function *except* that the constants K3 and K4 are treated as parameters. This may be useful to correct for small experimental errors that may arise as result of instrumental calibration errors.

Ftn 0510: Light I-V: 6 Parameters & 2 Constants



Equation

$$Y = P4*\{A\}+\left[(P4*P2-P3)*\{A\}+P3-X-Y*P2\right]*$$

$$\left[\frac{P6-P4*\{B\}}{(P4*P2-P3)*\{B\}+P3-P5-P6*P2}\right]$$

with

$$A = \frac{e^{k_o*P3} - e^{k_o(X+Y*P2)}}{e^{k_o*P3} - e^{k_o*P4*P2}},$$

$$B = \frac{e^{k_o*K3} - e^{k_o*(P5+P6*P2)}}{e^{k_o*P3} - e^{k_o*P4*P2}},$$

and

$$k_o = \frac{K1}{P1*(273.15+K2)}$$

in which

- Y is the cell operating current, I, in amperes.
- X is the cell operating voltage, V, in volts.

Constants

Constant	Name	Comments
K1	q/k	Elementary charge, q = 1.602177E-19 Coulomb, divided by Boltzmann's constant, k = 1.380662E-23J/ ºK. Default value is 1.160441151E4CºK/J.
K2	t	Temperature (in ºC). Default value is 25.0 ºC.

Parameters

Parameter	Name	Comments
P1	n	Cell diode factor. For an ideal diode n = 1. For a non-ideal diode n > 1.
P2	Rs	Series resistance (in ohms). (Rs >= 0).
P3	Voc	Voltage at Open Circuit (in volts).
P4	Isc	Current at Short Circuit (in amperes).
P5	Vmp	Voltage at Maximum Power (in volts).
P6	Imp	Current at Maximum Power (in amps).

Sample Applications

- Characterizing the light current-voltage behaviour of solar cells.
- Characterizing the current-voltage behaviour of semiconductor diodes.

Remarks

This is an implicit function. That is, the dependent variable, Y, appears on both sides of the equation. ***FitAll*** uses an iterative method to evaluate this function. Function evaluations are more time consuming than normal and the regression analysis is correspondingly slower.

FitAll is not able to make reliable initial estimates.

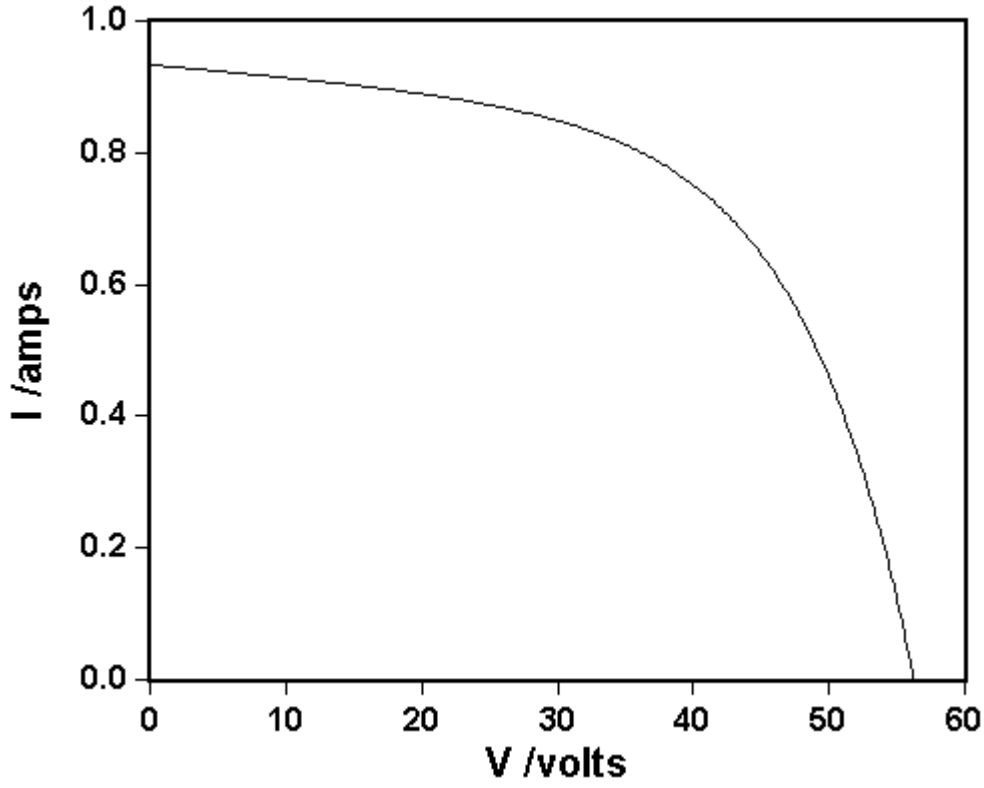
It is essential that you assign reasonable initial parameter values before doing the regression analysis.

All currents and voltages are assumed to be greater than or equal to zero.

Also See

Function 0508 24, which is the same as this function except that the parameters P3 to P6 are treated as constants.

Ftn 0511: Light I-V: 4 Parameters & 2 Constants with Rs=0



Equation

$$Y = P4*(A) + [(-P3)*(A) + P3 - X]/P2$$

with

$$A = \frac{e^{k_o*P3} - e^{k_o*X}}{e^{k_o*P3} - 1},$$

and

$$k_o = \frac{K1}{P1*(273.15 + K2)}$$

in which

- Y is the cell operating current, I, in amperes.
- X is the cell operating voltage, V, in volts.

Constants

Constant	Name	Comments
K1	q/k	Elementary charge, q = 1.602177E-19 Coulomb, divided by Boltzmann's constant, k = 1.380662E-23J/ ºK. Default value is 1.160441151E4 CºK/J.
K2	t	Temperature (in ºC). Default value is 25.0 ºC.

Parameters

Parameter	Name	Comments
P1	n	Cell diode factor. For an ideal diode n = 1. For a non-ideal diode n > 1.
P2	Rsh	Cell shunt resistance (in ohms). (Rsh >= 0).
P3	Voc	Voltage at Open Circuit (in volts).
P4	Isc	Current at Short Circuit (in amperes).

Sample Applications

- Characterizing the light current-voltage behaviour of solar cells.
- Characterizing the current-voltage behaviour of semiconductor diodes.

Remarks

FitAll is not able to make reliable initial estimates.

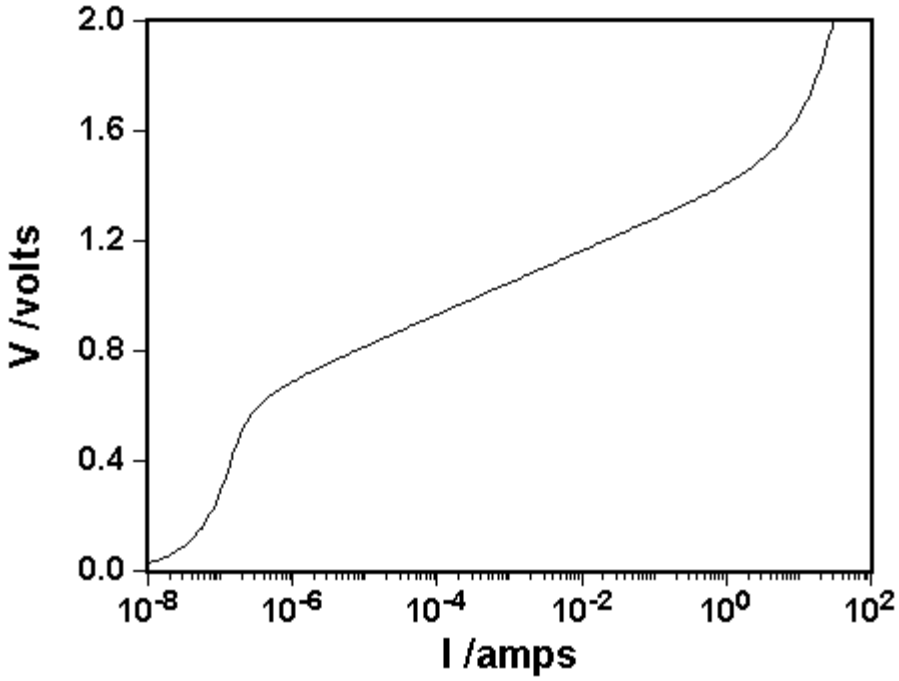
It is essential that you assign reasonable initial parameter values before doing the regression analysis.

All currents and voltages are assumed to be greater than or equal to zero.

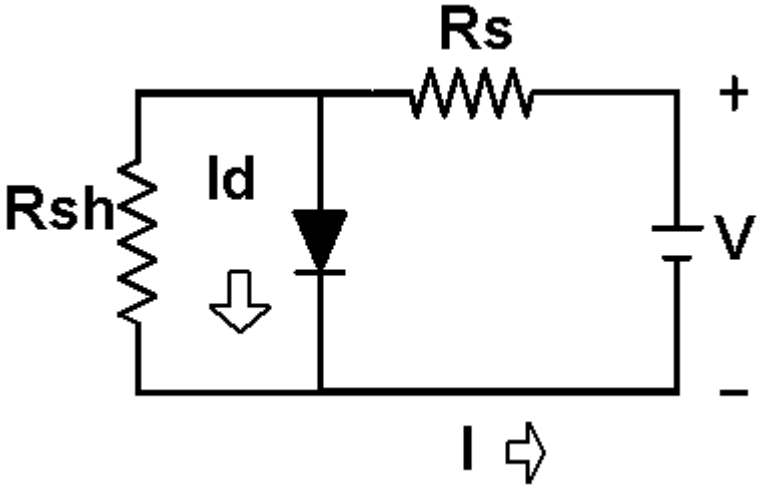
Also See

Function 0509 27, which is the same as this function except that the parameters P3 and P4 are treated as constants.

Ftn 0512: Dark Current-Voltage: Non-Ideal with Rs



Equivalent Circuit



Equation

$$Y = P1 * \left(X - P2 * \left\{ e^{\left[\frac{K1 * (Y - X * P4)}{(P3 * (273.15 + K2))} \right]} - 1 \right\} \right) + X * P4$$

in which:

- Y is the measured response, the voltage in volts.
- X is the independent variable, the current in amperes.

Constants

Constant	Name	Comments
K1	q/k	Elementary charge, q = 1.602177E-19 Coulomb, divided by Boltzmann's constant, k = 1.380662E-23 J/ºK. Default value is 1.160441151E4 CºK/J
K2	t	Temperature in ºC. Default value is 25 ºC.

Parameters

Parameter	Name	Comments
P1	Rsh	Shunt resistance.
P2	Io	Diode saturation current for recombination mechanisms with ideality factor equal to one.
P3	n	Ideality factor, equal to one for an ideal semiconductor diode. When doing a fit it is often advantageous to limit the value of n to the range 1 to 5.
P4	Rs	Series resistance. It is often advantageous to limit Rs to values greater than or equal to zero. These are the only physically meaningful values of Rs.

Sample Applications

- Characterizing the current-voltage behaviour of semiconductor diodes.
- Characterizing the dark current-voltage behaviour of solar cells.

Remarks

This function is an implicit function; that is, its value depends on itself. The dependent variable, Y, appears on both sides of the equation. ***FitAll*** uses an iterative method to evaluate this function. Function

evaluations are more time consuming than normal and the regression analysis is correspondingly slower.

All currents and voltages are assumed to be greater than or equal to zero.

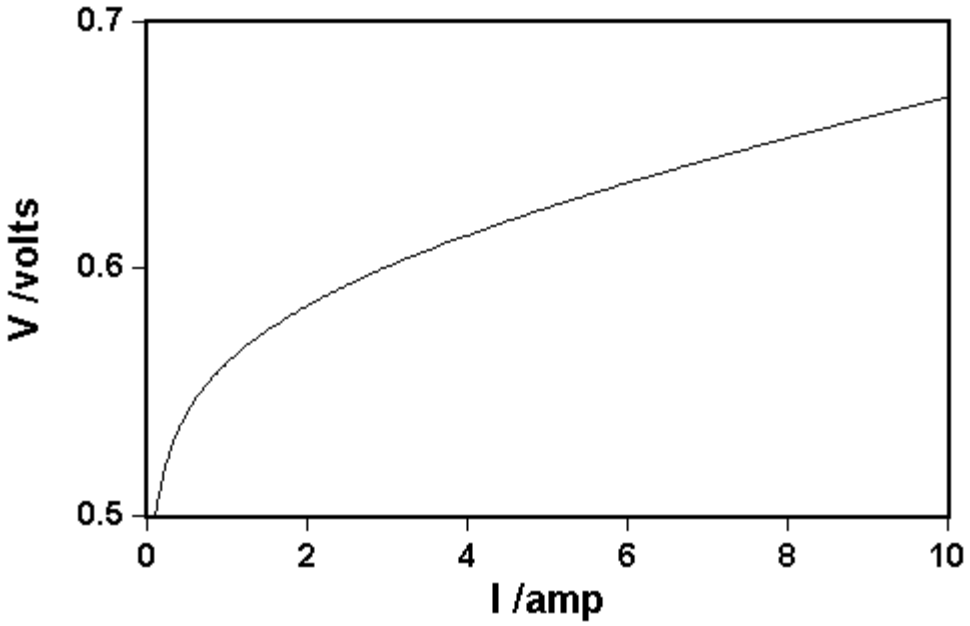
When automatic initial estimates are made, ***FitAll*** assumes that the data are sorted on column number 1, that is, the X-values.

Also See

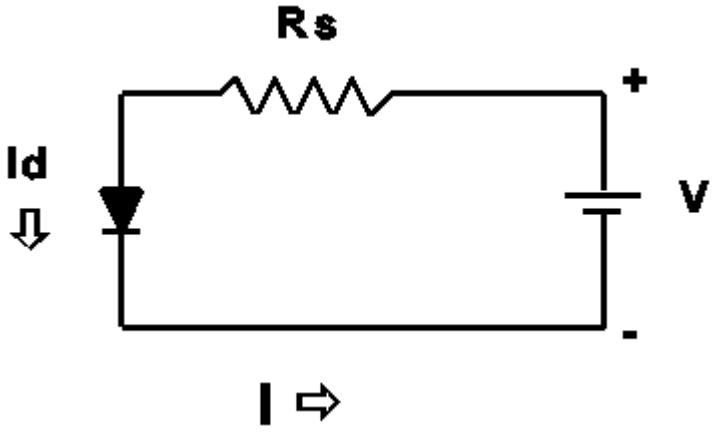
Function 0502 7, which is the same as this function except that the definitions of the dependent and independent variables are switched. That is, the meanings of X and Y are interchanged.

Function 0506 18, which is similar to this function except that the series resistance, Rs, is not present in the equivalent circuit.

Ftn 0514: Dark I-V: Model 1B: High I-range: "n" as a Parameter



Equivalent Circuit



Equation

$$Y = \frac{P3*(273.15+K2)}{K1}*Ln\left|\frac{(X+P1)}{P1}\right|+X*P2$$

in which:

- Y is the measured response -- the voltage in volts.
- X is the independent variable -- the current in amperes.

Constants

Constant	Name	Comments
K1	q/k	Elementary charge, q=1.602177E-19 Coulomb, divided by Boltzmann's constant, k = 1.380662E-23 J/ºK. Default value is 1.160441151E4 CºK/J.
K2	t	Temperature in ºC. Default value is 25.0 ºC.

Parameters

Parameter	Name	Comments
P1	Id	Saturation current for diode, in amperes
P2	Rs	Series resistance in ohms. Rs >= 0.
P3	n	Ideality factor for the diode. For an ideal diode, n = 1. For a non-ideal diode, n > 1.

Sample Applications

- Characterizing the current-voltage behaviour of semiconductor diodes.
- Characterizing the dark current-voltage behaviour of solar cells.

Remarks

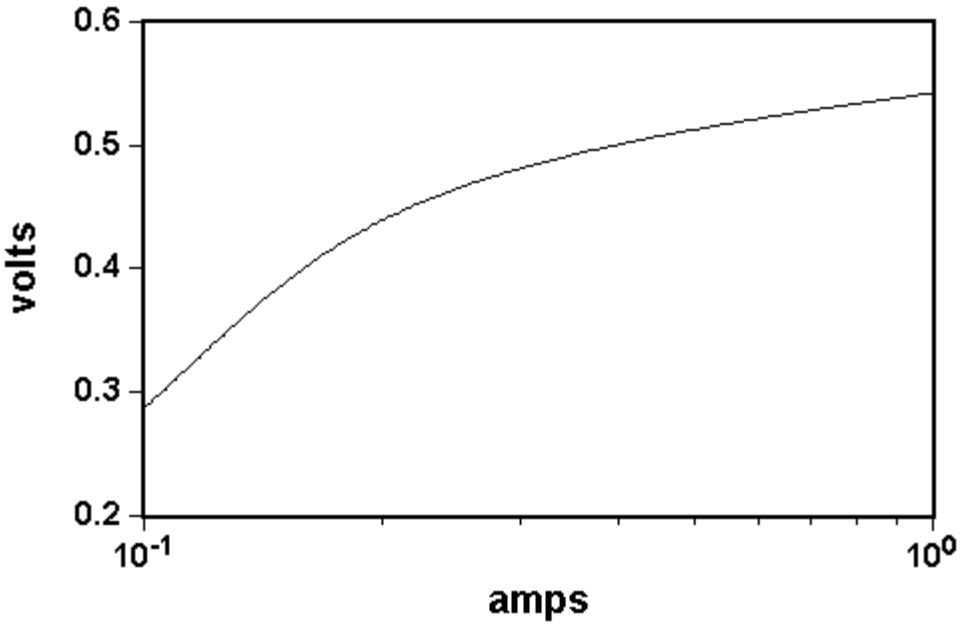
All currents and voltages are assumed to be greater than or equal to zero.

When automatic initial estimates are made, ***FitAll*** assumes that the data are sorted on column number 1, that is, the X-values.

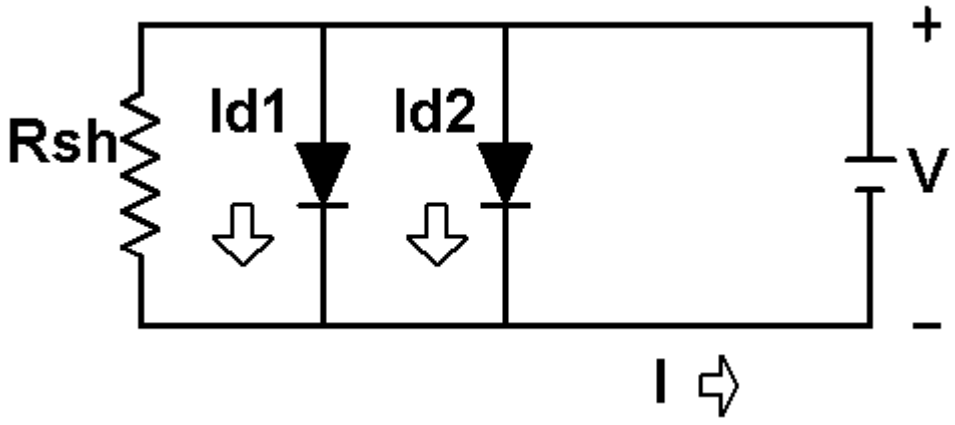
Also See

Function 0504 13, which is the same as this function except that the diode ideality factor,parameter P3, is treated as a manually adjustable constant.

Ftn 0515: Dark I-V: Model 2B: Mid I-range: 2 Non-Ideal Diodes



Equivalent Circuit



Equation

$$Y = P1 * \left(X - P2 * \left\{ e^{\left[\frac{K1 * Y}{(P5 * (273.15 + K2))} \right]} - 1 \right\} - P3 * \left\{ e^{\left[\frac{K1 * Y}{(P4 * (273.15 + K2))} \right]} - 1 \right\} \right).$$

in which:

- Y is the measured response -- the voltage in volts.
- X is the independent variable -- the current in amperes.

Constants

Constant	Name	Comments
K1	q/k	Elementary charge, q=1.602177E-19 Coulomb, divided by Boltzmann's constant, k = 1.380662E-23 J/ºK. Default value is 1.160441151E4 CºK/J.
K2	t	Temperature in ºC. Default value is 25.0 ºC.

Parameters

Parameter	Name	Comments
P1	Rsh	Shunt resistance in ohms.
P2	Id1	Saturation current for ideal diode 1, in amperes
P3	Id2	Saturation current for non-ideal diode 2, in amperes
P4	n2	Ideality factor for diode 2. For an ideal diode, n = 1. For a non-ideal diode, n > 1.
P5	n1	Ideality factor for diode 1. For an ideal diode, n = 1. For a non-ideal diode, n > 1.

Sample Applications

- Characterizing the current-voltage behaviour of semiconductor diodes.
- Characterizing the dark current-voltage behaviour of solar cells.

Remarks

Because of the exponential nature of this function and the magnitude of the constants, some of the values

generated can be very large (or very small) -- in fact, large enough to exceed the numeric range of your computer. If this happens, one or more error messages will appear and the calculations will be terminated.

This is an implicit function; that is, the dependent variable, Y, appears on both sides of the equation. ***FitAll*** uses an iterative method to evaluate this function. Function evaluations are more time consuming than normal and the regression analysis is correspondingly slower.

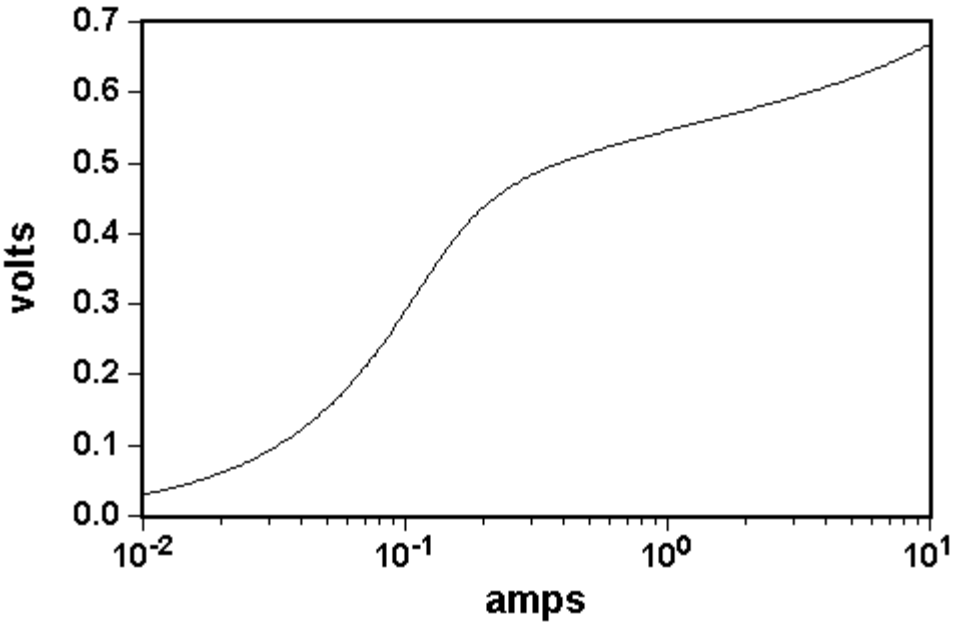
All currents and voltages are assumed to be greater than or equal to zero.

When automatic initial estimates are made, ***FitAll*** assumes that the data are sorted on column number 1, that is, the X-values.

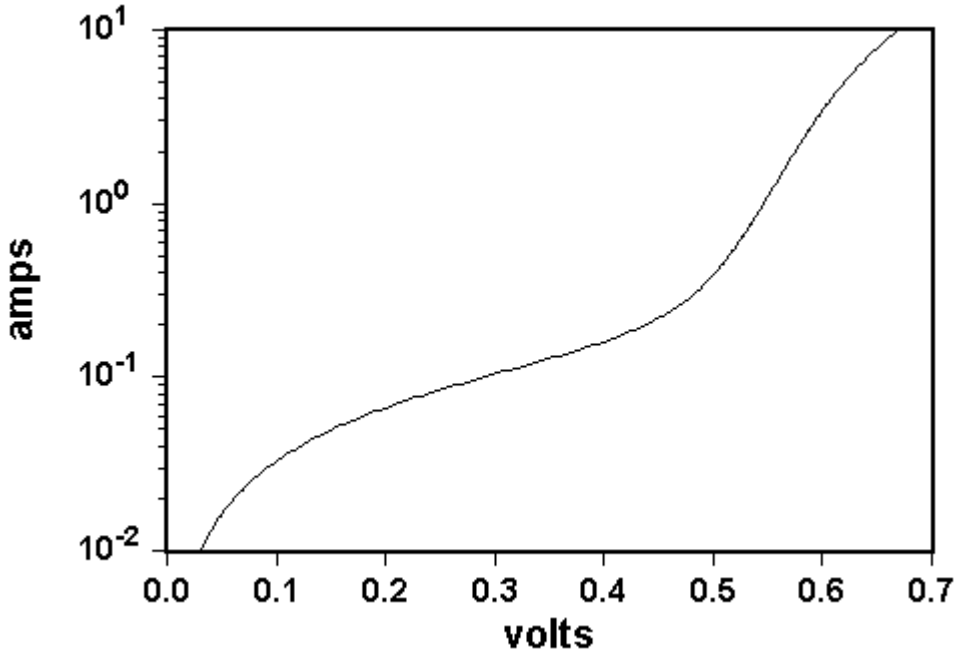
Also See

Function 0505 15, which is the same as this function except that diode 1 is treated as an ideal diode; that is, its ideality factor, n1, is assumed to have a value of 1.0.

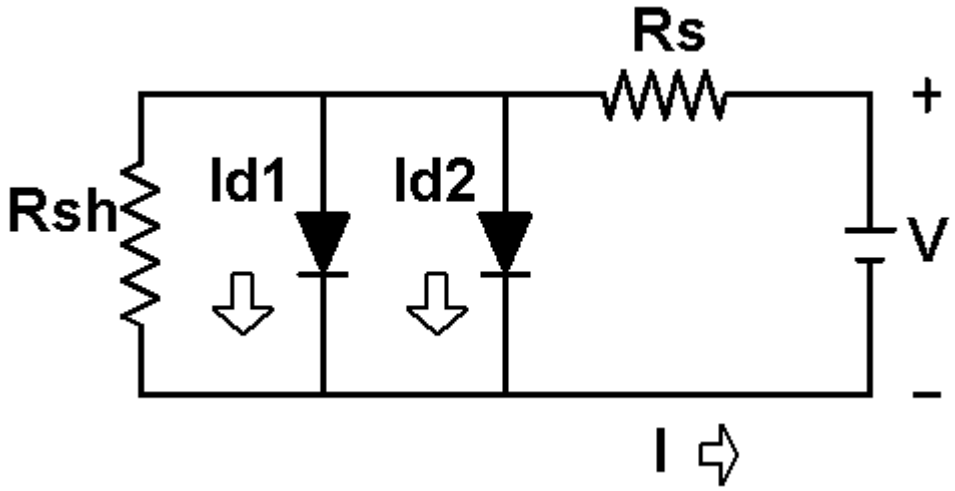
Ftn 0517: Dark I-V: Model 4B: Full I-range: 2 Non-Ideal Diodes



OR



Equivalent Circuit



Equation

$$Y = P1 * \left(X - P2 * \left\{ e^{\left[\frac{K1 * (Y - X * P5)}{(P6 * (273.15 + K2))} \right]} - 1 \right\} - P3 * \left\{ e^{\left[\frac{K1 * (Y - X * P5)}{(P4 * (273.15 + K2))} \right]} - 1 \right\} \right) + X * P5$$

in which:

- Y is the measured response -- the voltage in volts.
- X is the independent variable -- the current in amperes.

Constants

Constant	Name	Comments
K1	q/k	Elementary charge, q=1.602177E-19 Coulomb, divided by Boltzmann's constant, k = 1.380662E-23 J/ºK. Default value is 1.160441151E4 CºK/J.
K2	t	Temperature in ºC. Default value is 25.0 ºC.

Parameters

Parameter	Name	Comments
P1	Rsh	Shunt resistance in ohms.
P2	Id1	Saturation current for diode 1, in amperes
P3	Id2	Saturation current for diode 2, in amperes.
P4	n2	Ideality factor for diode 2. For an ideal diode, n = 1. For a non-ideal diode, n > 1.
P5	Rs	Series resistance in ohms.
P6	n1	Ideality factor for diode 1. For an ideal diode, n = 1. For a non-ideal diode, n > 1.

Sample Applications

- Characterizing the current-voltage behaviour of semiconductor diodes.
- Characterizing the dark current-voltage behaviour of solar cells.

Remarks

Because of the exponential nature of this function and the magnitude of the constants, some of the values generated can be very large (or very small) -- in fact, large enough to exceed the numeric range of your computer. If this happens, one or more error messages will appear and the calculations will be terminated.

This is an implicit function; that is, the dependent variable, Y, appears on both sides of the equation. ***FitAll*** uses an iterative method to evaluate this function. Function evaluations are more time consuming than normal and the regression analysis is correspondingly slower.

All currents and voltages are assumed to be greater than or equal to zero.

When automatic initial estimates are made, ***FitAll*** assumes that the data are sorted on column number 1, that is, the X-values.

Also See

Function 0507 21, which is the same as this function except that one of the diodes is assumed to be an ideal diode; that is, it has an ideality factor, n, equal to 1.

Appendix

Getting Help

To get technical or other assistance from MTR Software you can:

Visit the FAQ page on MTR Software's web site at:

www.fitall.com

Email MTR Software at:

support@fitall.com

Write to MTR Software at:

MTR Software

77 Carlton Street, Suite 808

Toronto ON Canada

M5B 2J7

Telephone MTR Software at:

416-596-1499

Describe your problem or difficulty as completely as you can. We will try to answer your query quickly and completely.

You should also include your email address as well as your daytime, evening and weekend telephone numbers.

Adding Functions to FitAll

There are three ways to add your own specialized functions to ***FitAll***.

1. You can contact ***MTR* Software** to get a quotation on the cost of creating a custom ***FitAll* Function Library** for you.

2. The ***FitAll*** Programmer's Guide, which is included with ***FitAll* Research Edition**, explains:

   - how to modify the supplied source code for the User Defined ***FitAll* Function Libraries** and

   - how to compile them using Borland Delphi version 5, 6, 7, 2005 and 2006.

3. You can contact ***MTR* Software** and request that the function be added to one of ***FitAll***'s **Function Libraries**.

Index

- A -

- C -

- E -

- F -

- H -

- I -

- S -