

## J18LV DC correlation of spice model to silicon

TSMC CMOS process 1.5/3.3V, 0.18um, 1P5M  
Fred Wahl, Device Engineering, Sep 21, 1999

### • Summary

A new spice model file, based upon the original TSMC spice model file 'c025njlv.l', (TSMC v1.0) rev 0.5 and release date 7/23/99, has received minor tuning and now better fits measurements done on Catwoman testchip transistors than the original.

Five device type models were adjusted: 1) 1.5V Nfet, 2) 1.5V Pfet, 3) 3.3V Nfet, 4) 3.3V Pfet and 5) 1.5V ZVTfet(Low Vt). Models 1) through 4) are built using 12 gate-width-and-length defining 'bins' and model 5) ,ZVT, is built from one single all-encompassing global bin.

These component models have been tuned to silicon by the adjustment of 6 'physical' parameters – 1) Tox, 2) delta L, 3) delta W, 4) Vt0, 5) mobility, and 6) saturation velocity. Improvement of fit of adjusted model to measured IV curve data is shown typically by a reduction in average maximum error of 4% and average RMS error of 2-3%.

The fit of adjusted models to the data from a single silicon die site (#33) can be observed in the attached simulation versus actual IV plots from Linear, Saturation, Subthreshold, Rout and Gm regions of transistor behavior.

### • Details

**Test Chip:** "Catwoman I", design CLI1129AA. Refer to Tech & Engr document: "0.18 TEST CHIP DOCUMENT, May 26 1999".

**Silicon Tested:** TSMC 'July 99' Shuttle lot: D80123.03, family: TM7612 C1, wafer #1, sawn die 'site #33'. Preliminary judgements and selection of 'site #33' based upon data collected by Simon Li in his phase one report: "J18LV PCM Quickcheck for 1<sup>st</sup> Shuttle Project", Aug 10, 1999.

**Testing:** An HP4156A Parametric Analyzer and HP4284A LCR meter were controlled using BTA's Bsimpro, version 4.3 to perform the IV and CV measurements needed. CV (capacitance-voltage) measurements were done to determine Cox accumulated on special test capacitors for each device type on 'site #33'. A Tempronic TP3010-B hot chuck and controller were used to force the sample to 25, 75 or 100 degrees C as needed.

### • Model Adjustments

For each of the 5 device types the following was done:

The method of model adjustment was to 1<sup>st</sup> select one of the 12 model bins for use as a global model. This model had to simulate in Bsimpro all device geometries and temperatures under study without major simulation distortion or numeric failure. Often 'bin' 8 or 9 served this function.

In this chosen or 'best' bin model the value of TOX was edited to have the actual Tox calculated from measured site #33 Cox.

With appropriate choice of room temperature data points from the 'Linear' and 'Saturation' regions of the IV curves for all device geometries measured, Bsimpro was used to re-extract parameters DL( Delta L), DW (Delta W), VTHO (Vt-zero), UO (mobility) and if necessary VSAT (saturation velocity).

These revised parameters were then edited back into the 12-bin model. DL/2 (entering the model as Lint) and DW/2 (as Wint) changes affected all bins as direct replacements. Delta Vt, the difference between the 'best' bin original and re-extracted VTH0, was added as an adjustment to each bins VTH0 if required. Similarly differences in UO and VSAT were converted to percent changes. These percent changes were then made to each of the corresponding parameters in each of the bins, if required.

Bsimpro was then re-run using the adjusted 12 bin model to check for maximum and rms fit error and the quality of IV fit. If required small DL, DW tweaks were made to improve final fit.

The table below summarizes these parameter changes by device type:

Device	Parm	bin	Original	Adjusted
N 1.5	Tox		3.56E-09	3.59E-09
	Lint		6.00E-09	-1.00E-08
	Wint		1.35E-08	-1.96E-08
	Vth0,best bin	9	0.4473	0.3921
P 1.5	Tox		3.62E-09	3.35E-09
	Lint	9	1.35E-08	5.00E-09
	Wint		9.45E-09	-3.13E-08
N 3.3	Tox		7.11E-09	6.70E-09
	Lint		9.45E-09	-2.40E-08
	Wint	6	2.15E-08	-5.00E-09
P 3.3	Tox		7.06E-09	6.50E-09
	Lint		1.80E-08	-6.04E-09
	Wint		2.50E-09	-4.48E-08
	Vth0,best bin	8	-0.574	-0.552
	U0, best bin		0.0121	0.0125
ZVT	Tox		3.56E-09	3.59E-09
	Lint		1.00E-08	-8.60E-08
	Wint		7.70E-09	-4.00E-08
	Vth0,ref bin		-0.0223	0.0324
	U0, ref bin		0.0523	0.0579
	Vsat		1.21E+05	1.54E+05

• **Graphs**

The attached graphical pages form the bulk of this report.

The first page shows the 'bin layout' for the first 4 models. The last model (ZVT) is a simple single bin global model needing no graph. A number 1 through 12 identifies each bin. Letters placed in these bins A, b, c, D, E, F signify devices presented in this report. . One can read the length and width of the device by its position on the bin diagram. A capital letter signifies a device tested also at 75 and 125 deg C in addition to the standard 25 deg C for non-capitalized devices.

The following table details the devices used in this study. Devices marked with a letter such as 'A' or the word 'yes' in the 'bin Letter' column are presented in this report. Data for other devices listed can be provided on request.

Device	Letter	Prefix	W	L	Device	Letter	Prefix	W	L		
N 1.5	A	N1D..	10	10	P 1.5	A	P1D..	10	10		
		N2D..	10	2			P2D..	10	2		
		N3D..	10	1			b	P3D..	10	1	
		N4D..	10	0.4			c	P4D..	10	0.4	
	c	N8D..	10	0.2		D	P8D..	10	0.2		
		N9D..	10	0.18			P9D..	10	0.18		
	E	N13D.	2	0.18		E	P13D.	2	0.18		
		N16D.	0.6	0.18			F	P16D.	0.6	0.18	
	F	N17D.	0.42	2		F	P17D.	0.42	2		
		N21D.	0.42	0.18			P21D.	0.42	0.18		
Device	Letter	Prefix	W	L	Device	Letter	Prefix	W	L		
N 3.3	A	M1D..	10	10	P 3.3	A	Q1D..	10	10		
		M2D..	10	2			Q2D..	10	2		
		b	M3D..	10			1	b	Q3D..	10	1
		c	M4D..	10			0.4	c	Q4D..	10	0.4
	D	M9D..	10	0.35		D	Q9D..	10	0.3		
		M13D.	2	0.35			Q15D.	1	0.3		
	E	M16D.	0.6	0.35		E	Q16D.	0.6	0.3		
		M17D.	0.42	2			F	Q17D.	0.42	2	
	F	M21D.	0.42	0.35		F	Q21D.	0.42	0.3		
		Device	here?	Prefix			W	L			
ZVT 1.5	yes	Z1D..	10	10							
		Z2D..	10	2							
	yes	Z3D..	10	1							
		Z4D..	10	0.6							
	yes	Z8D..	10	0.4							
		Z9D..	10	0.35							
	yes	Z13D.	2	0.35							
		Z15D.	1	0.35							
	yes	Z16D.	0.6	0.35							
		Z17D.	0.42	2							
	yes	Z21D.	0.42	0.35							

Following the bin-diagram plots come the device IV plots. For each device type normally 8 pages are presented, one page for each device (and temperature). These graphs show Linear(ID-VG), Saturation(ID-VD), Subthreshold (log ID-VG) and Rout regions.

The reference device (Wide/Lmin --'D' or Z9D..) has graphs at 75 and 125 degrees presented here also.

Next come 2 pages showing the Gm plots for the same 8 devices.

- **Conclusions**

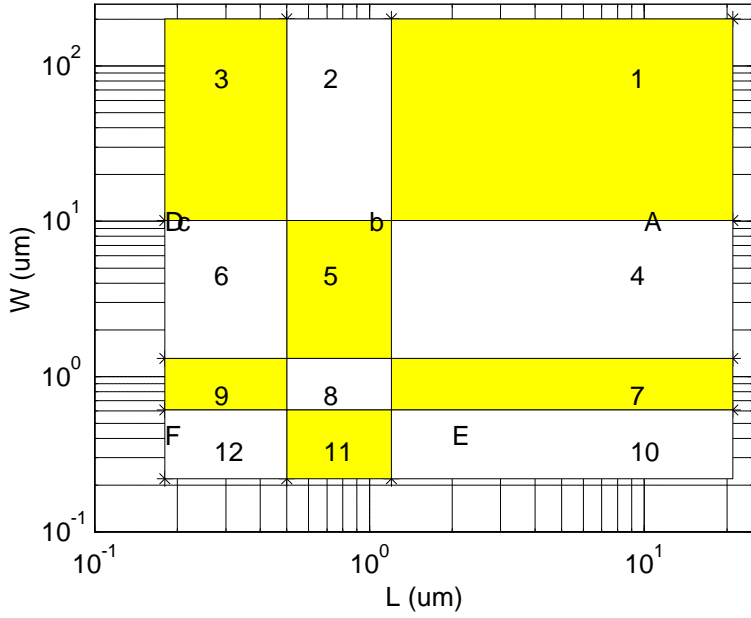
Examination of each graph shows a maximum percent fitting error at its lower left corner and an average root-mean-square fitting error percent at its lower right-hand corner.

The model to silicon adjustment process outlined in this report has been fairly successful. Typical Saturation region RMS errors have been reduced to the 1 to 3 percent range and maximum percent errors to the 2 to 5 percent range. Linear and Rout regions have had their errors controlled as well.

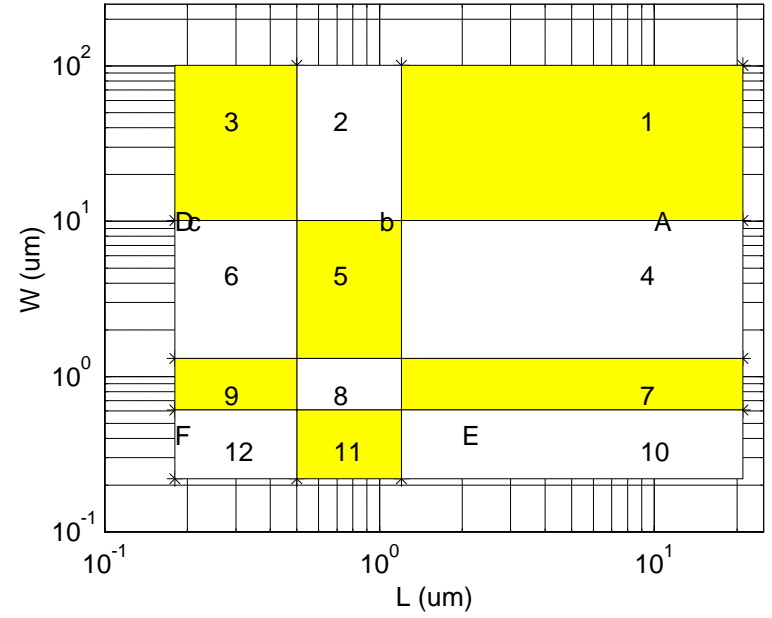
Examining the 'quality' of fit for the ZVT devices and Gm fits however we must say there is still room for improvement.

An AC correlation of model to silicon report for this process including simulation of Ring Oscillators is under development and will be published shortly.

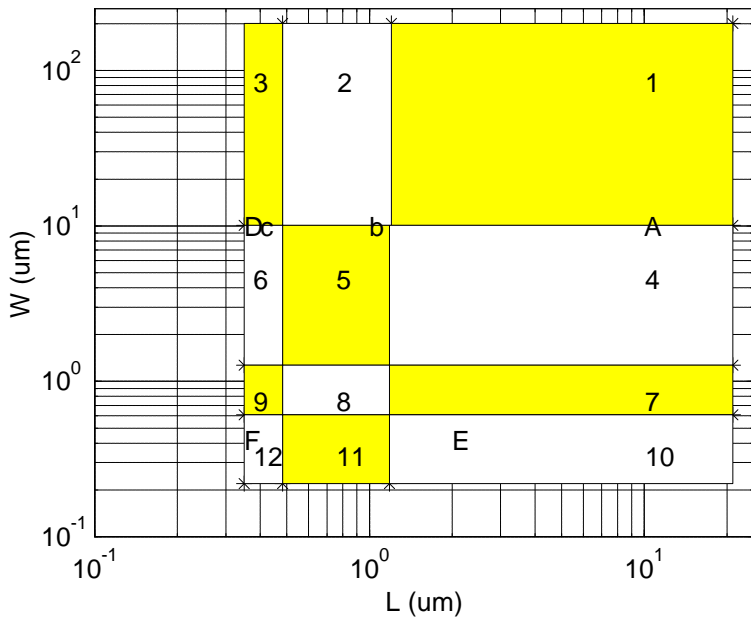
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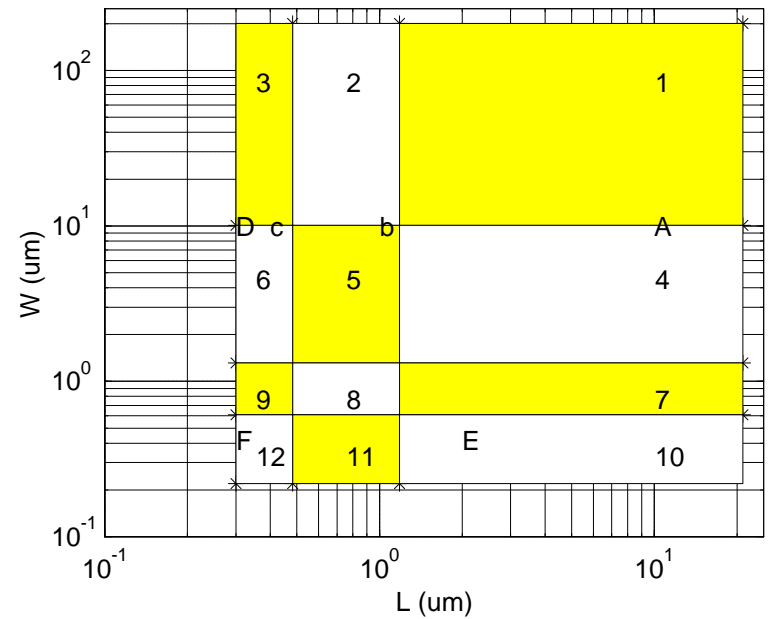
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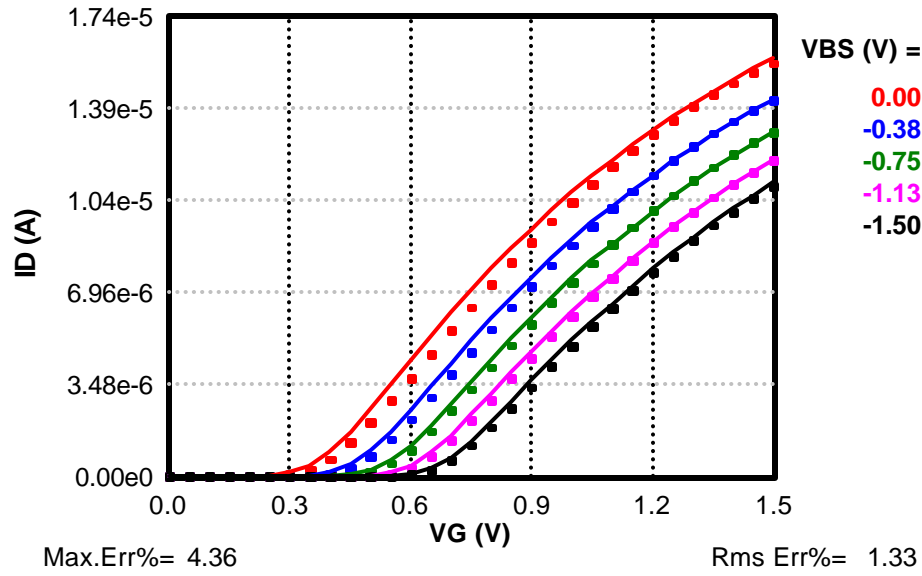
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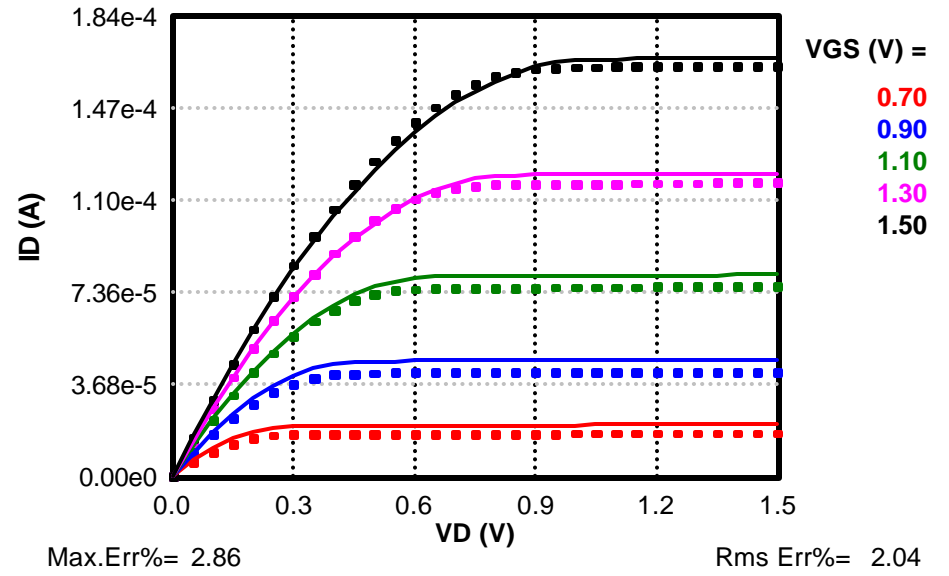
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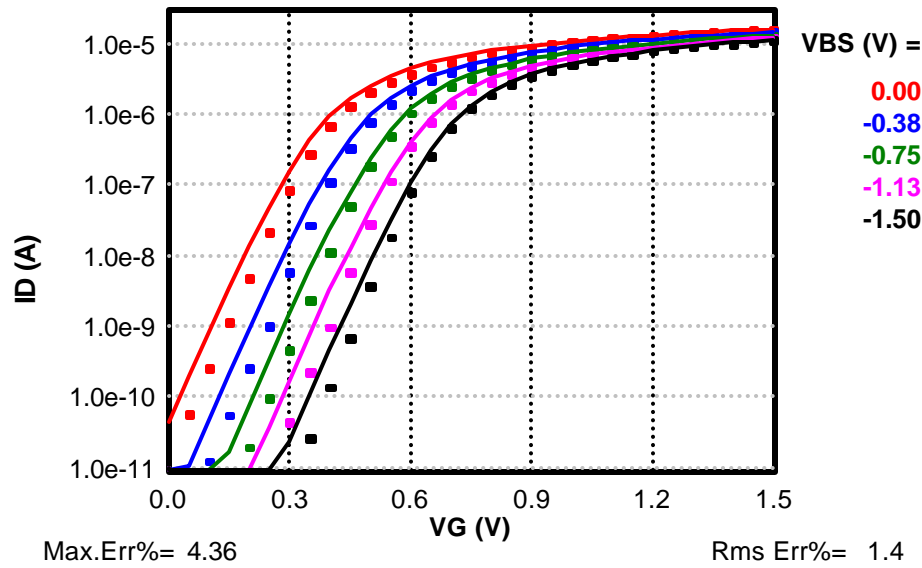
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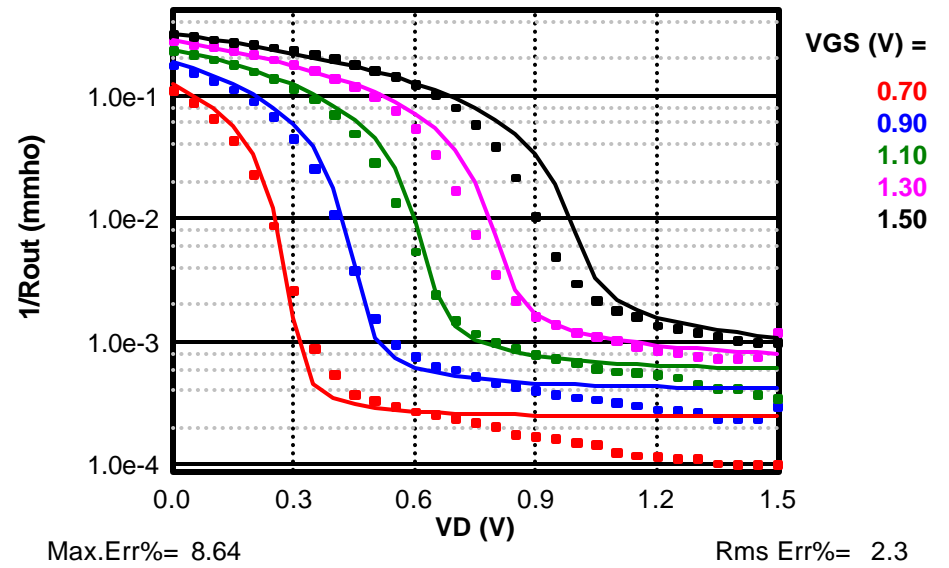
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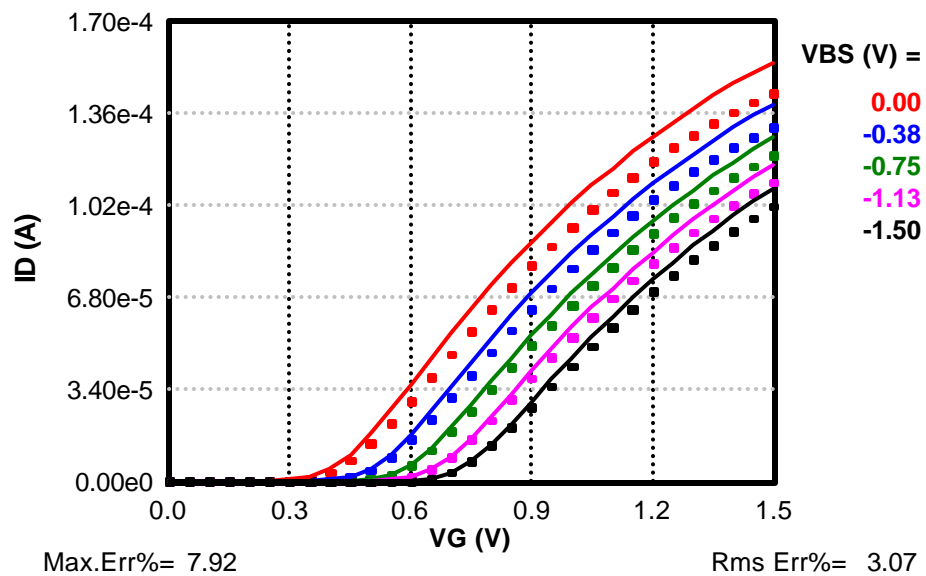
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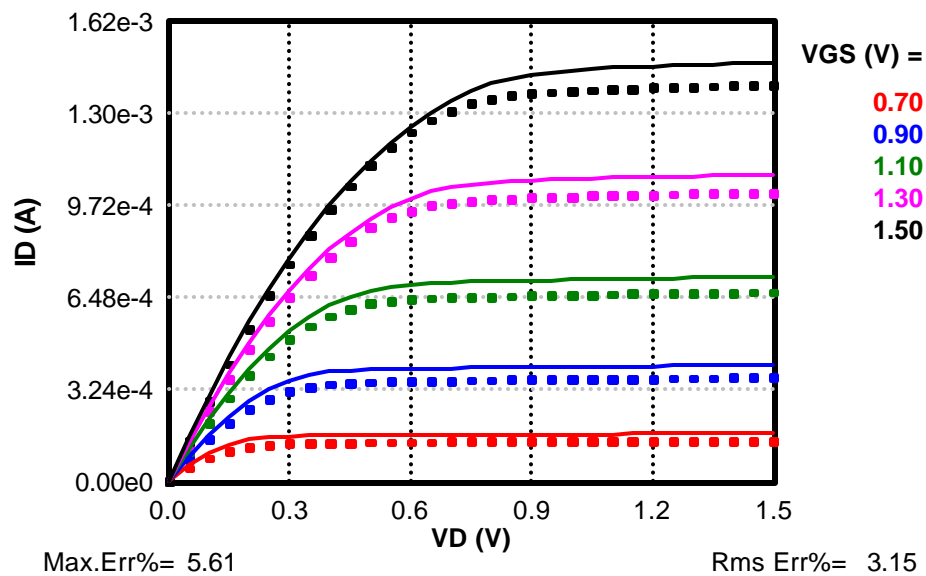
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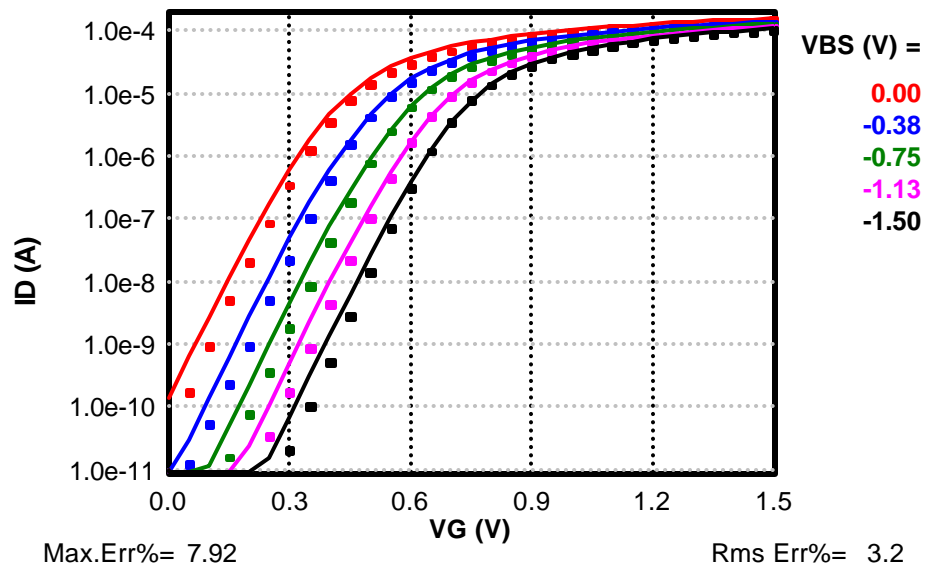
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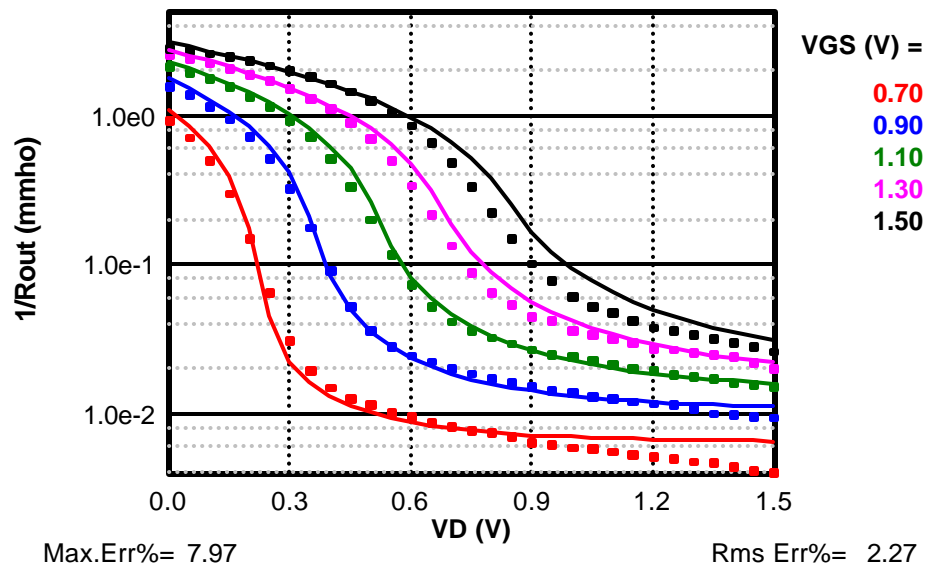
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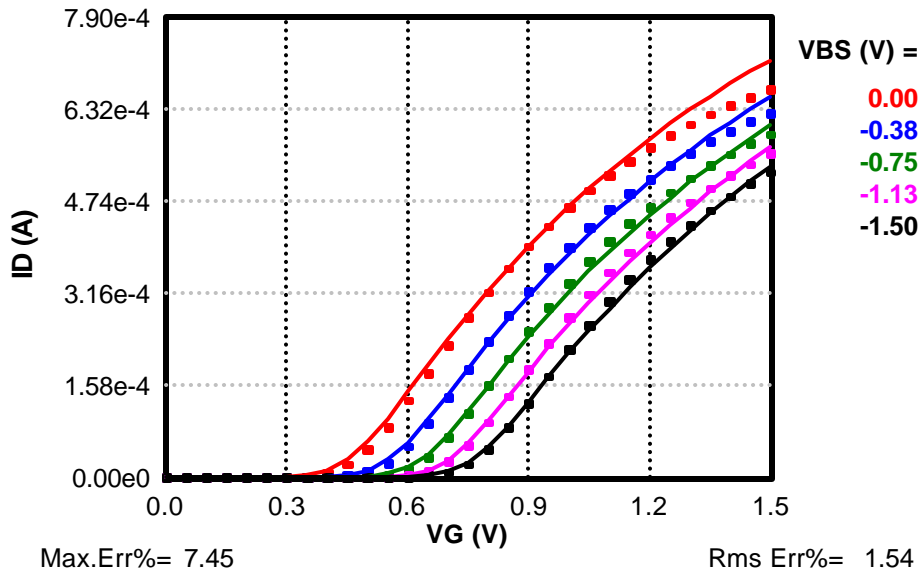
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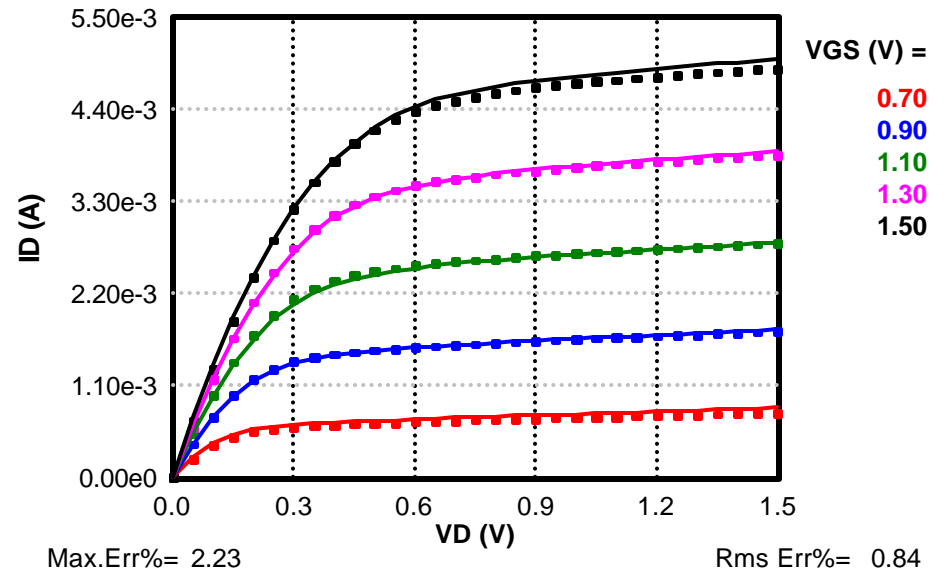
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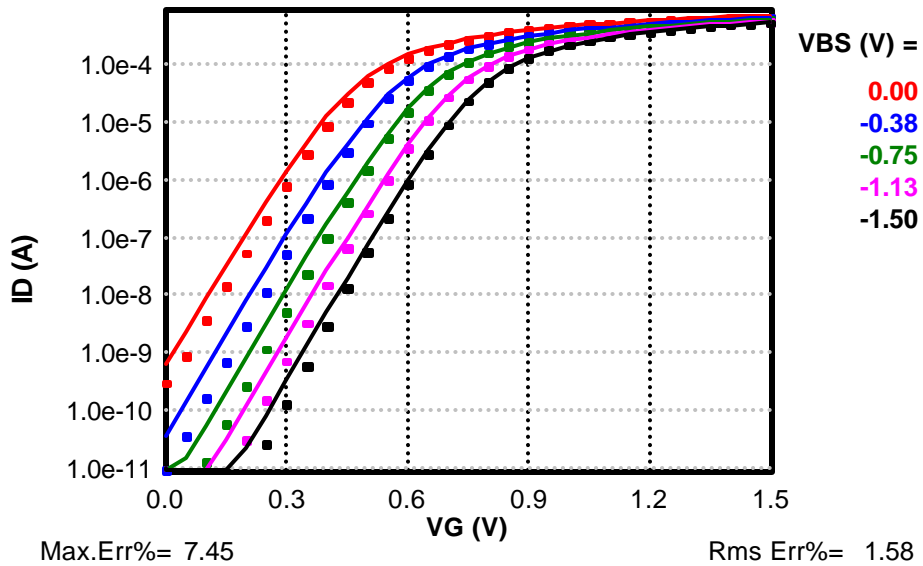
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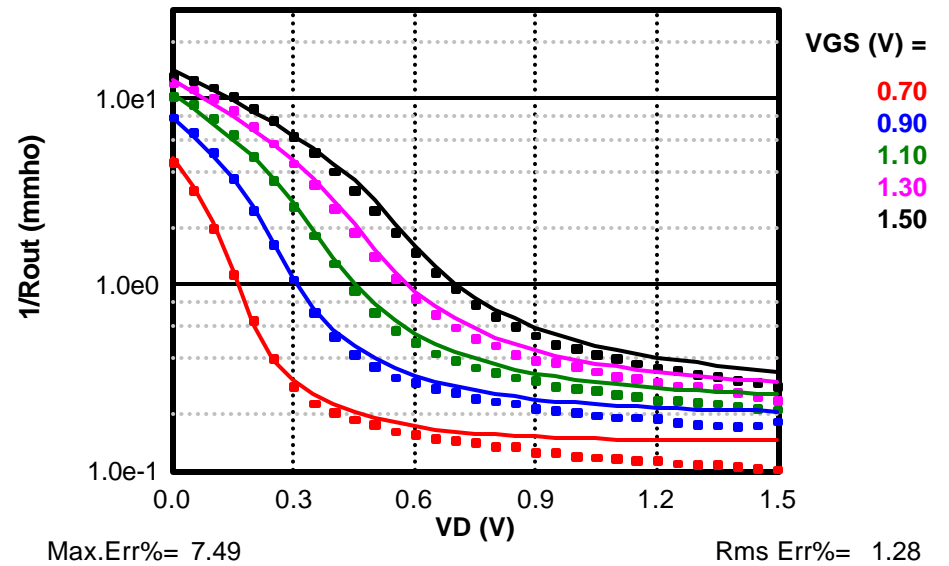
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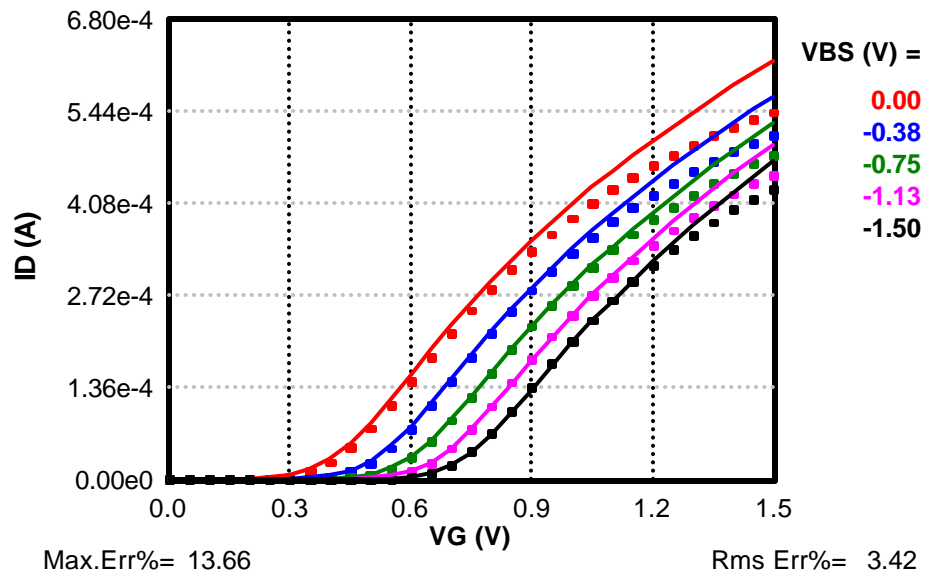
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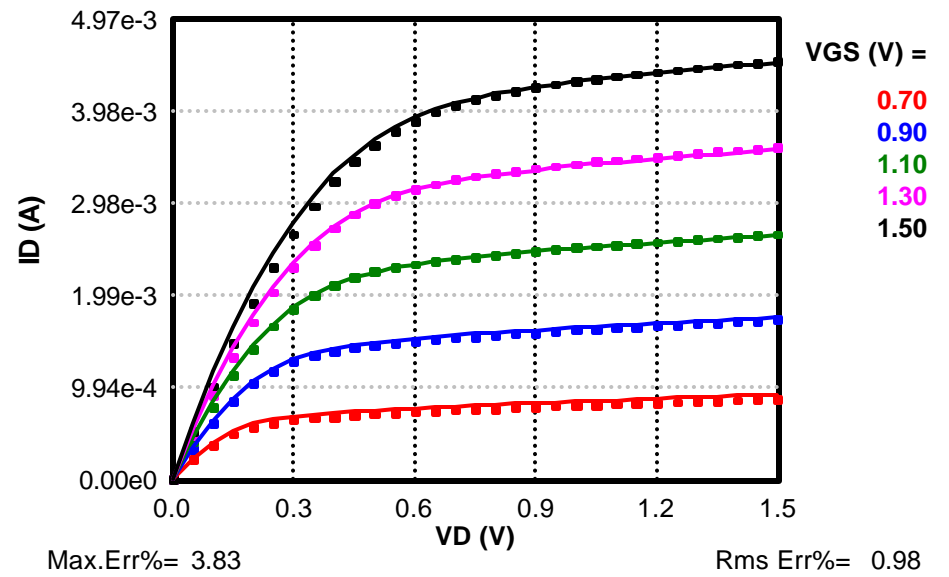
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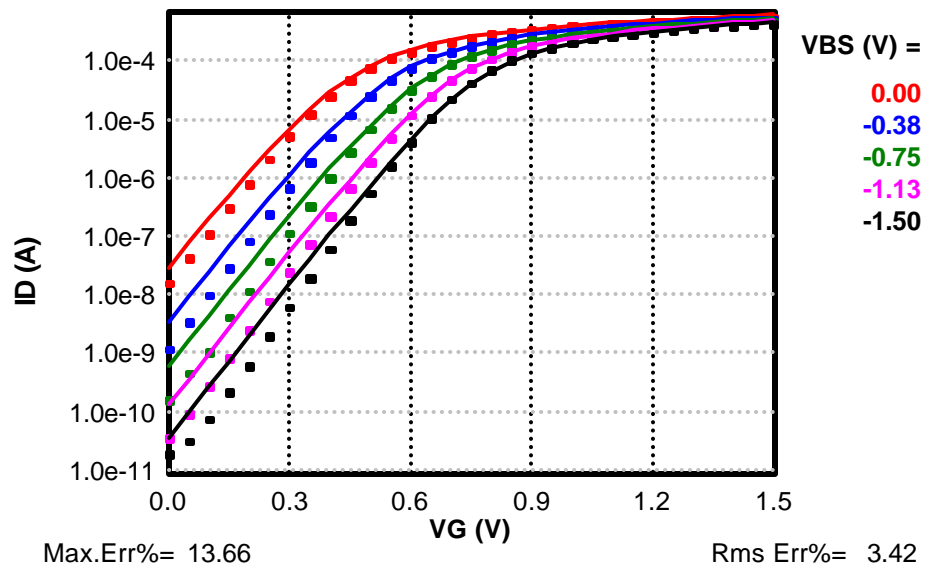
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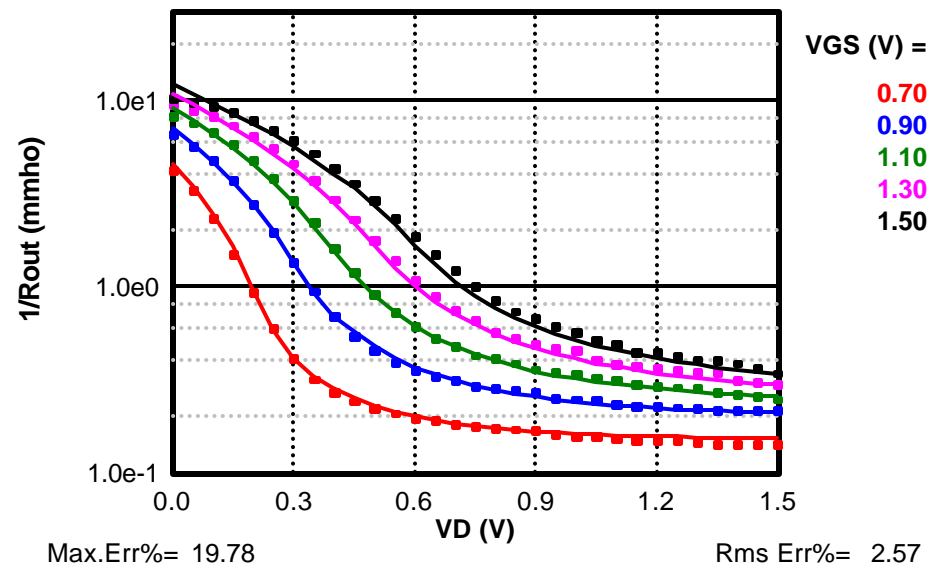
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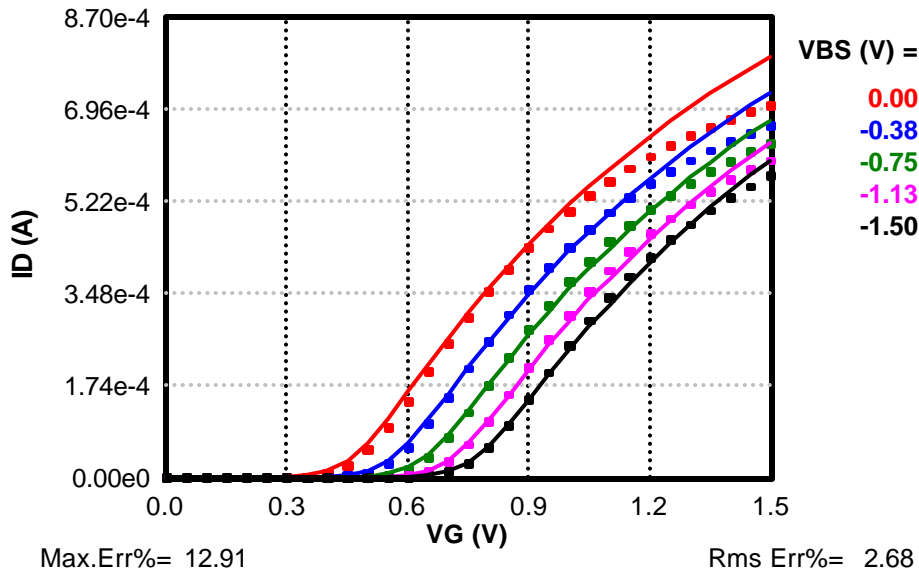


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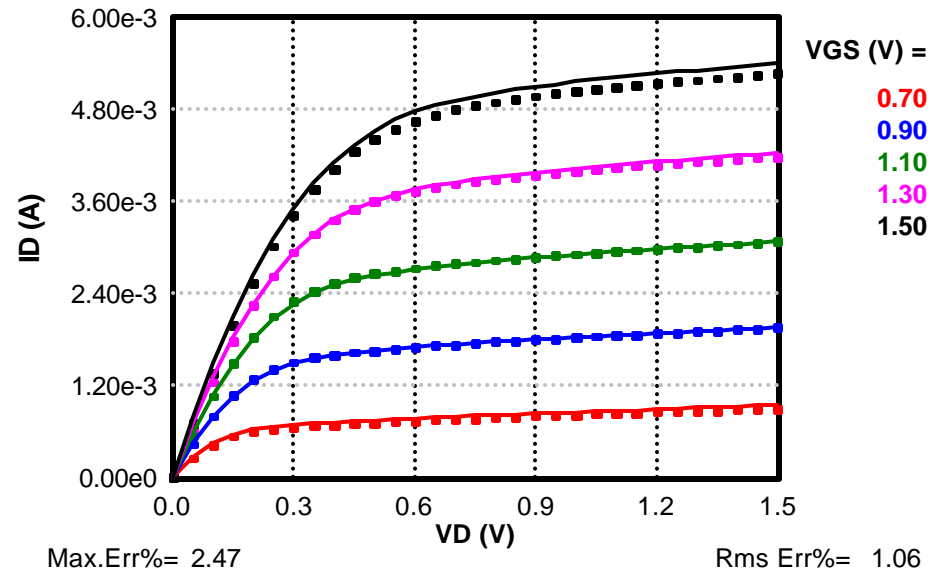




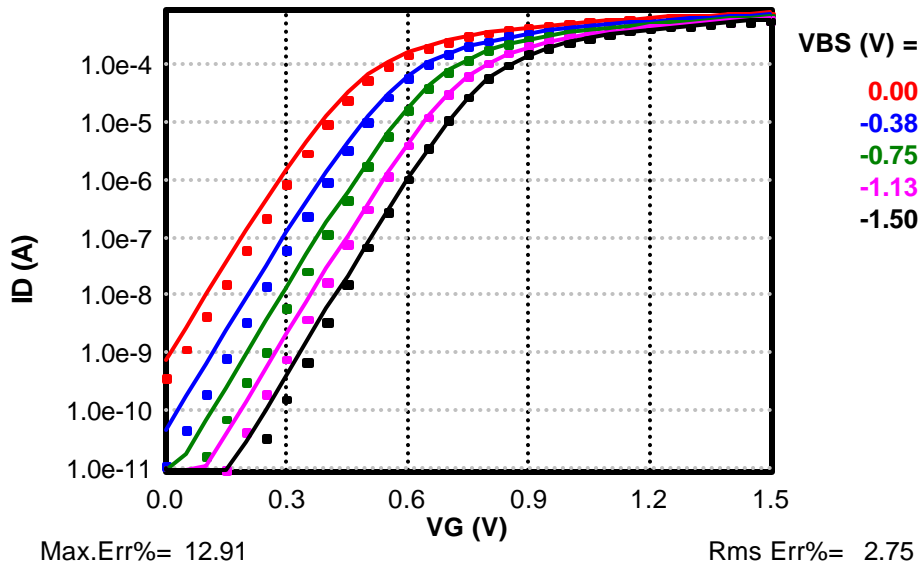
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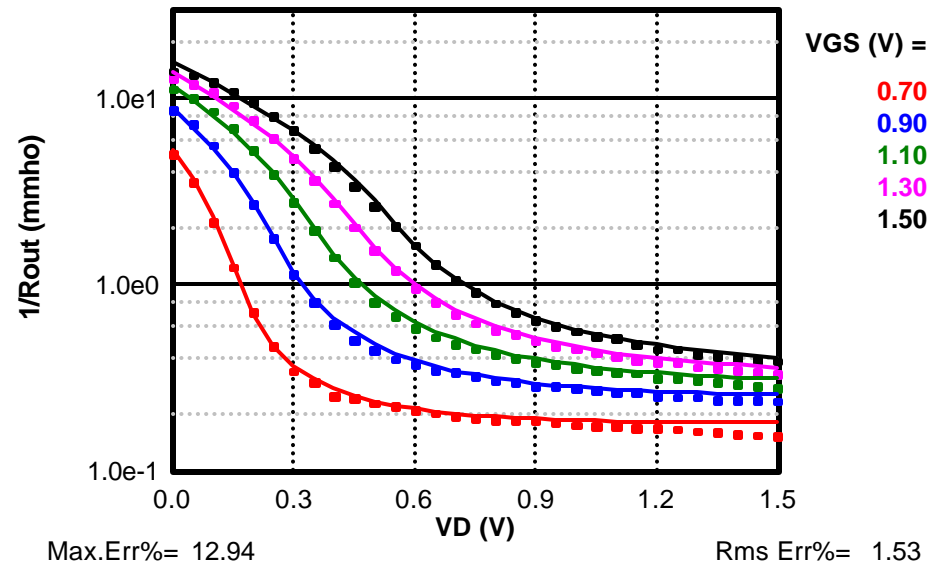
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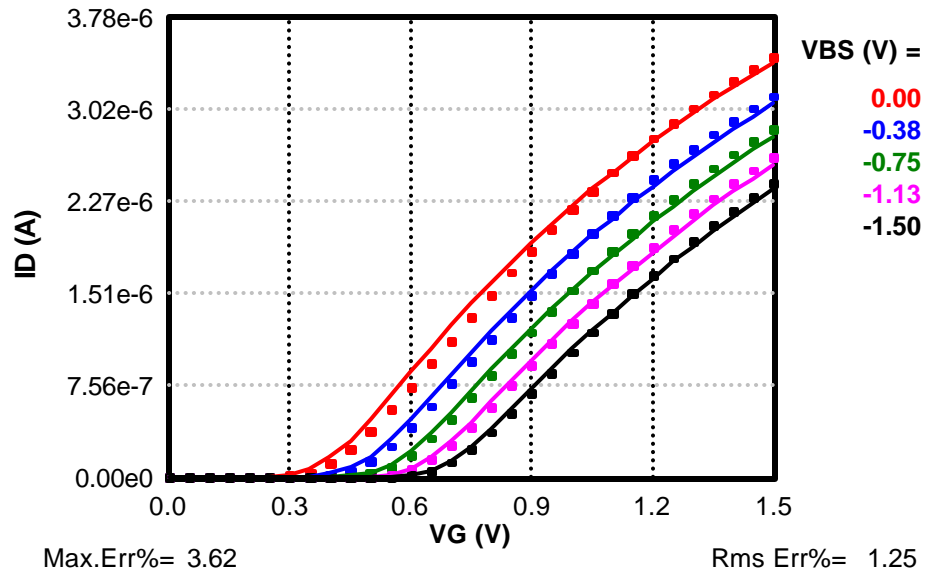
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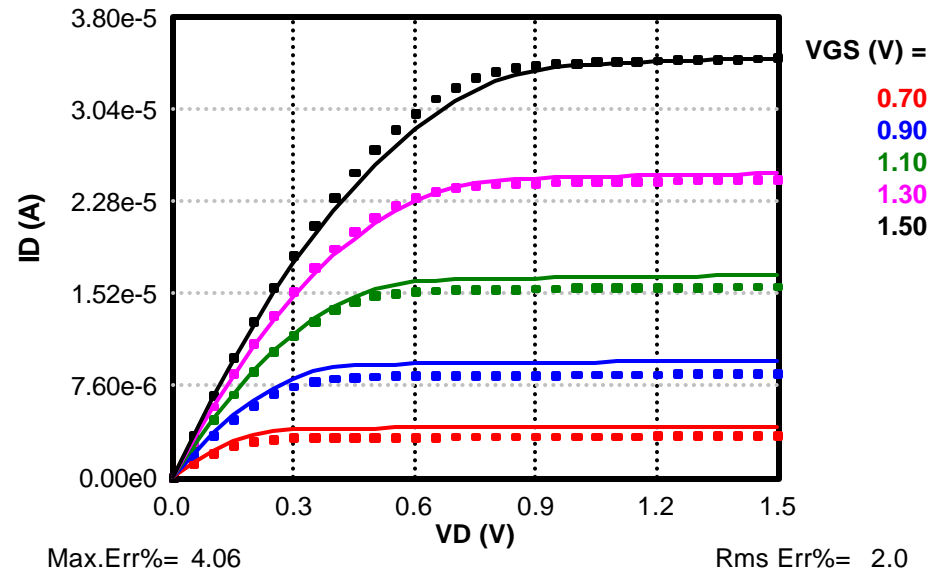
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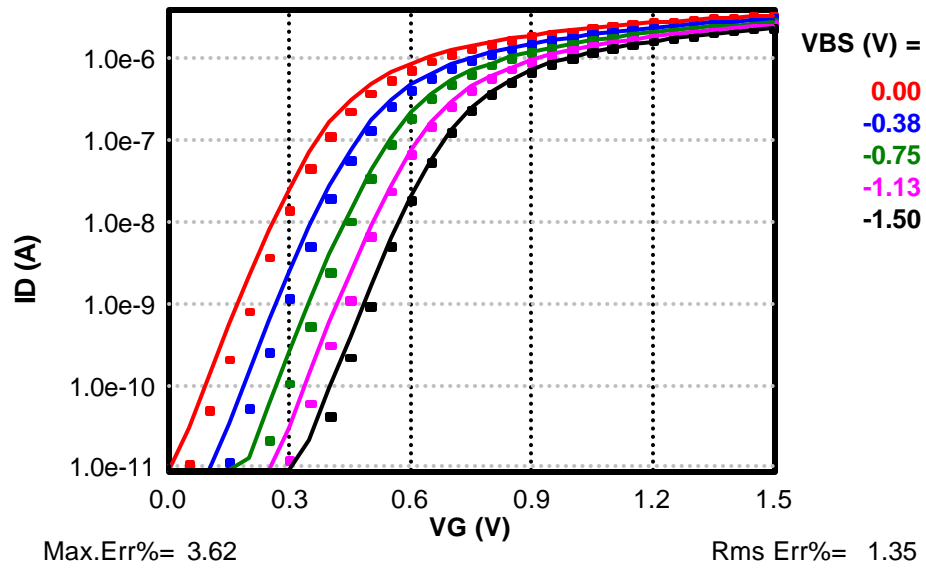
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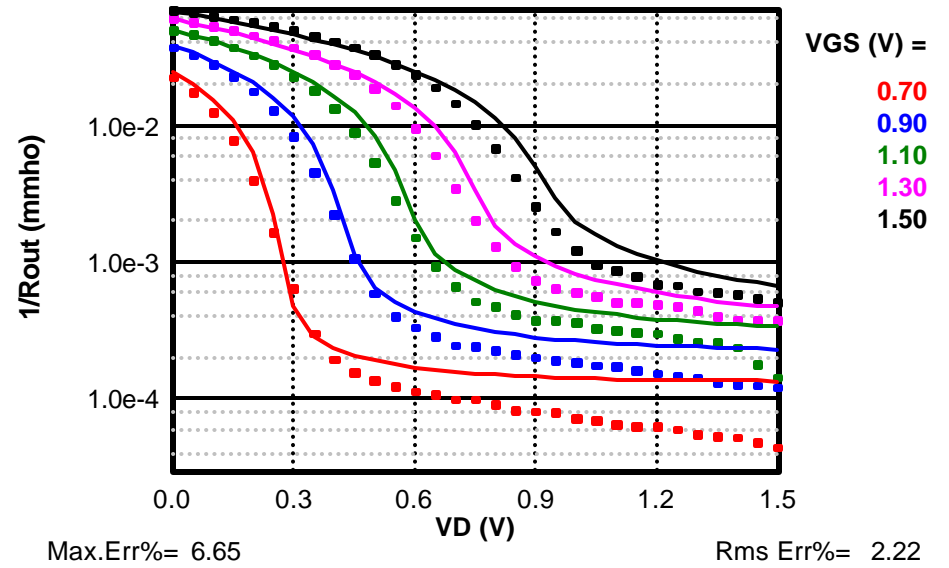
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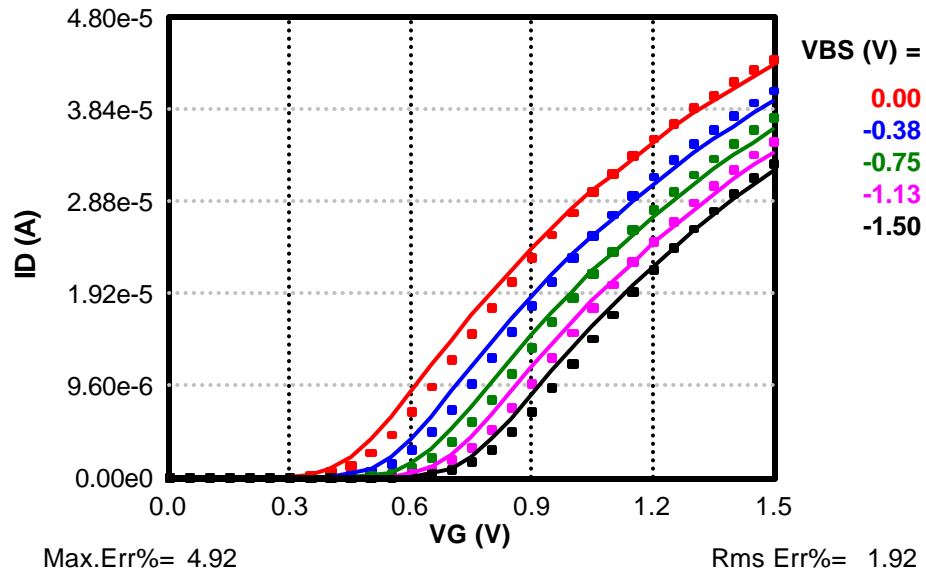
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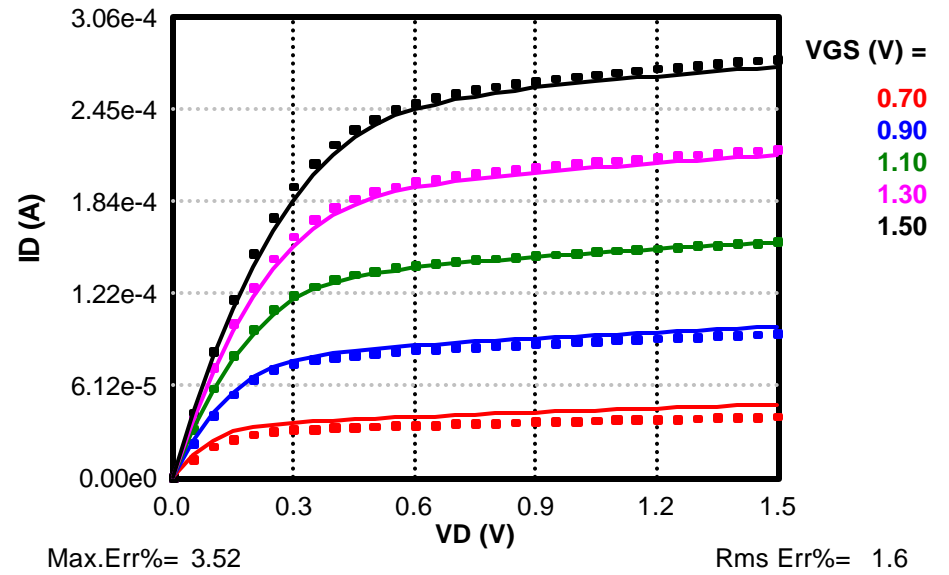
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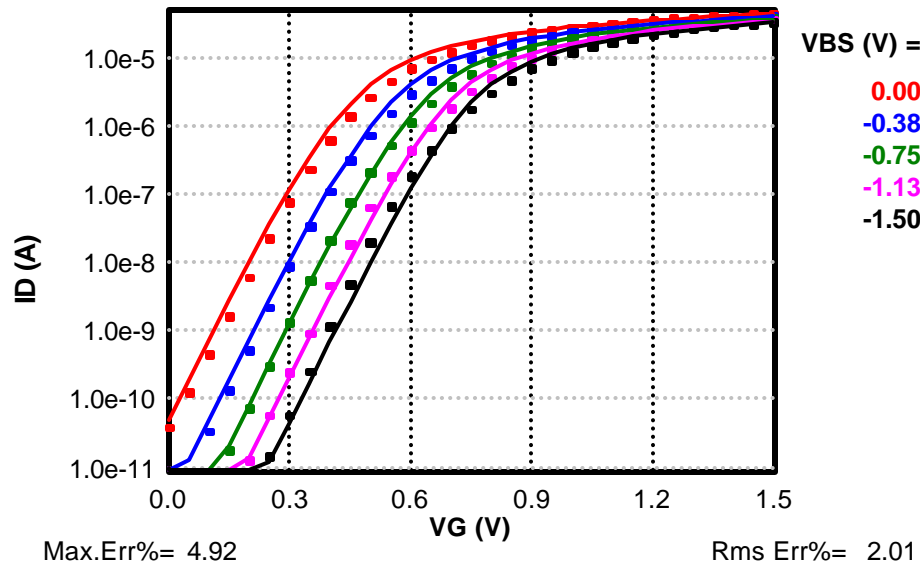
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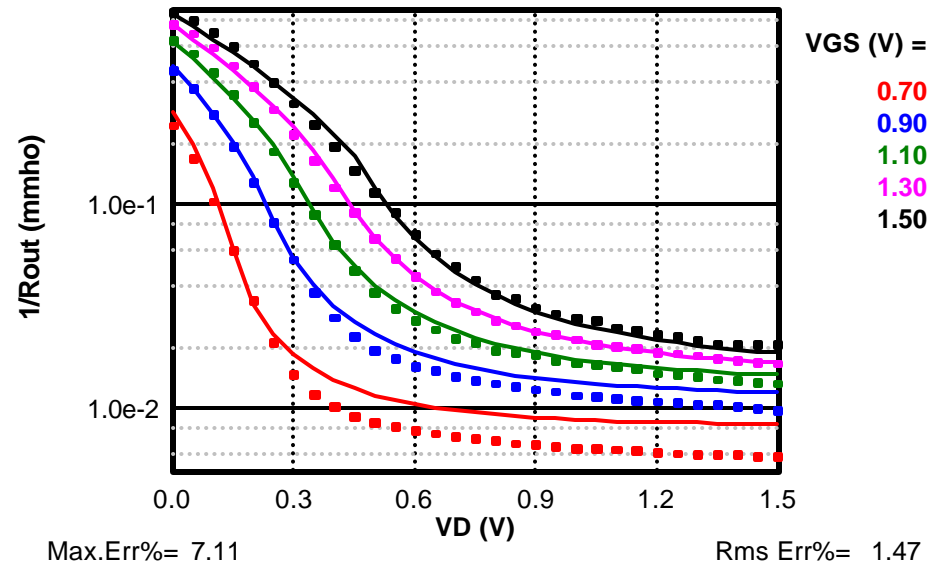
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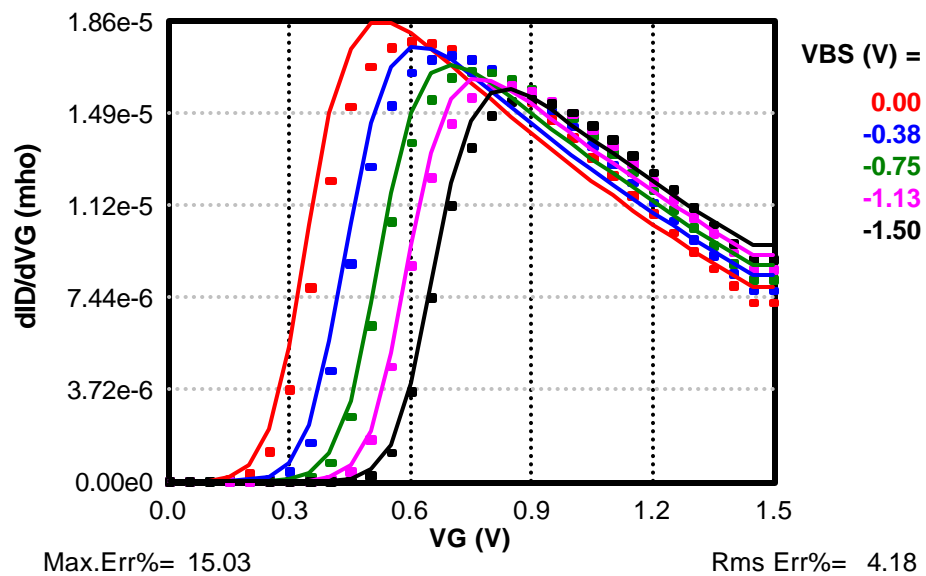
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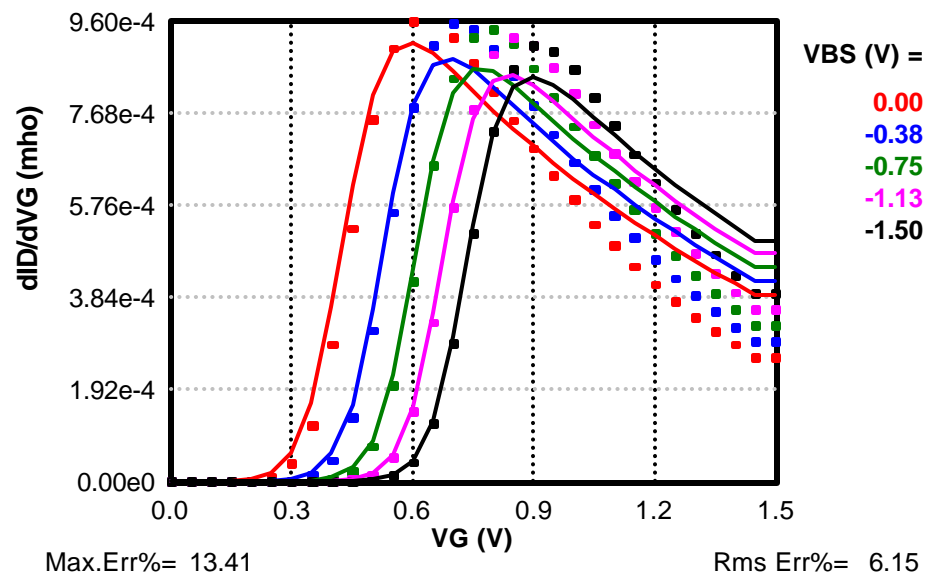
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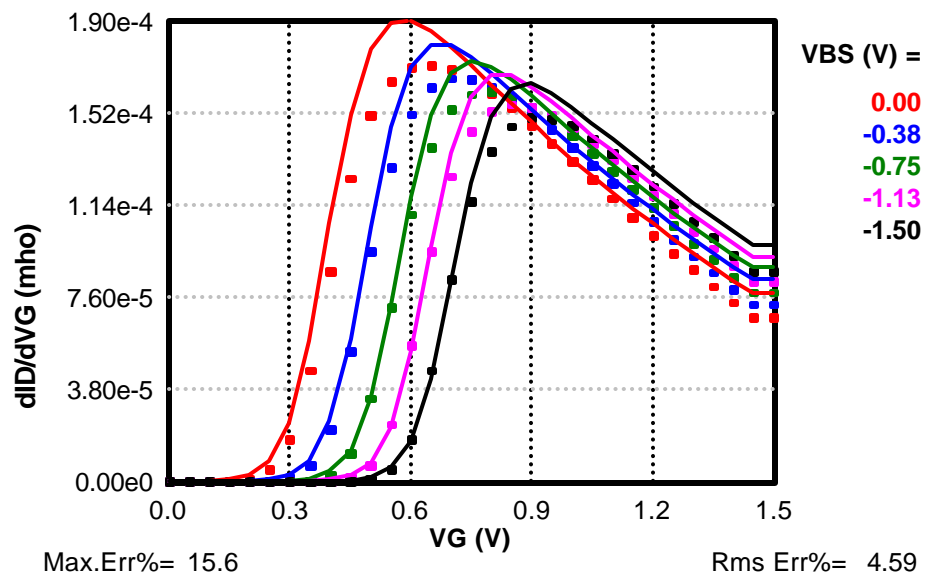
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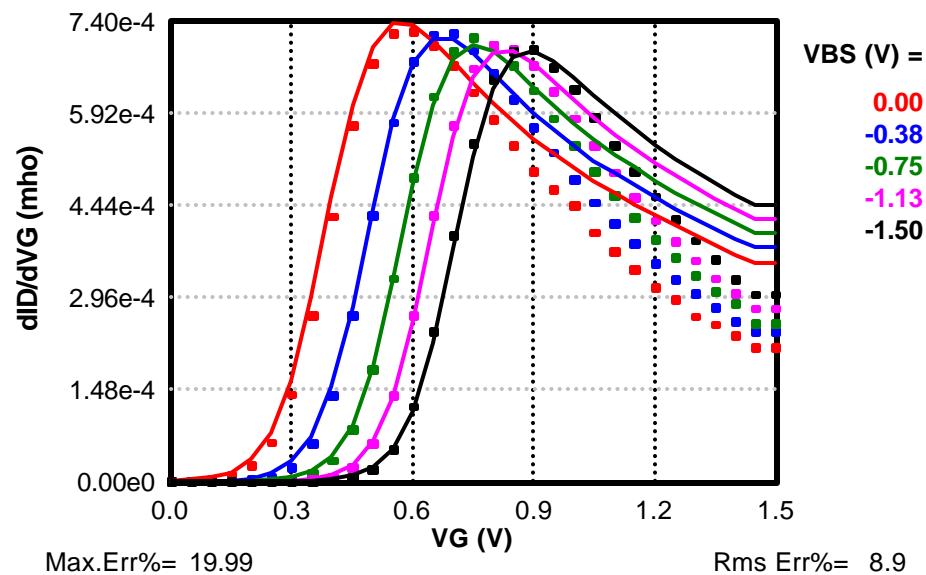
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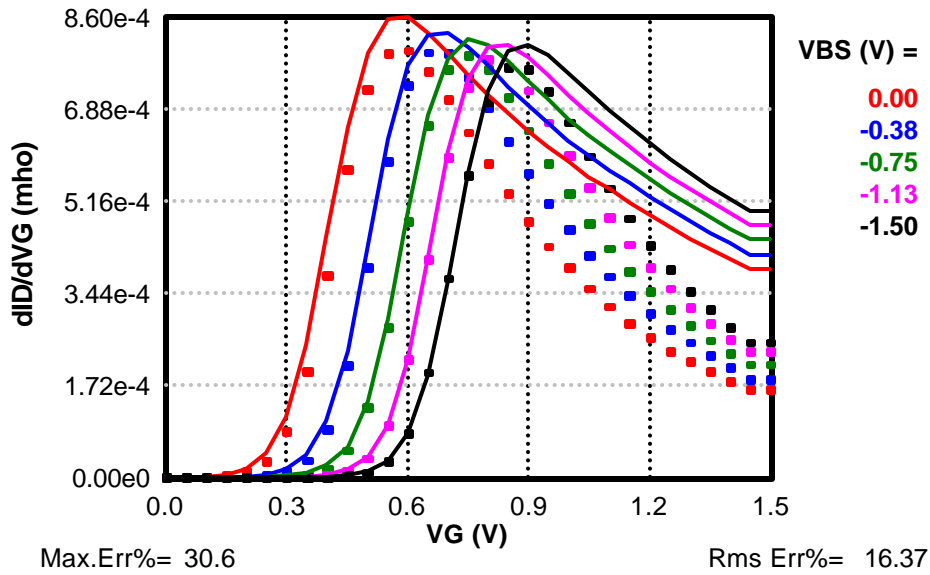
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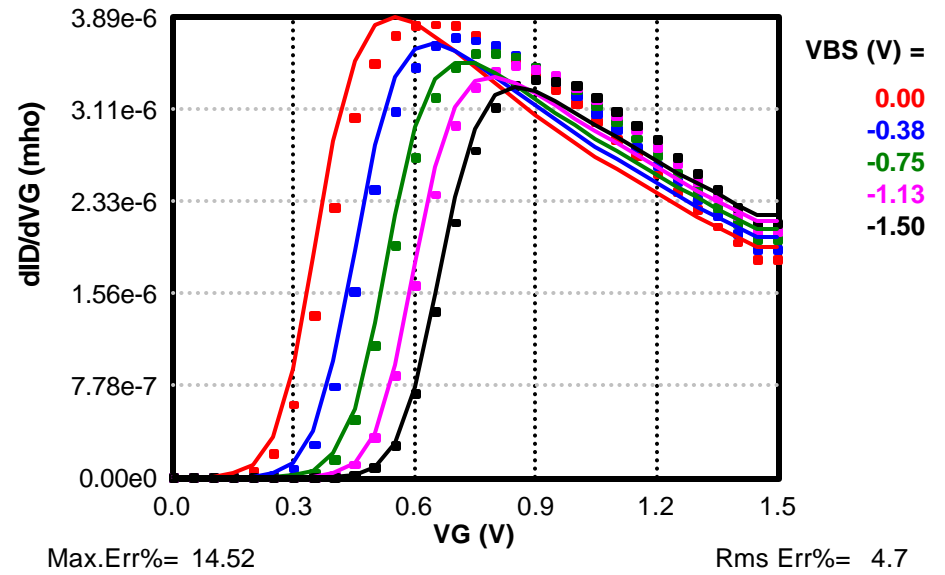
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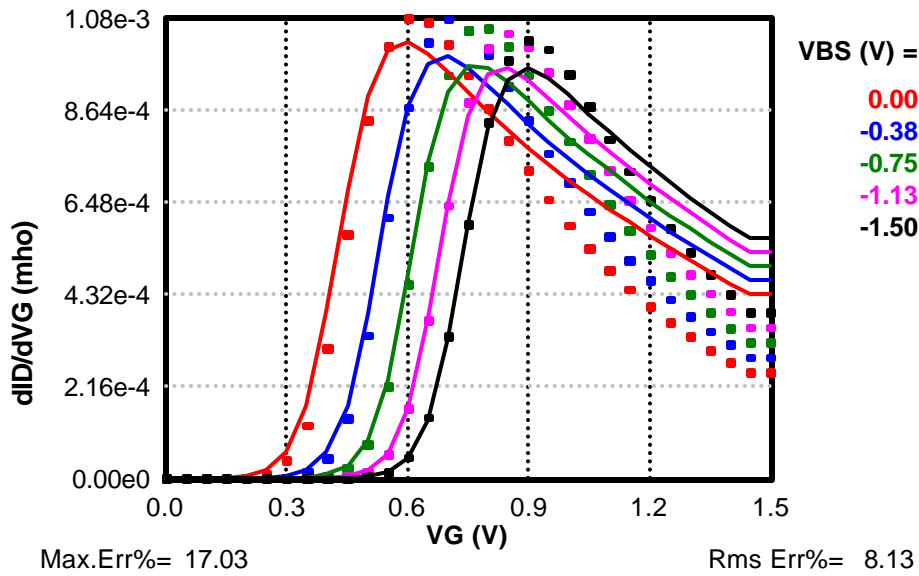
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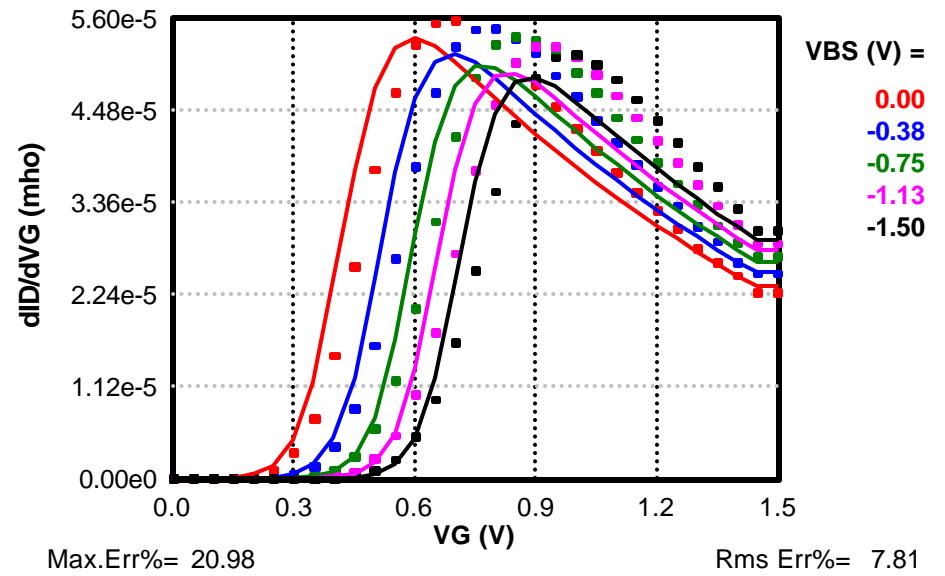
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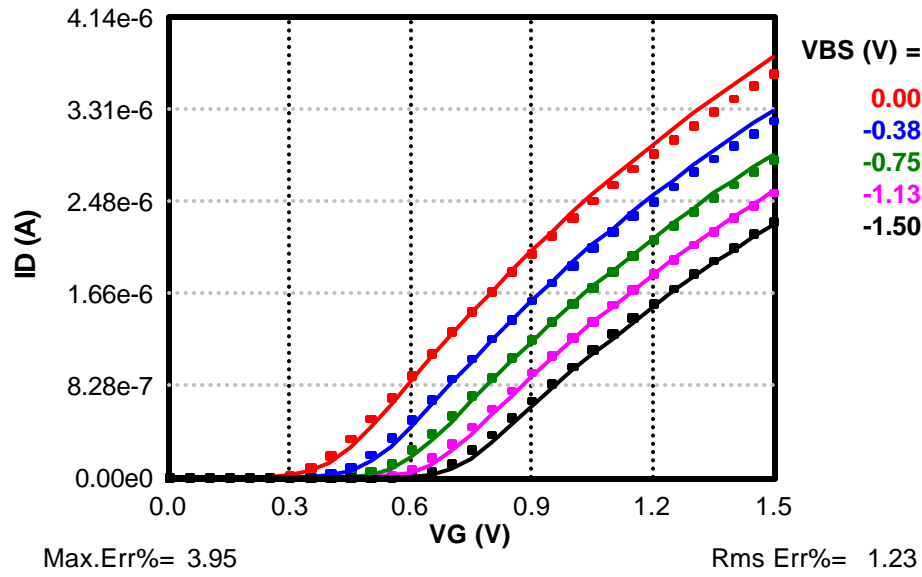
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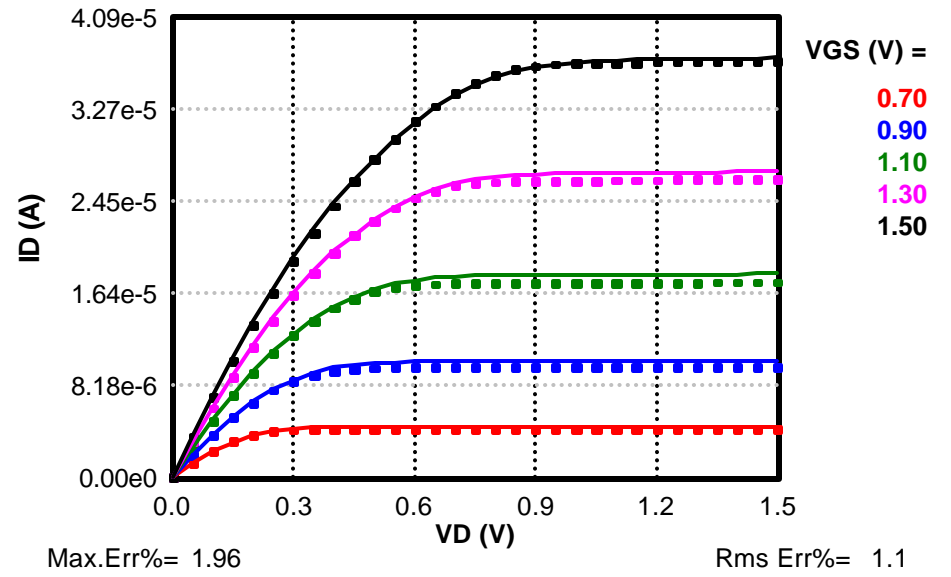
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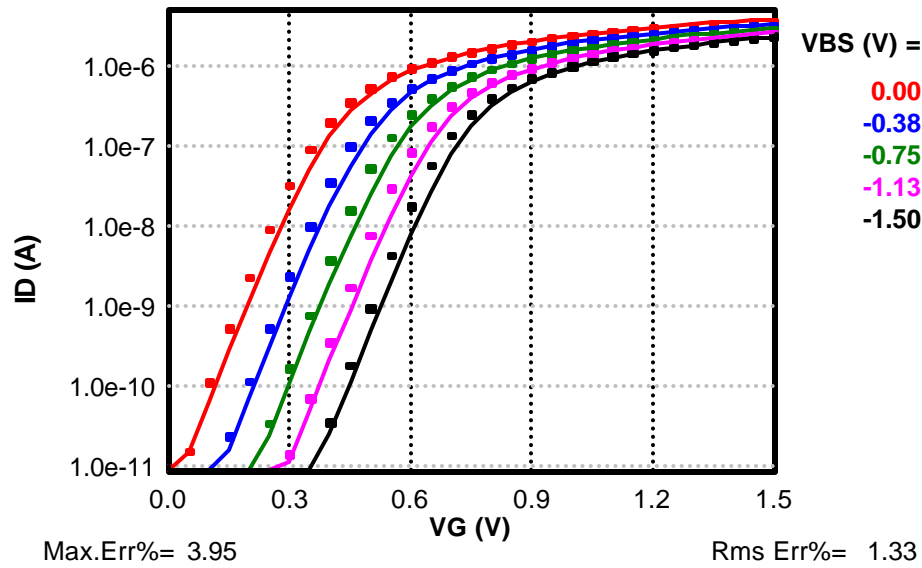
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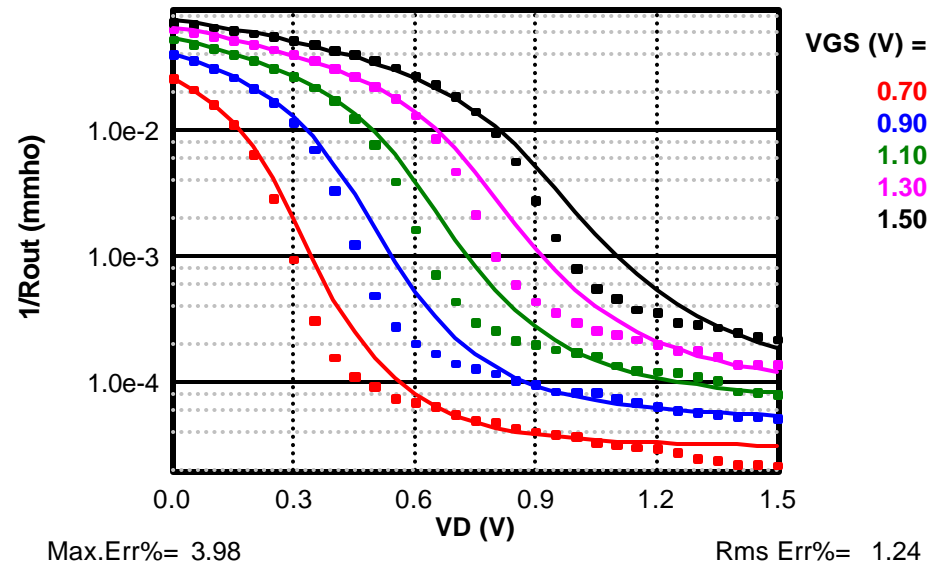
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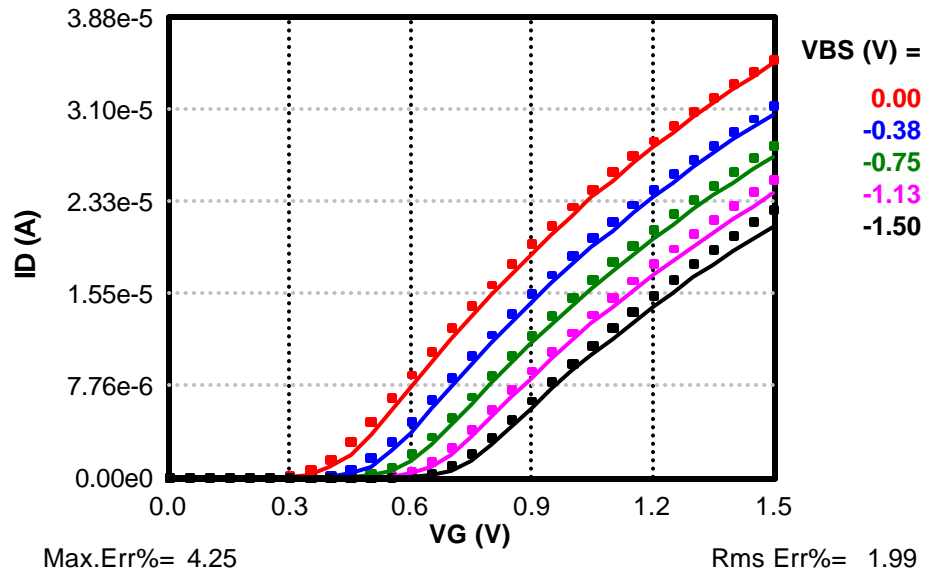
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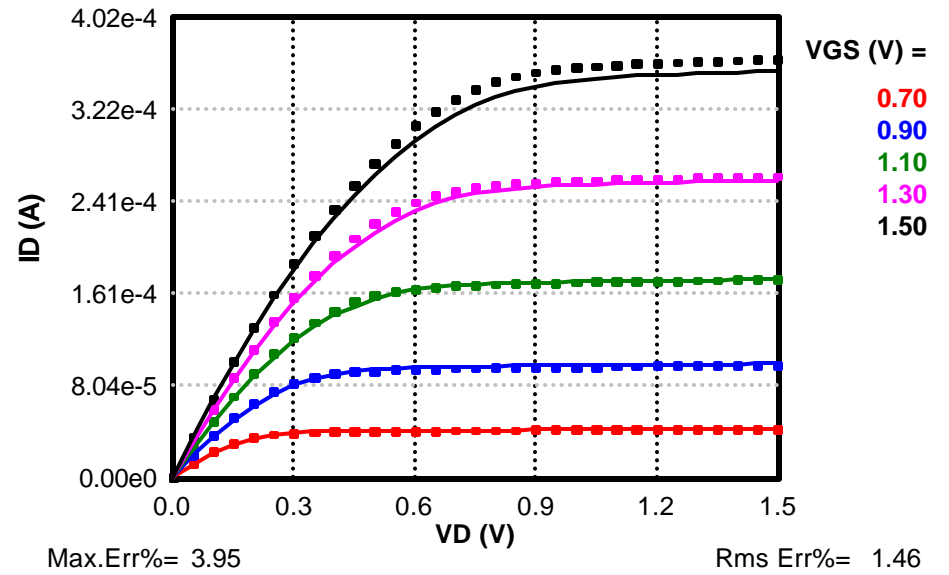
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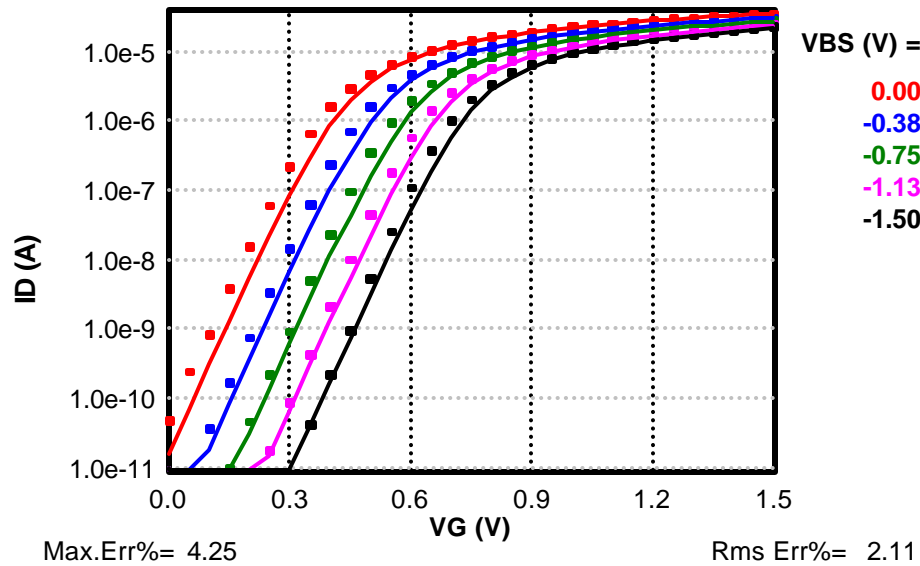
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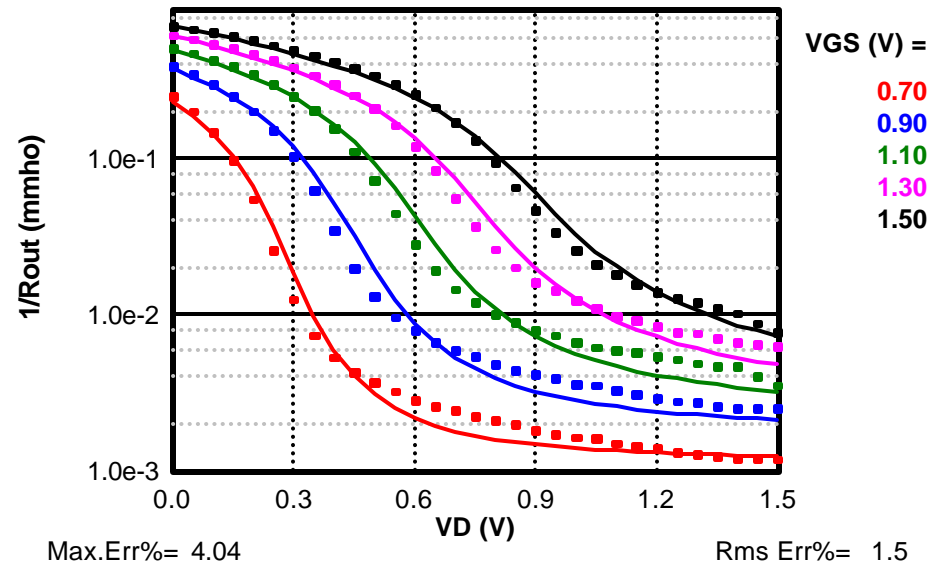
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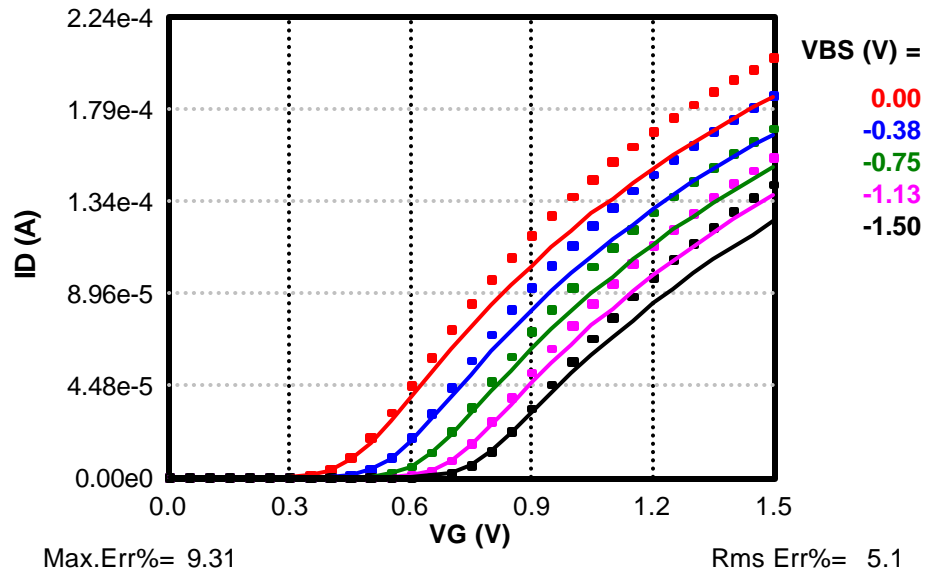
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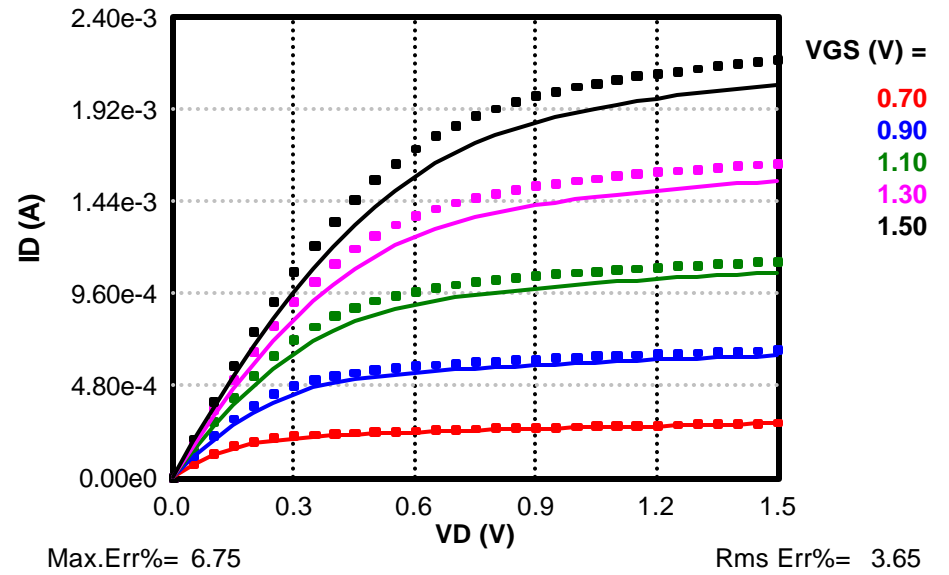
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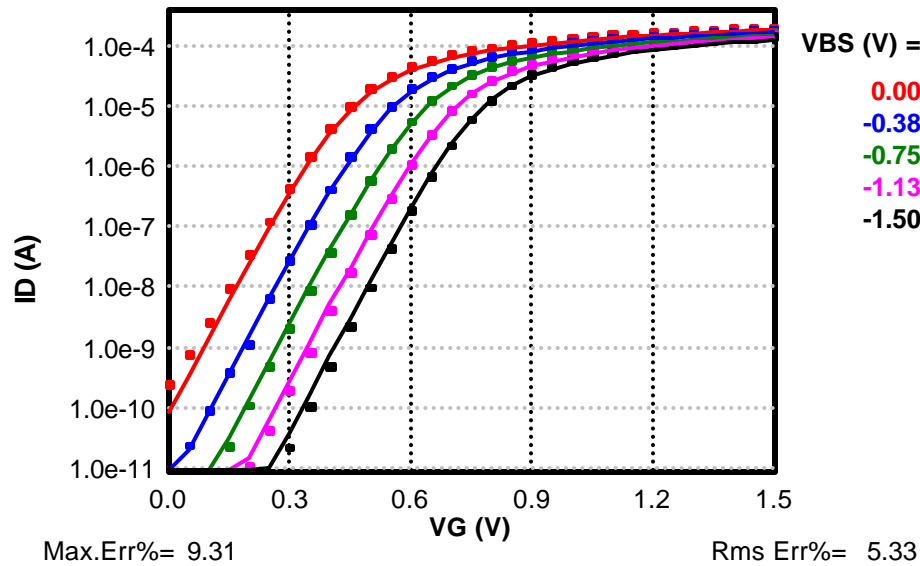
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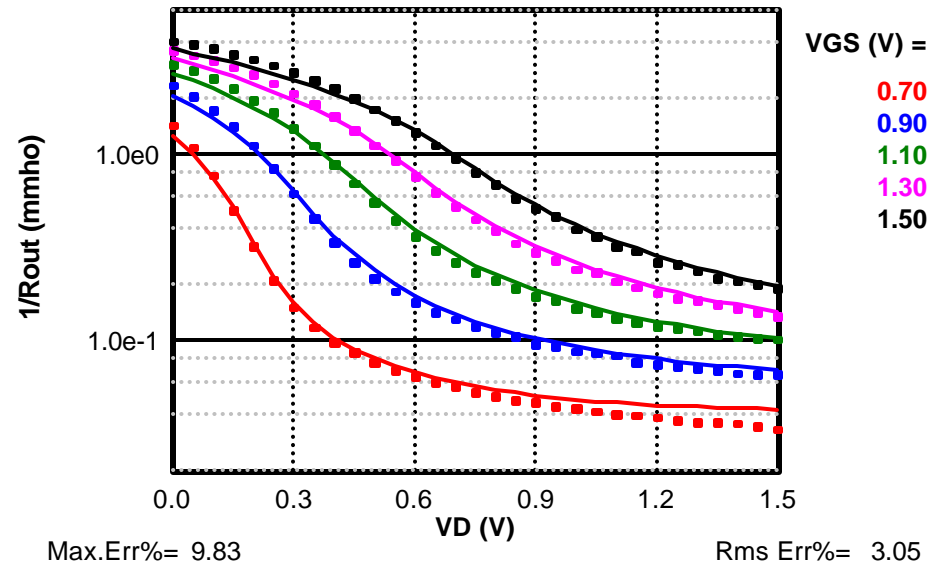
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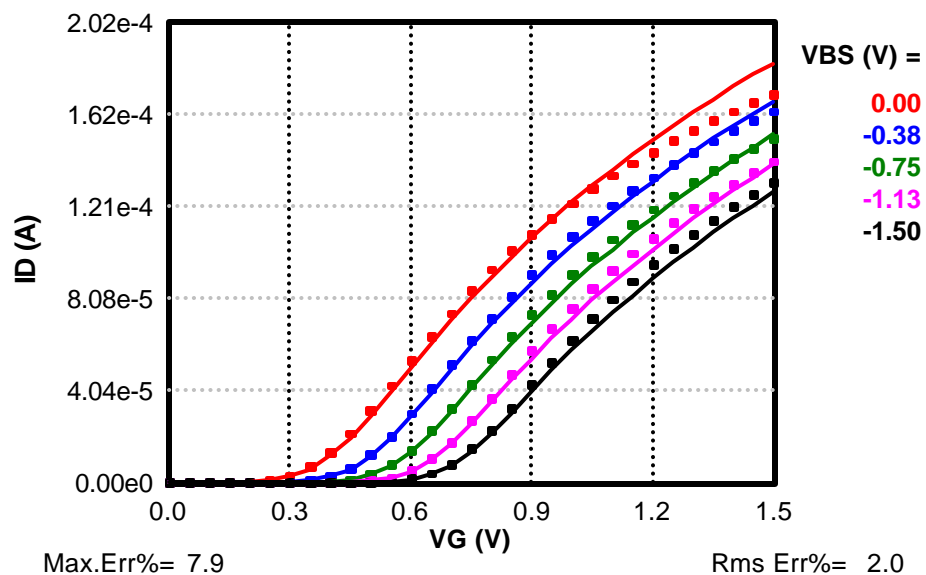


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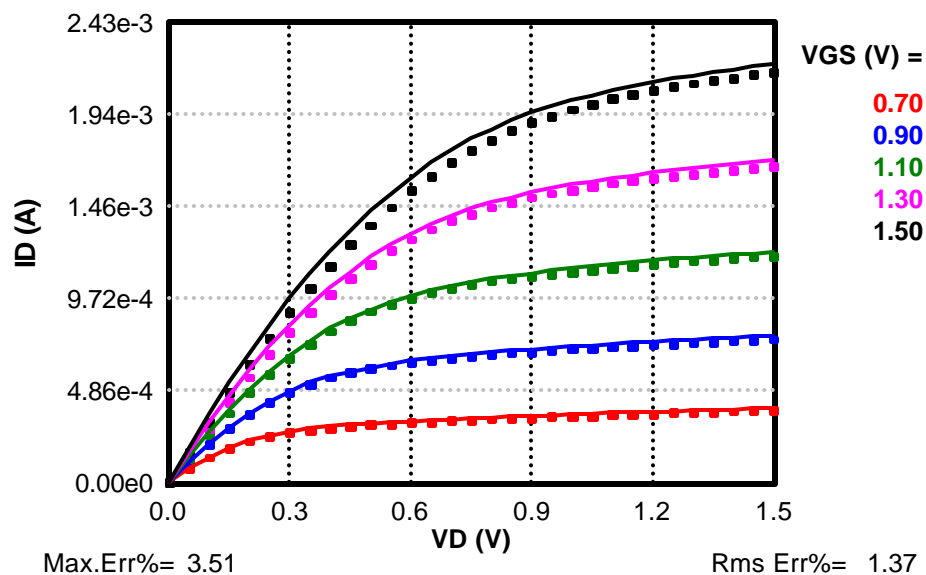




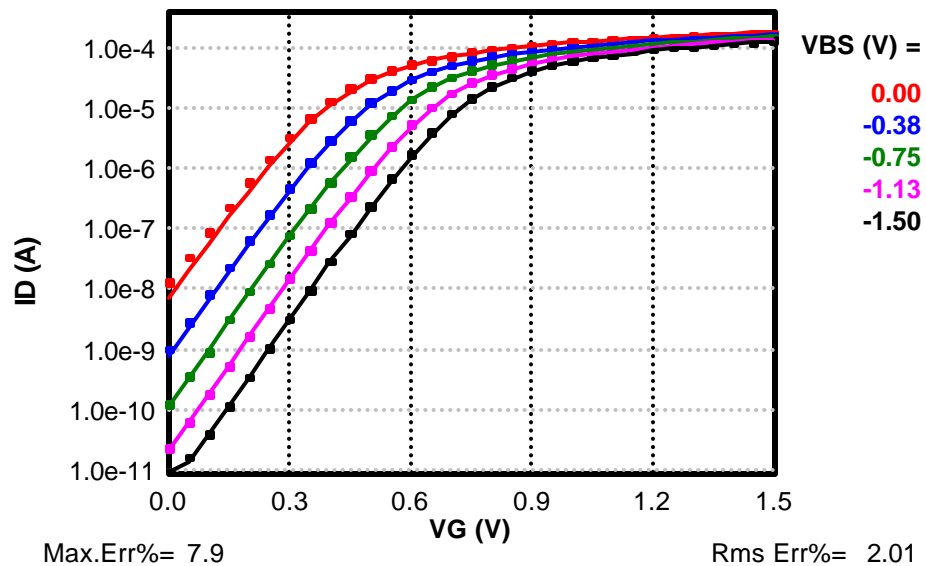
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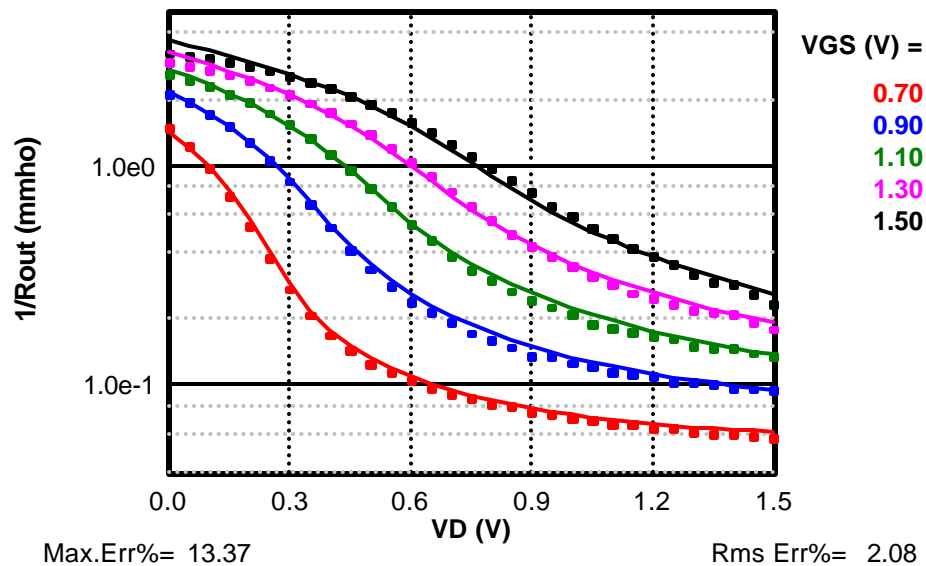
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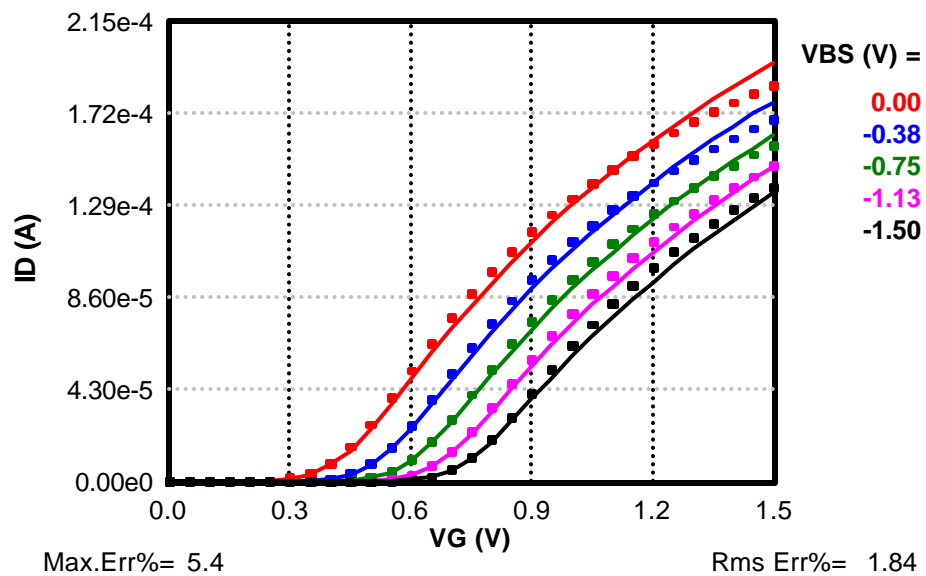
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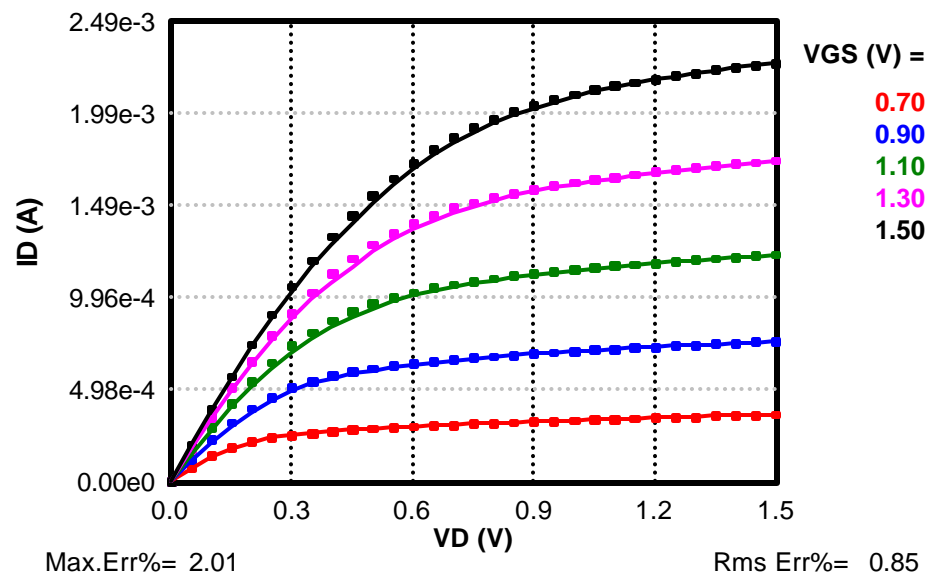
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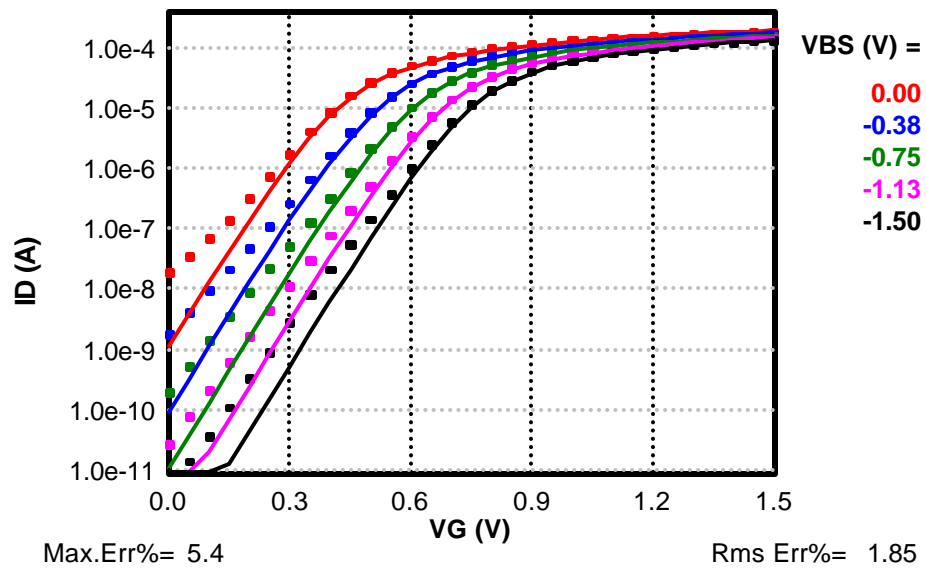
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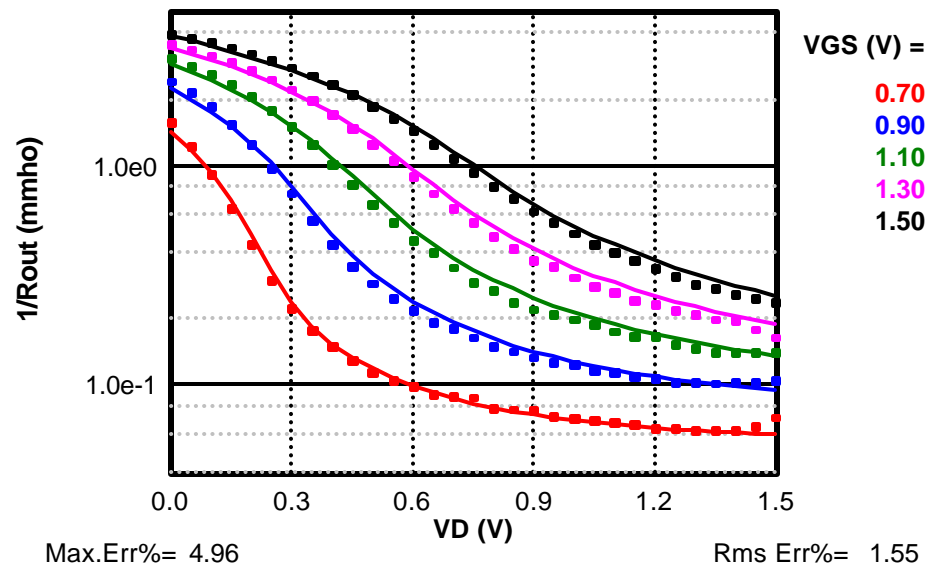
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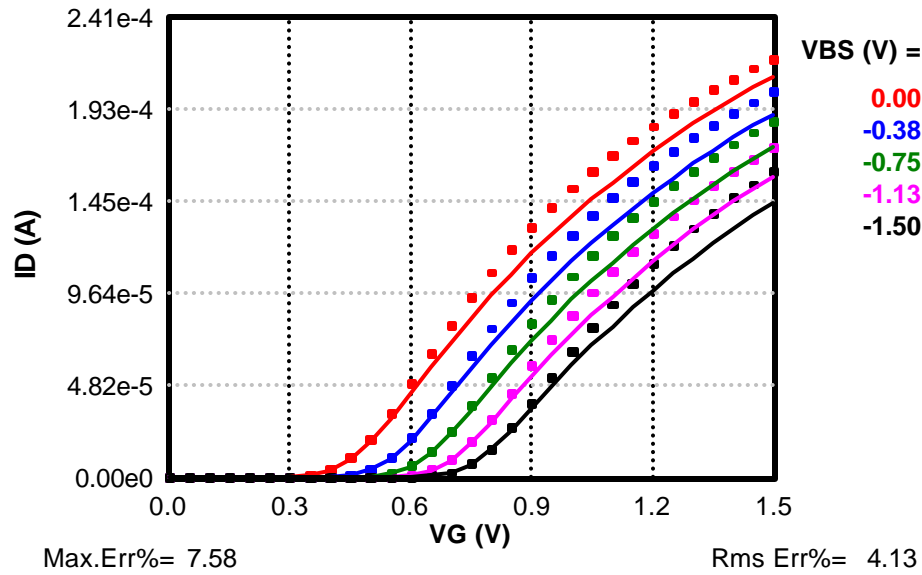
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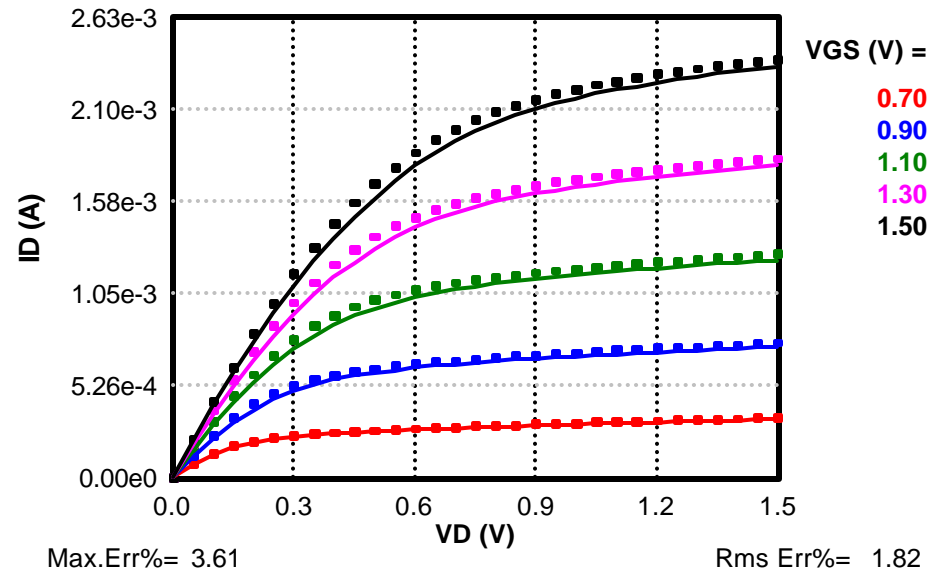
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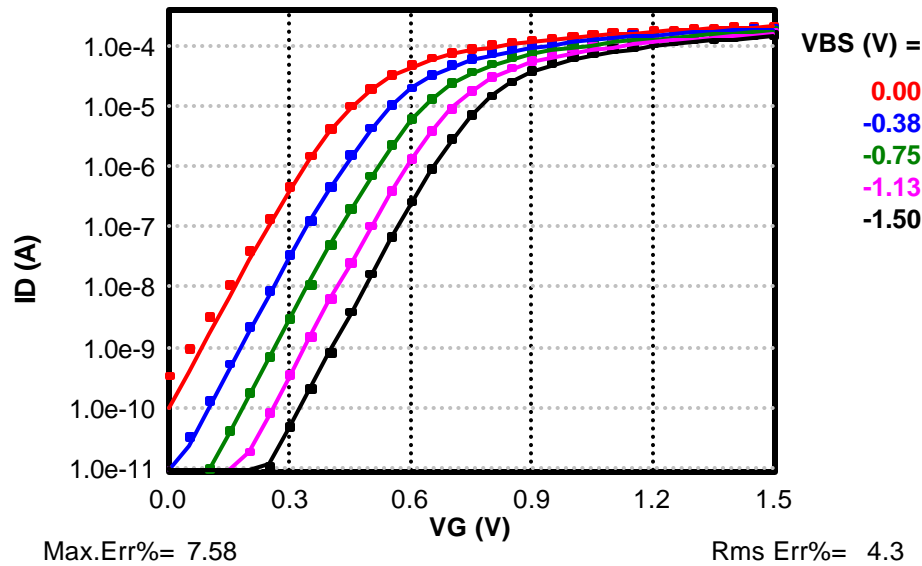
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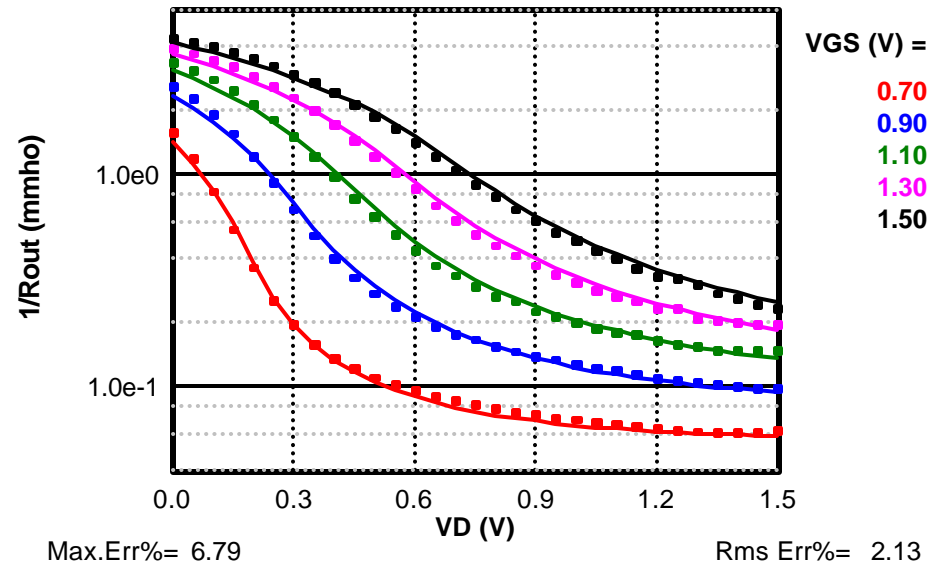
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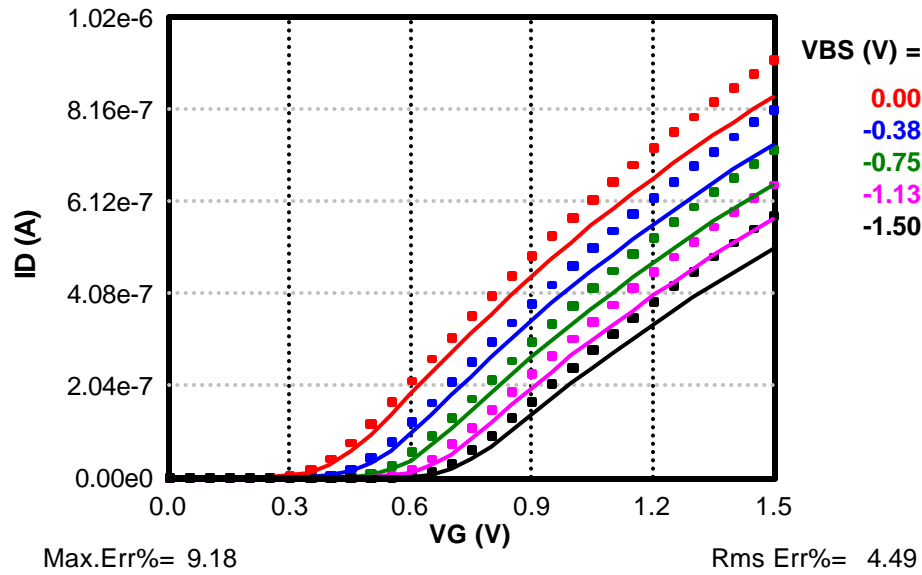
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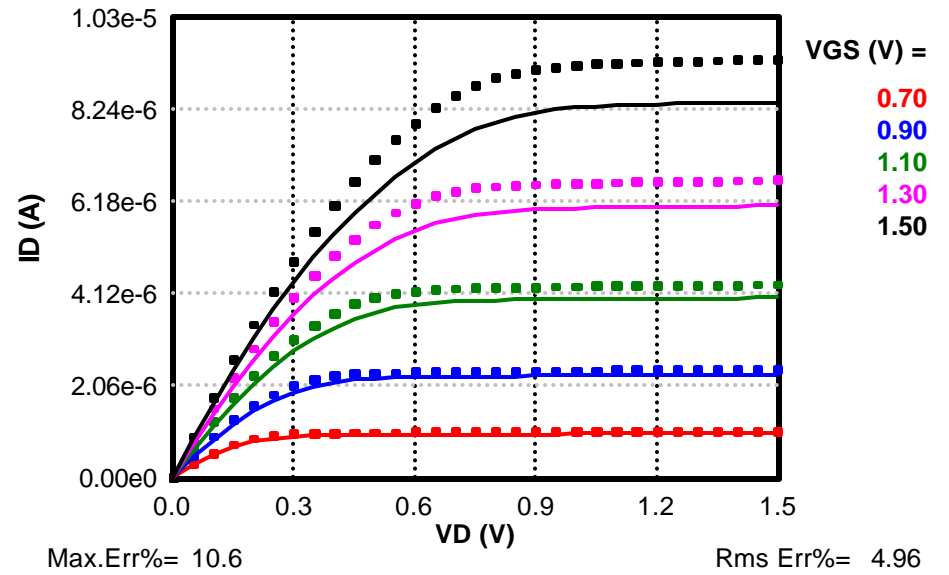
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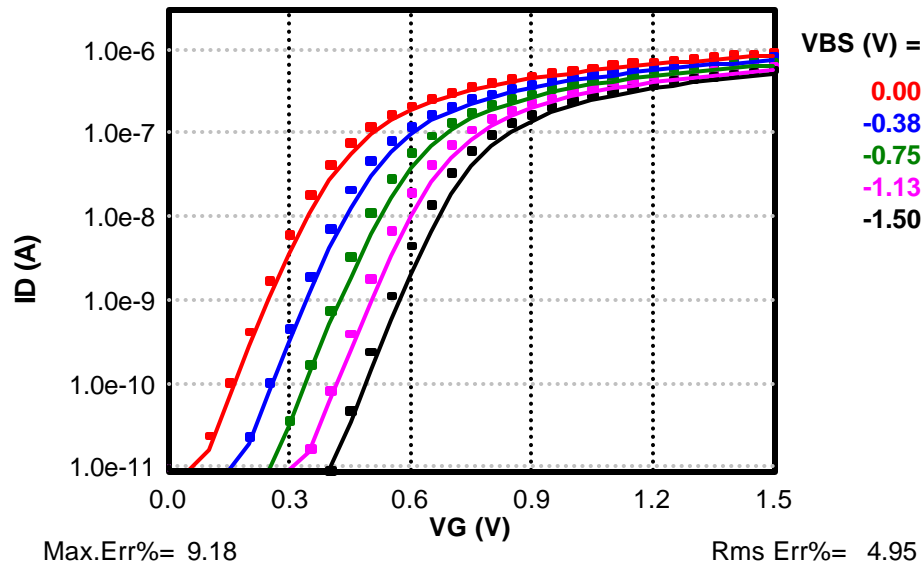
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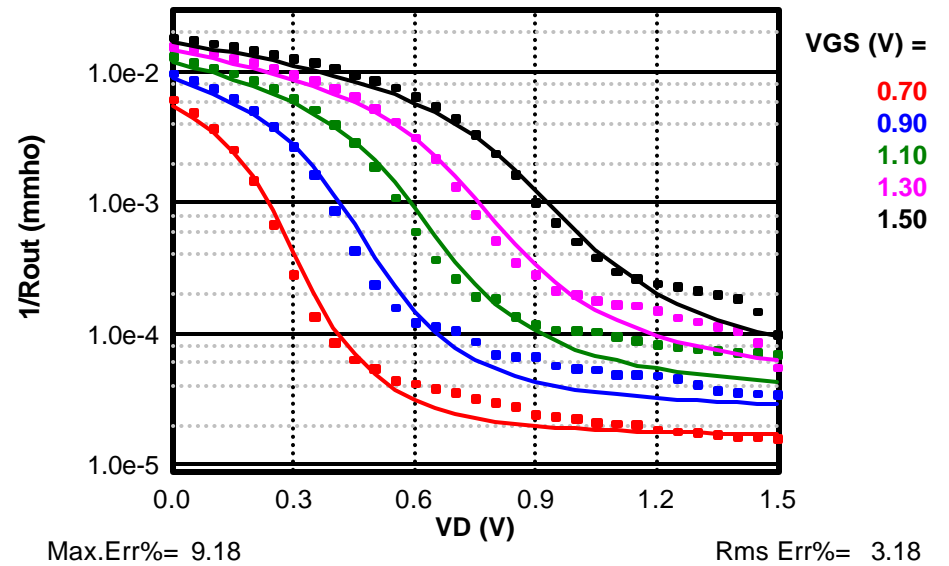
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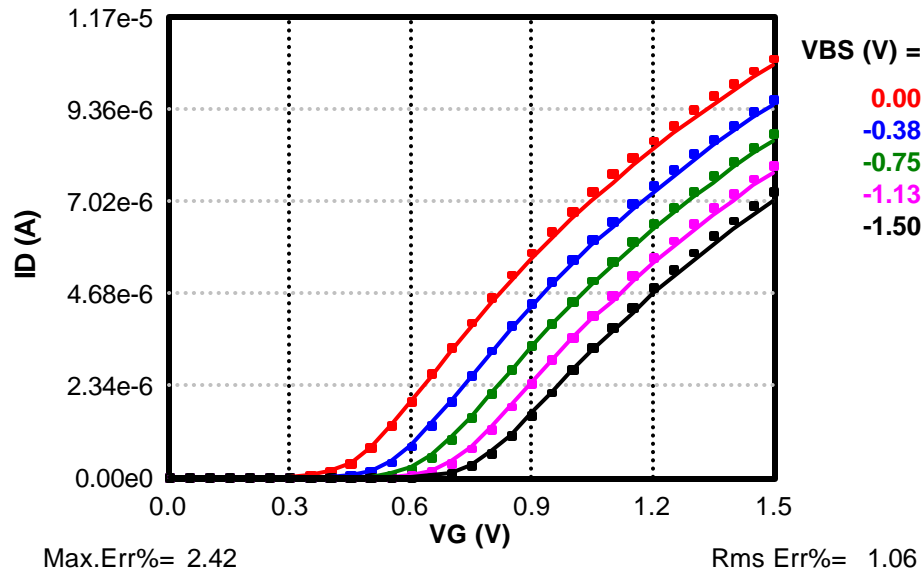
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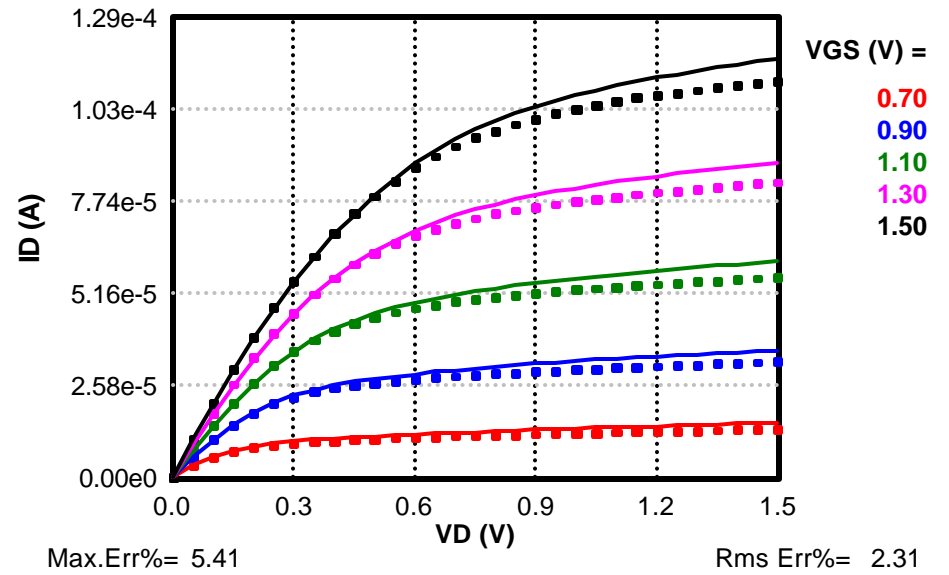
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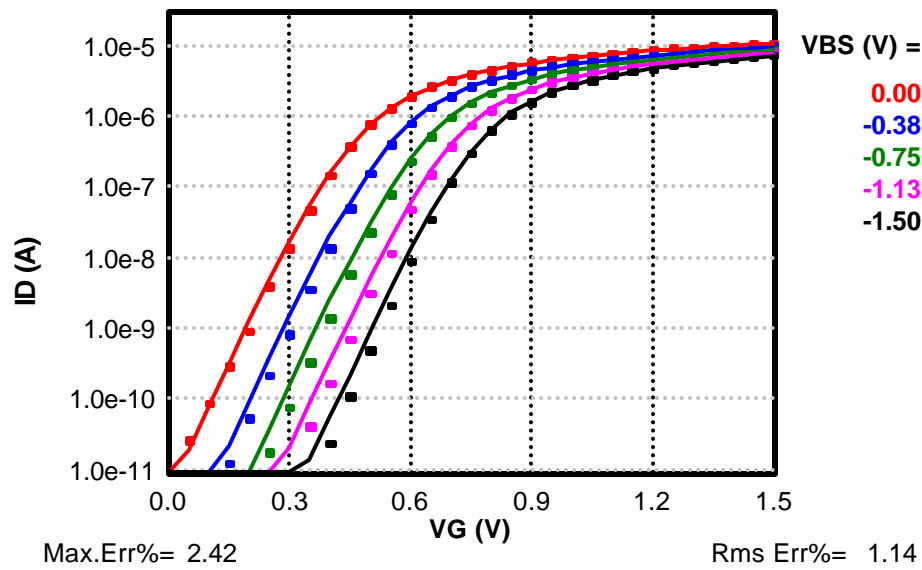
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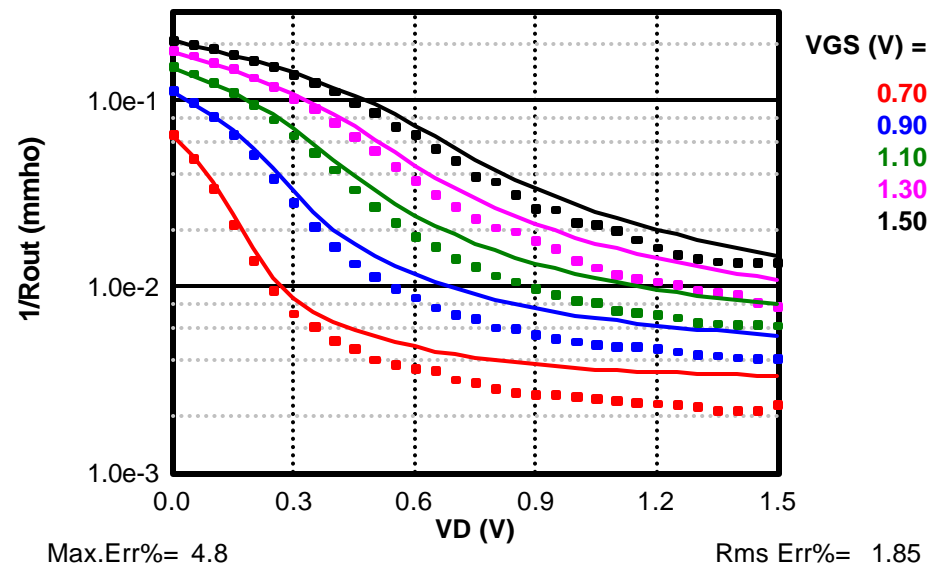
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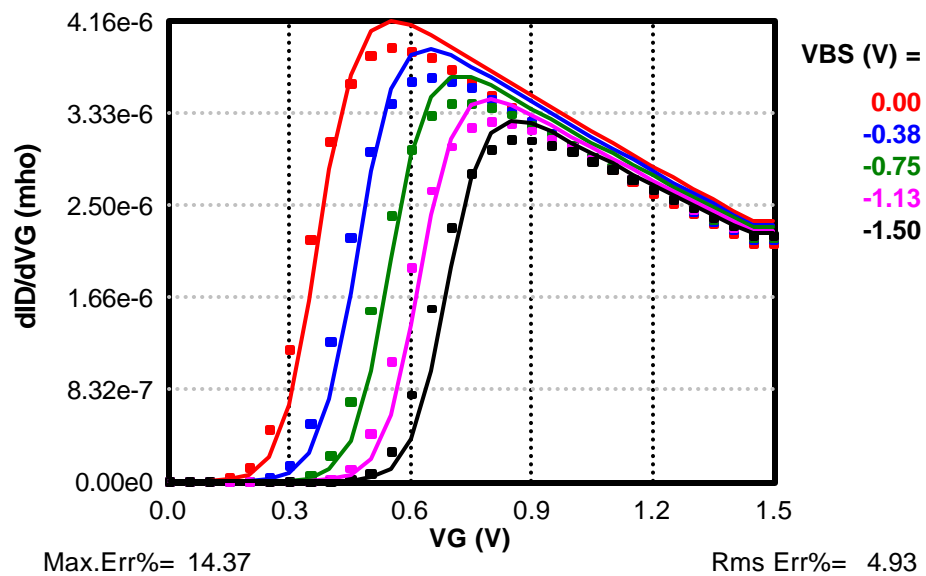
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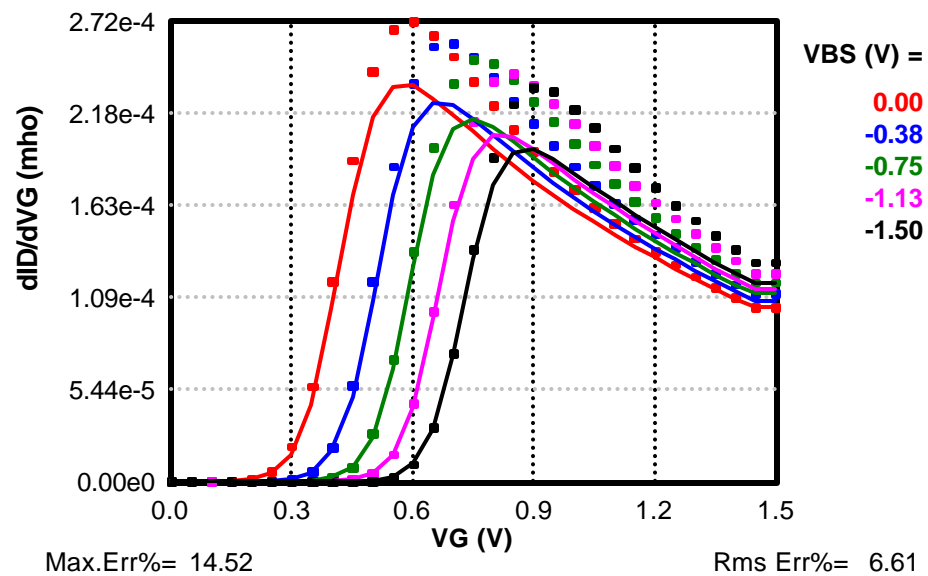
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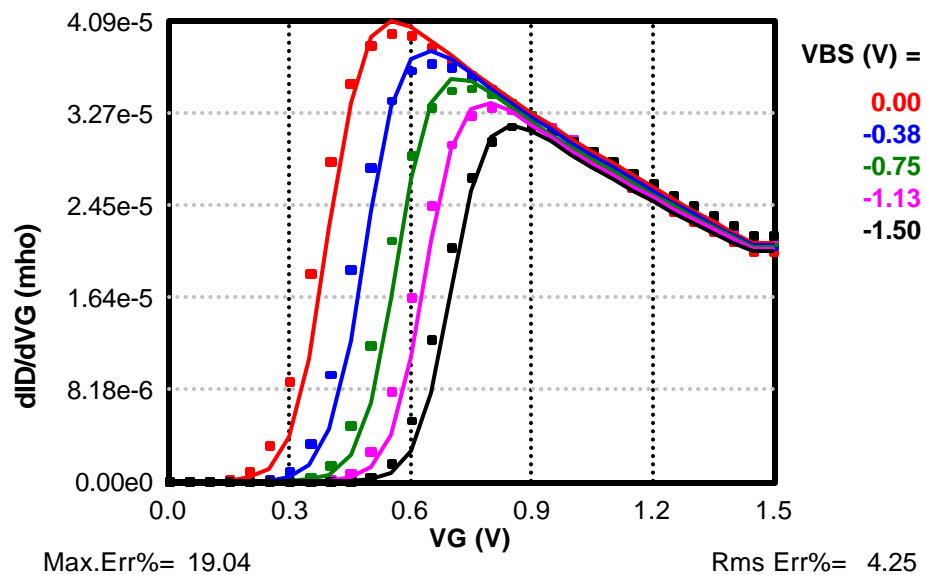
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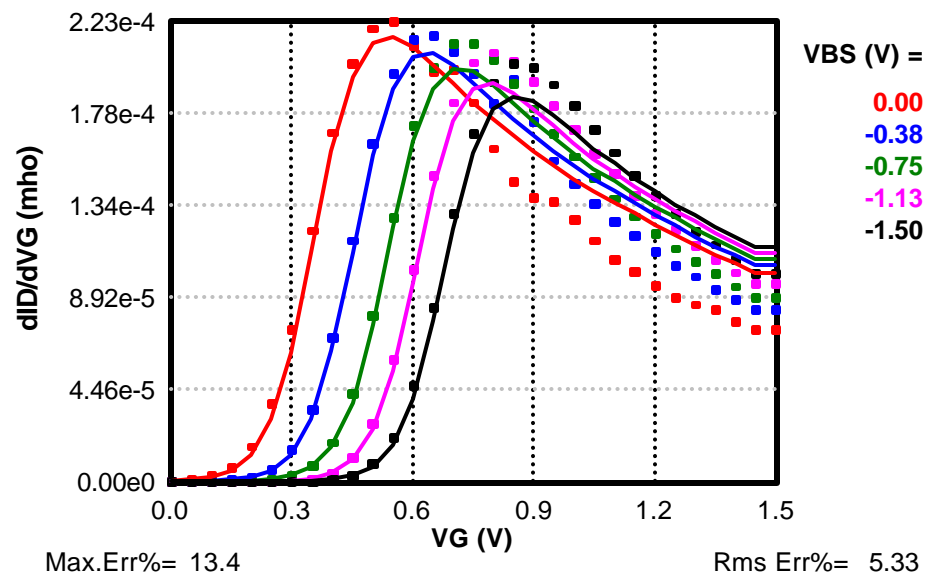
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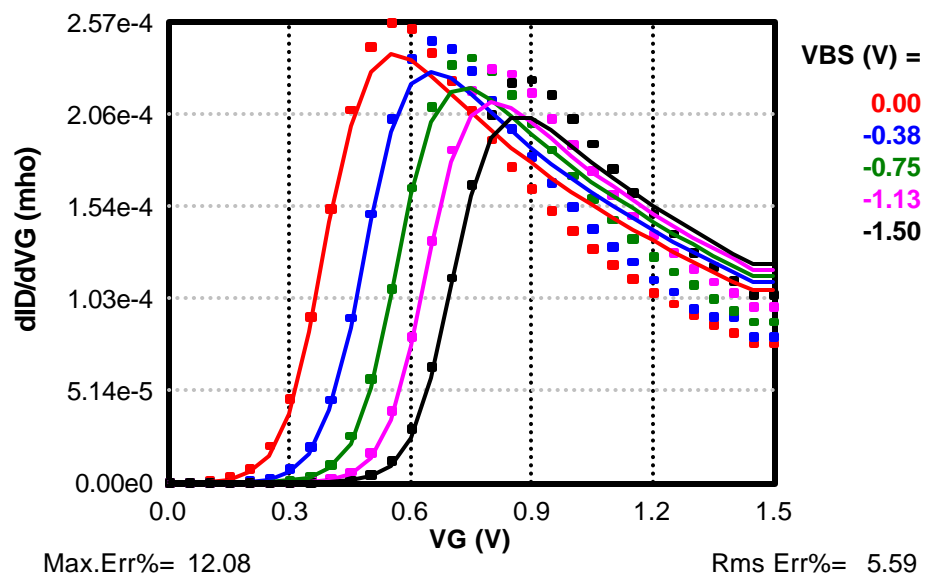
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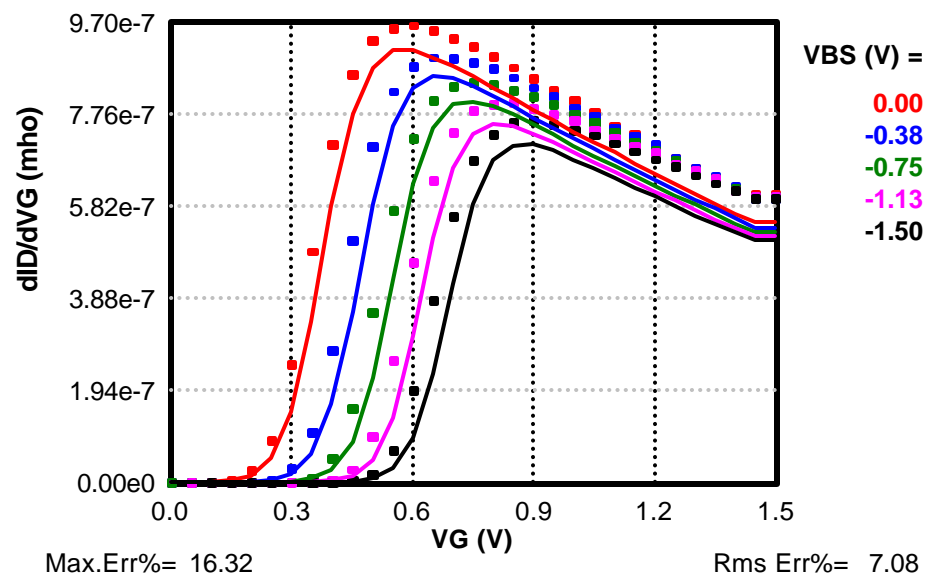
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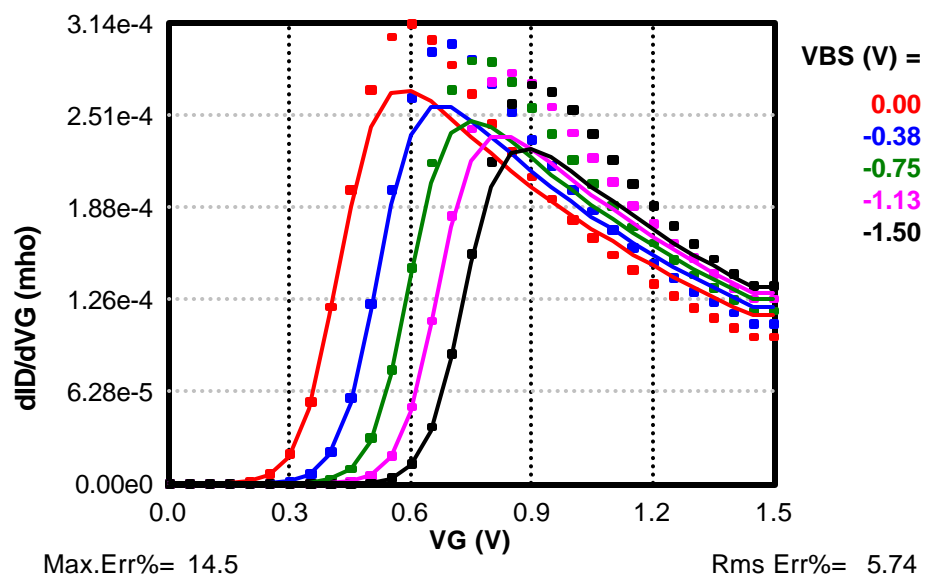
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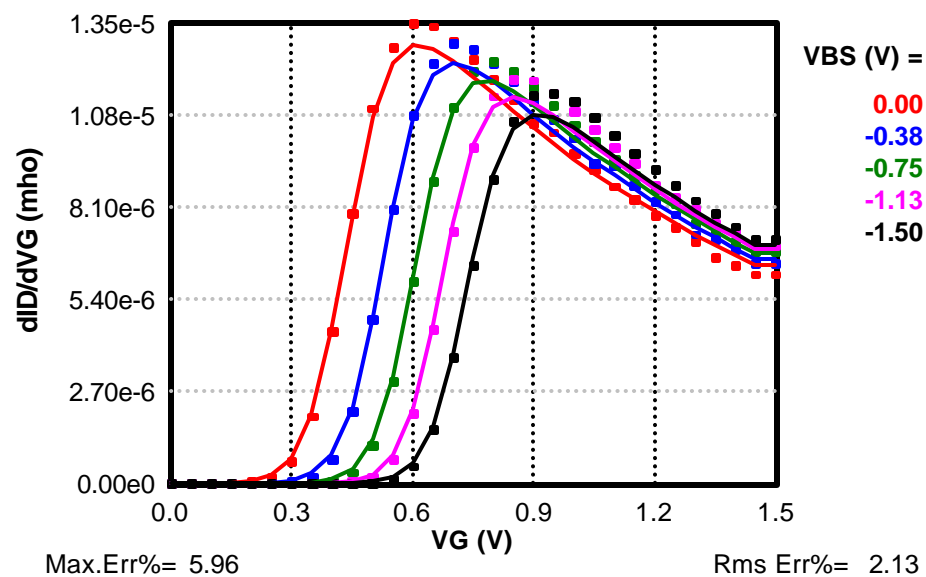
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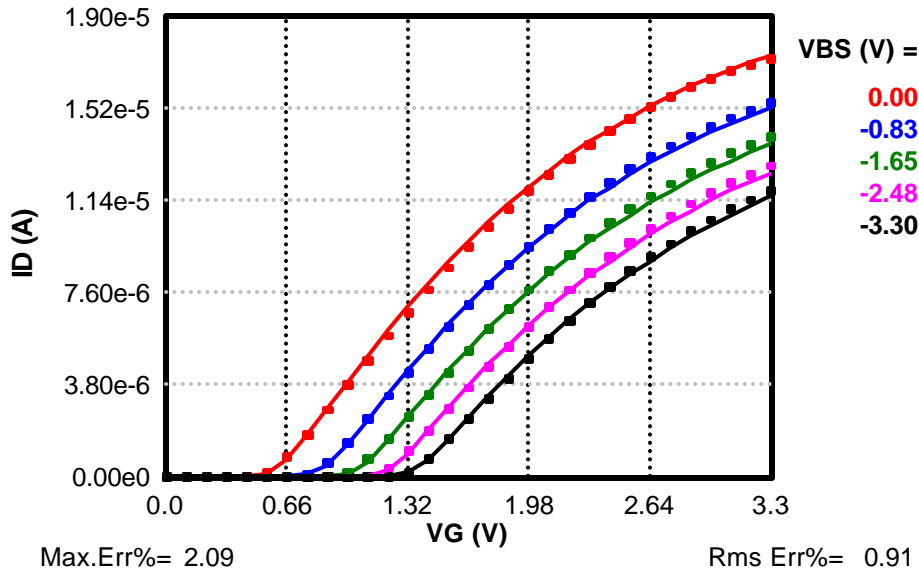
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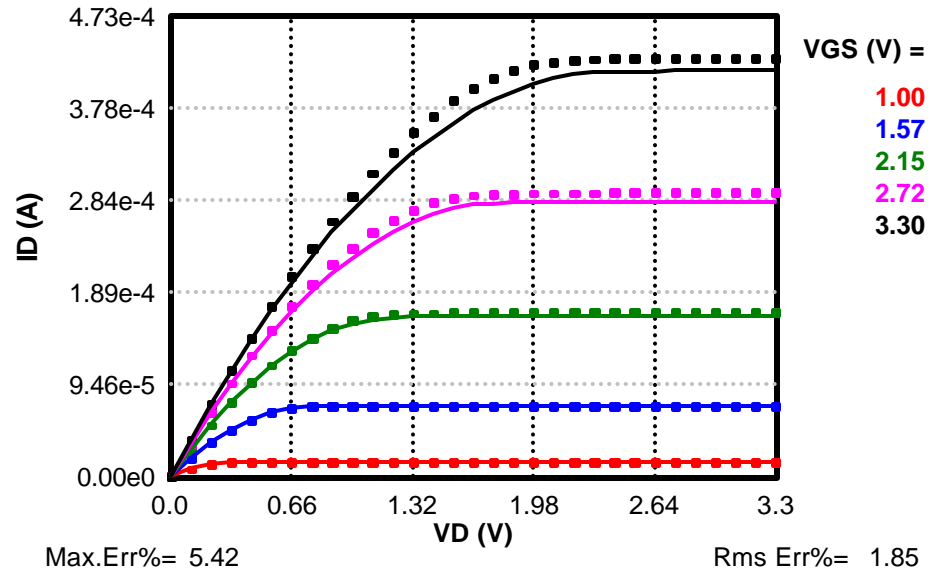
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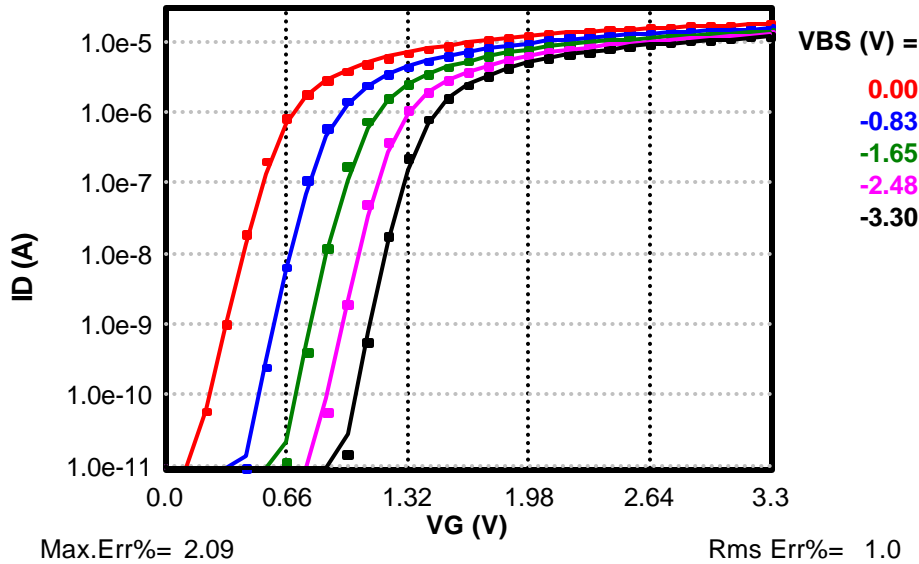
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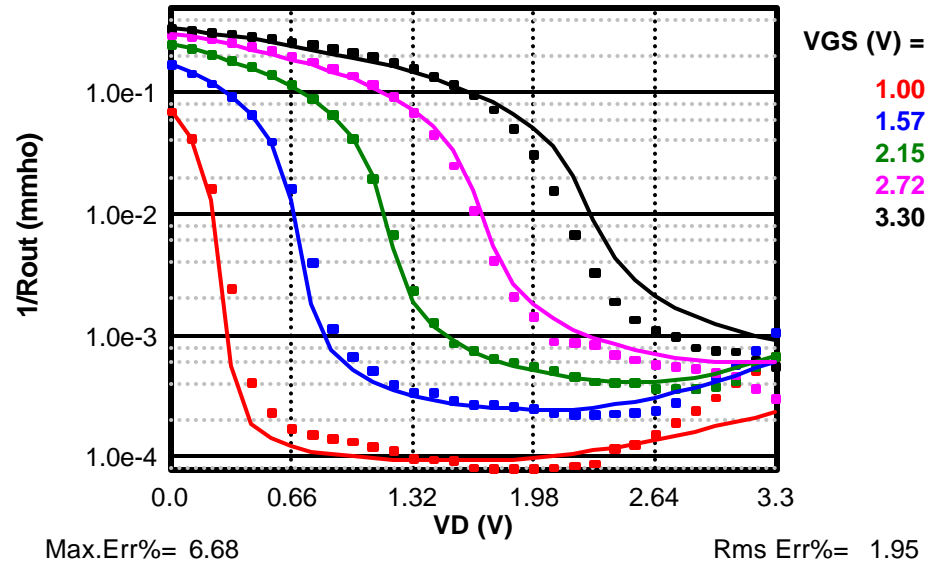
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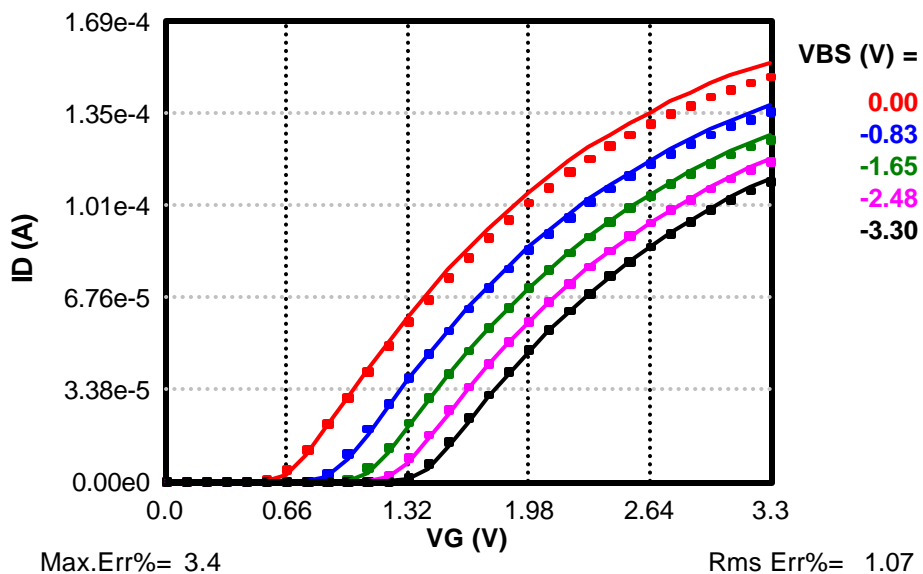


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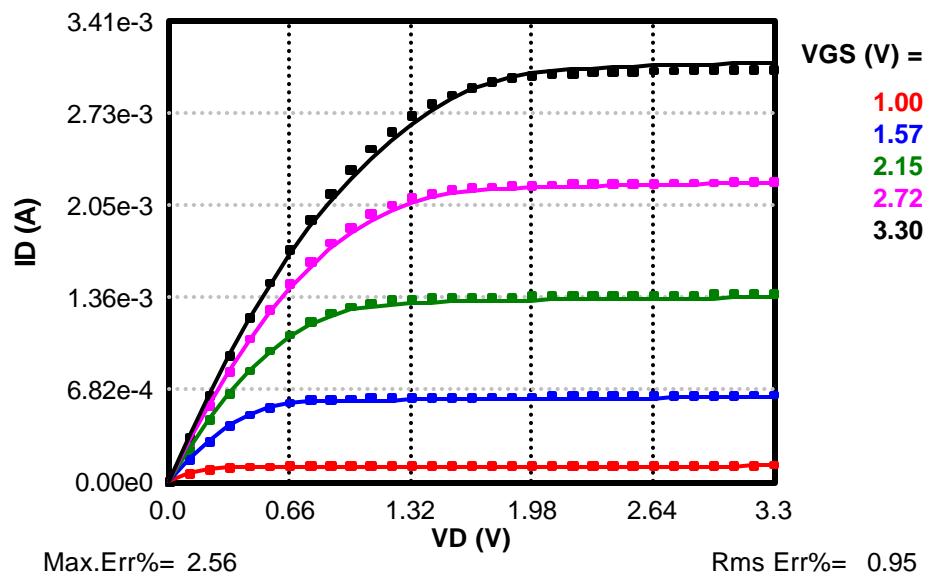




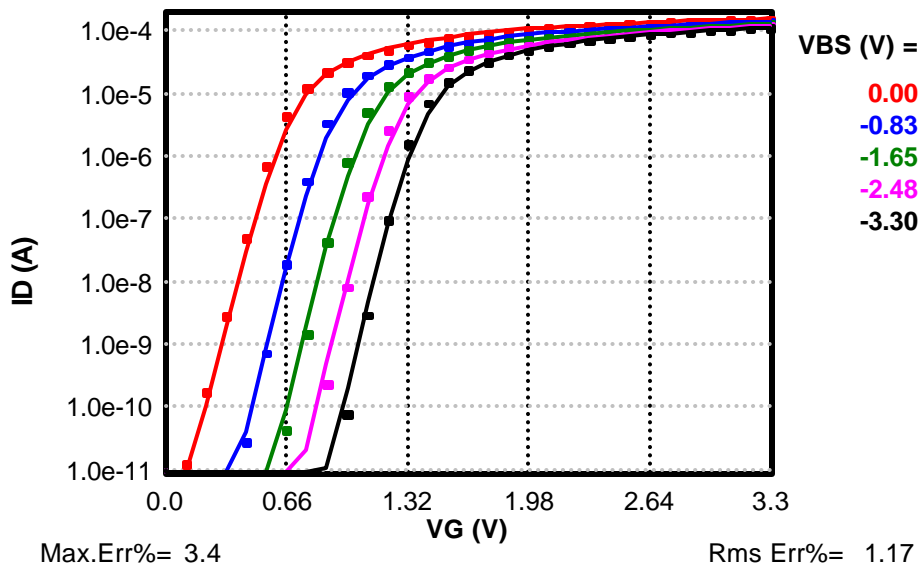
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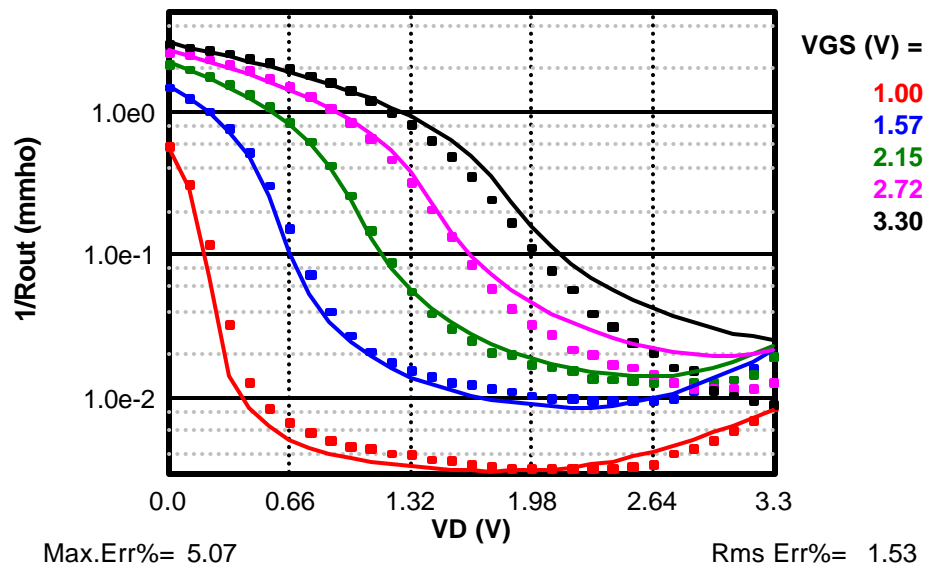
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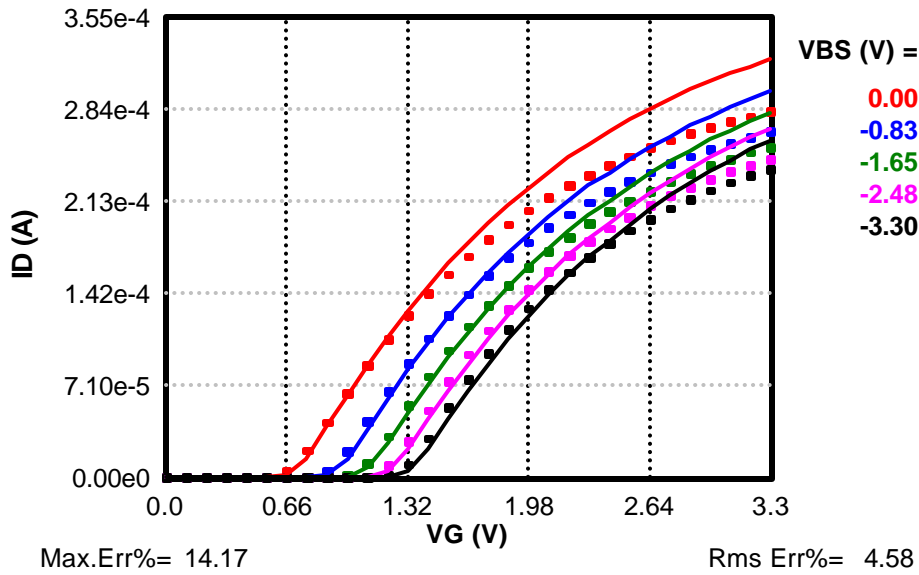
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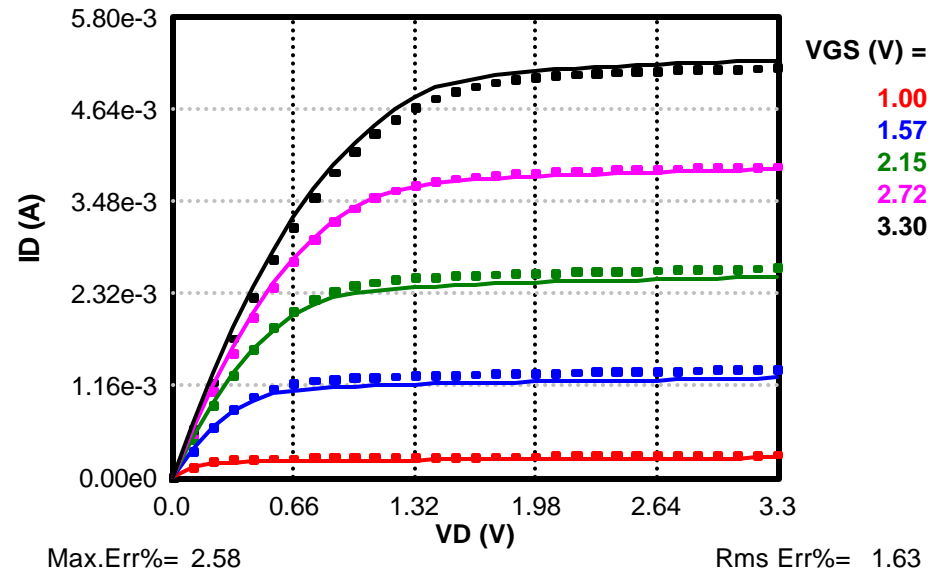
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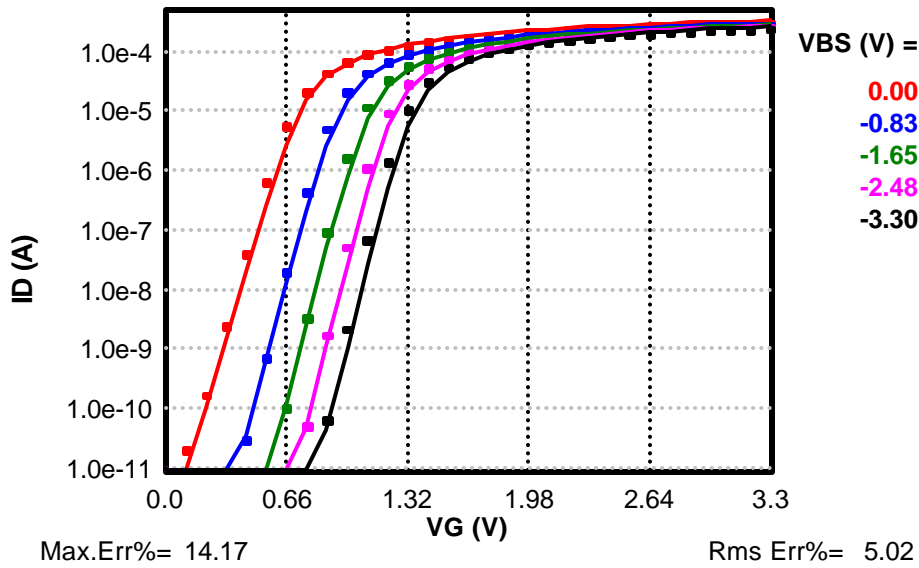
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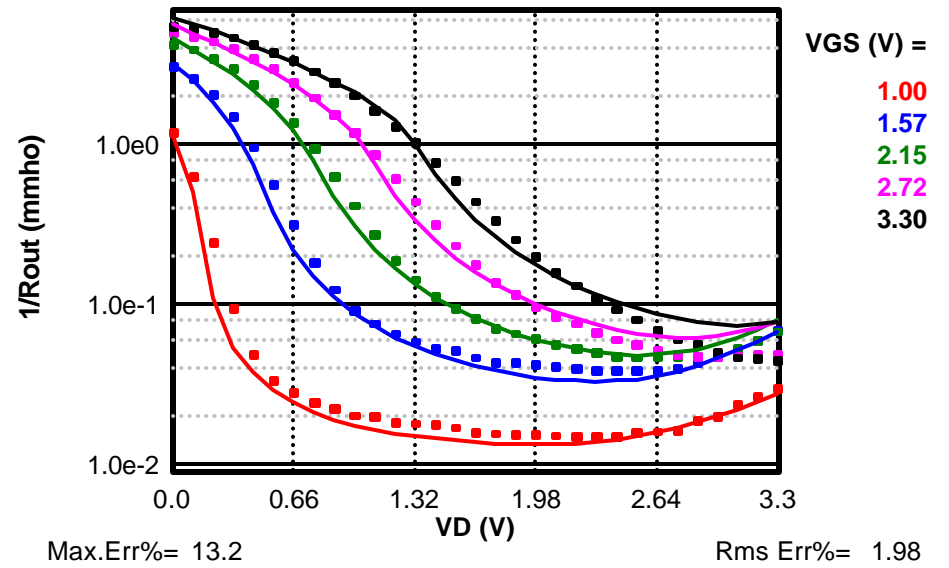
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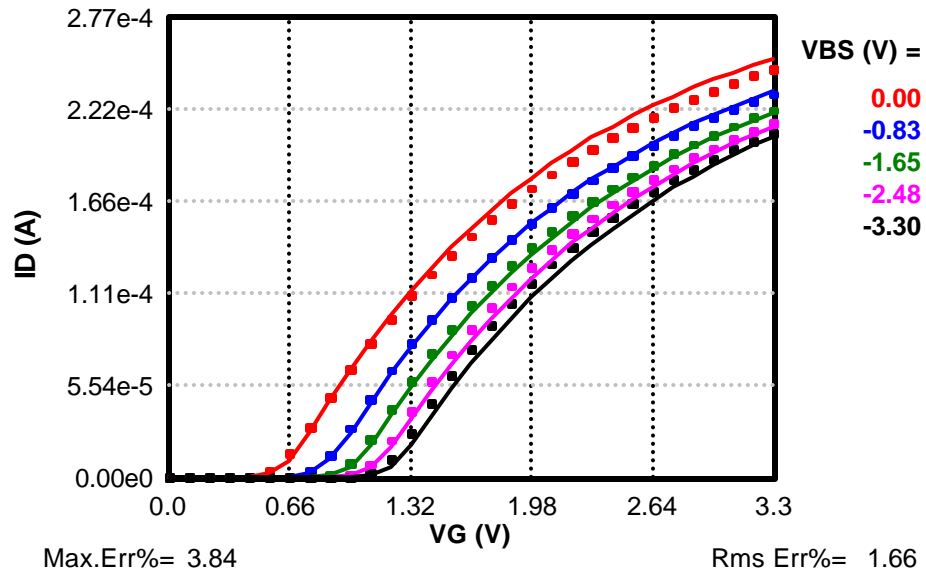
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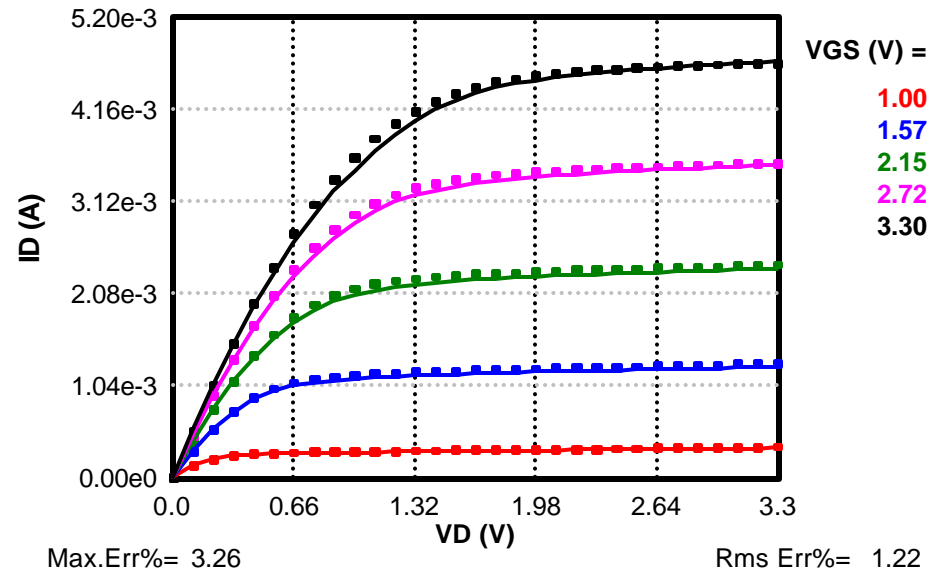
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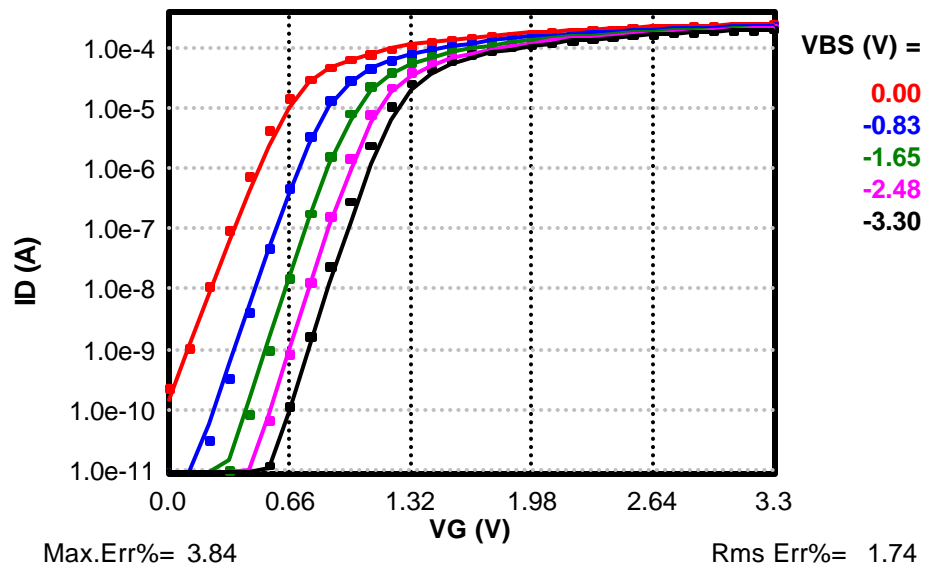
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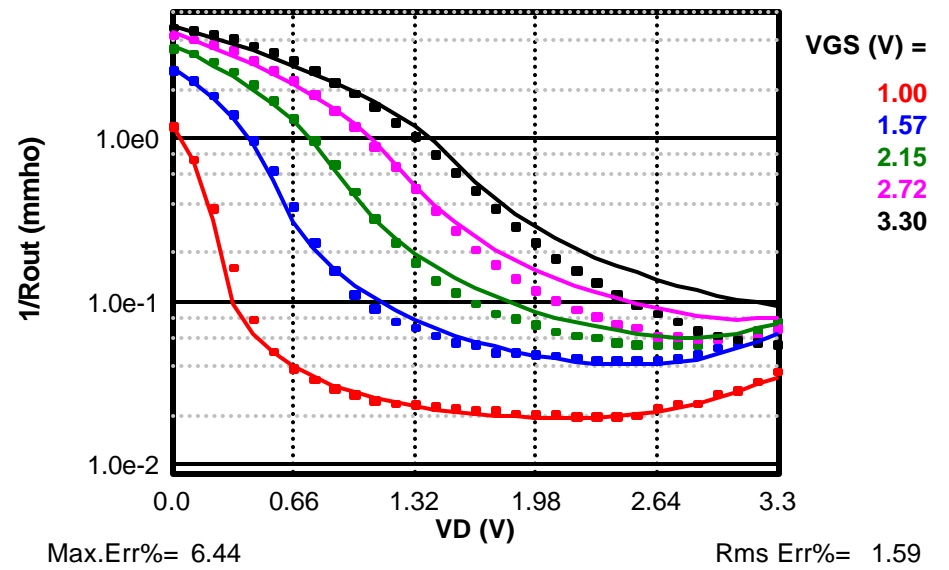
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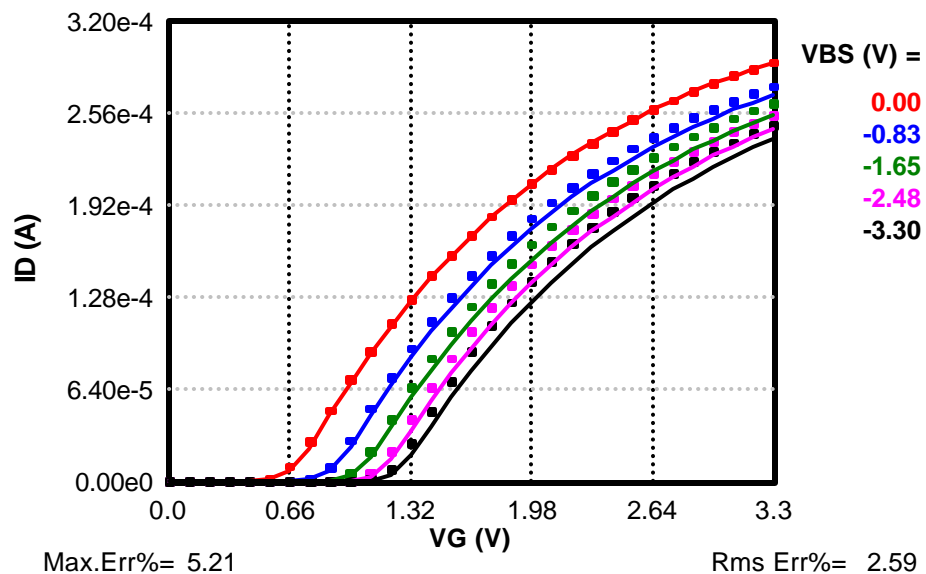
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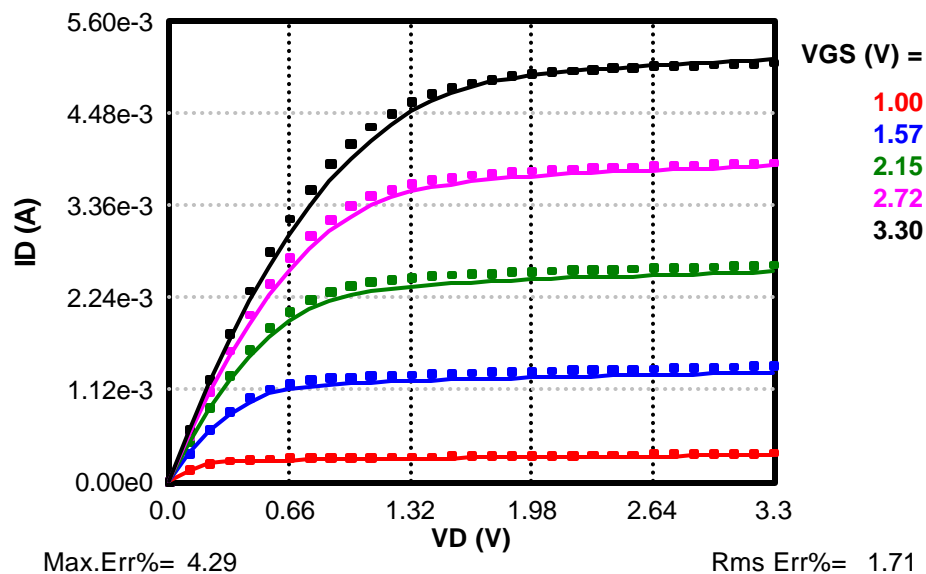
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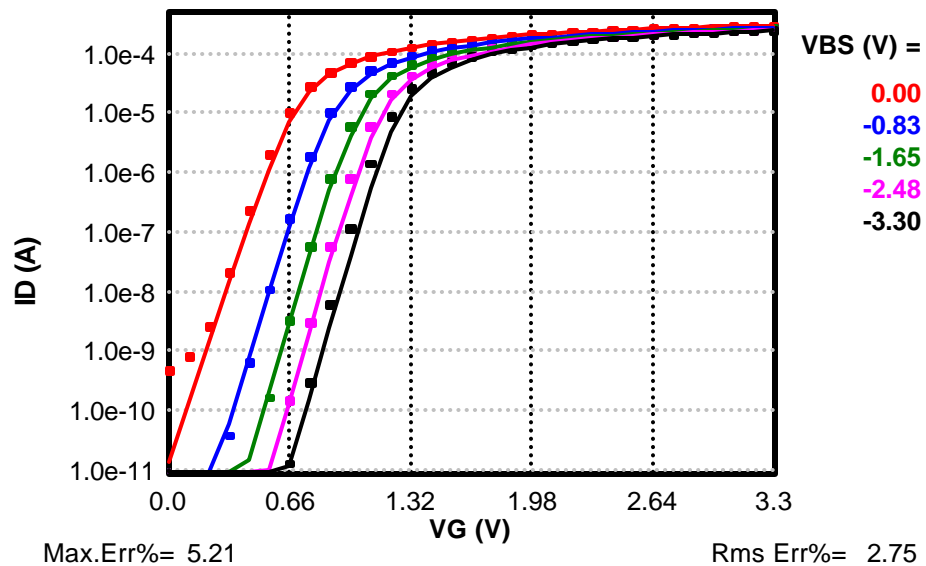
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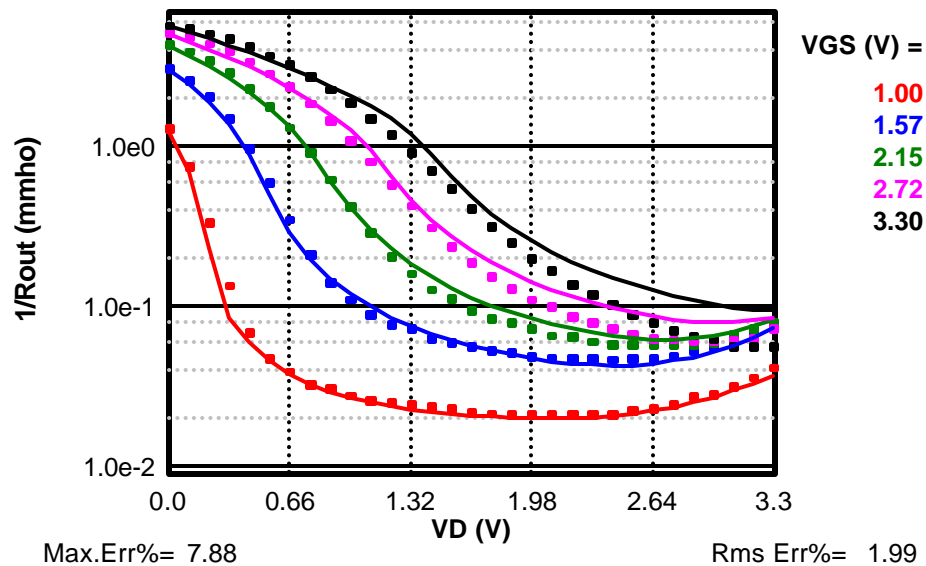
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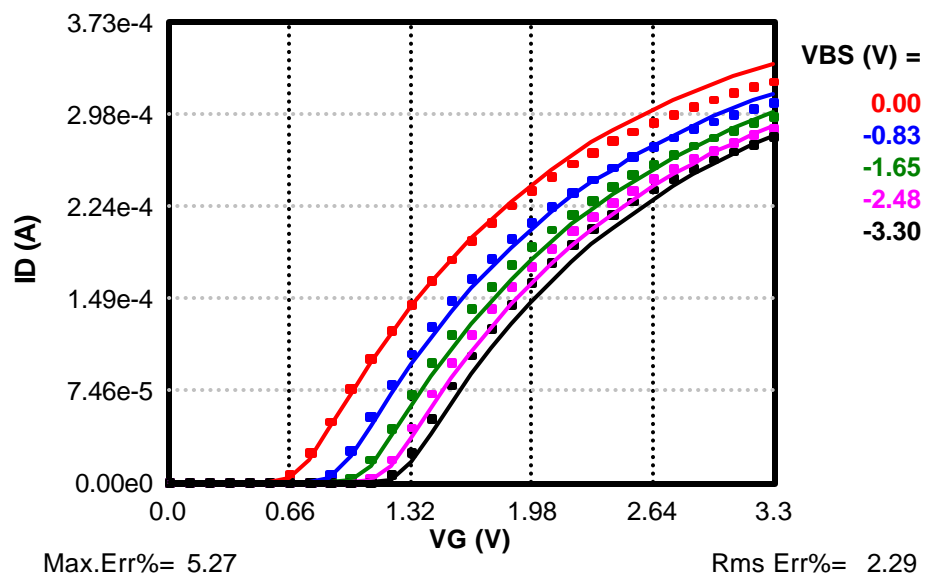
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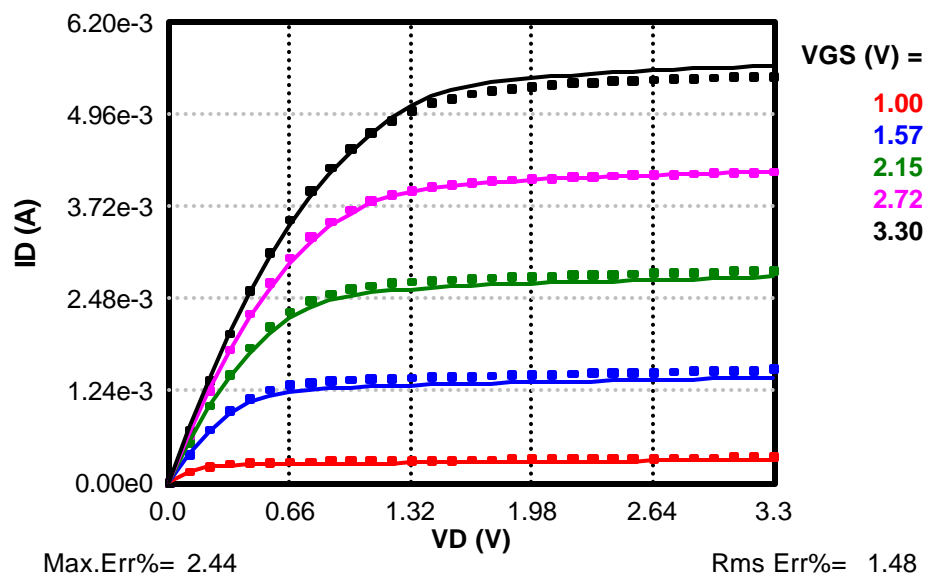
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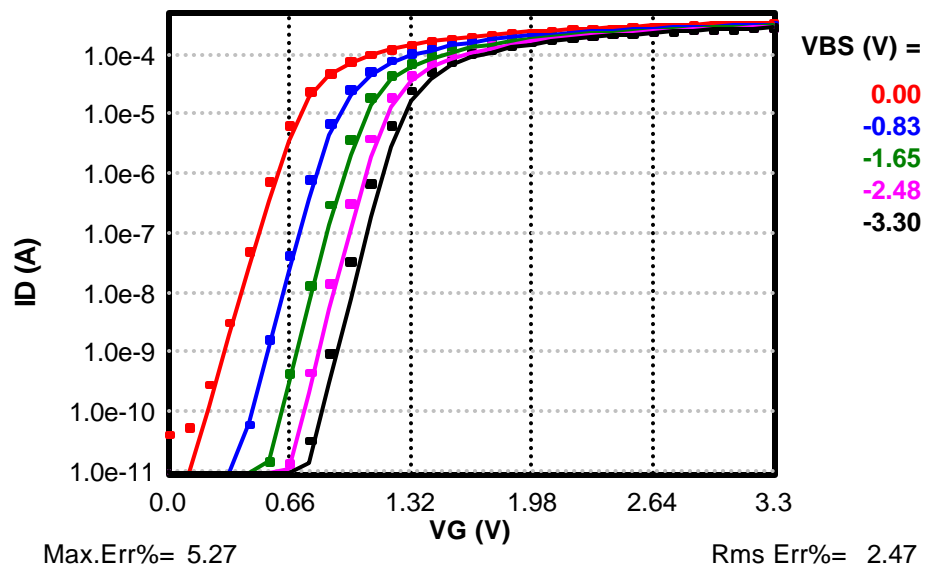
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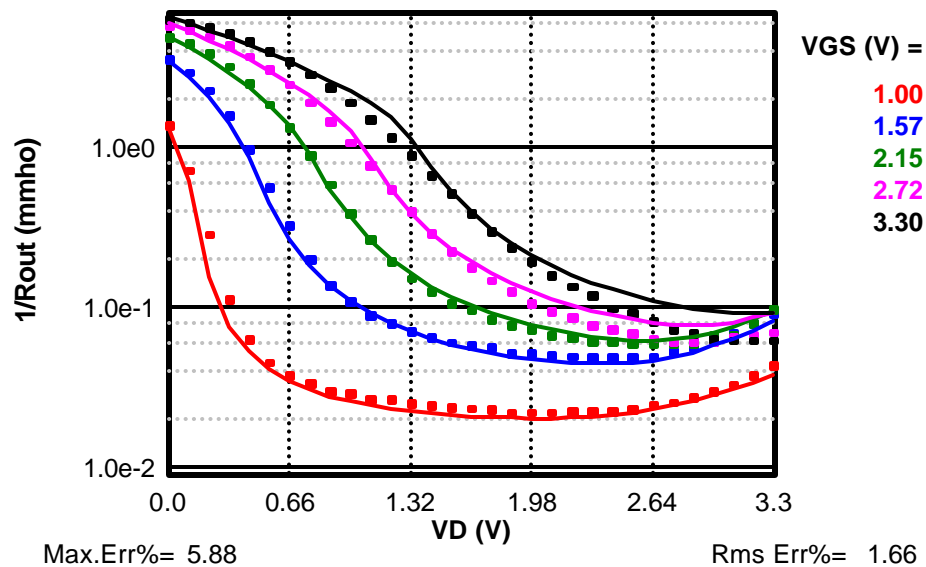
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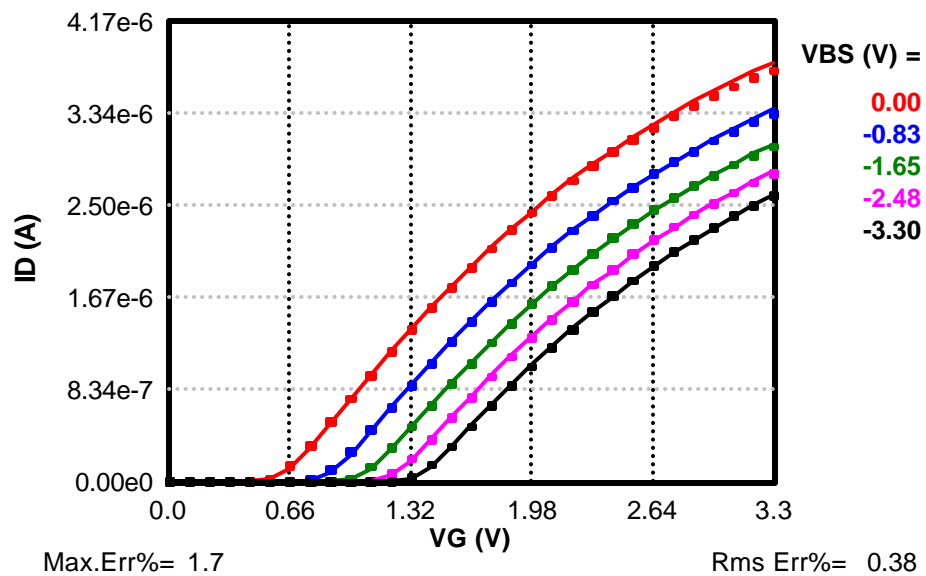
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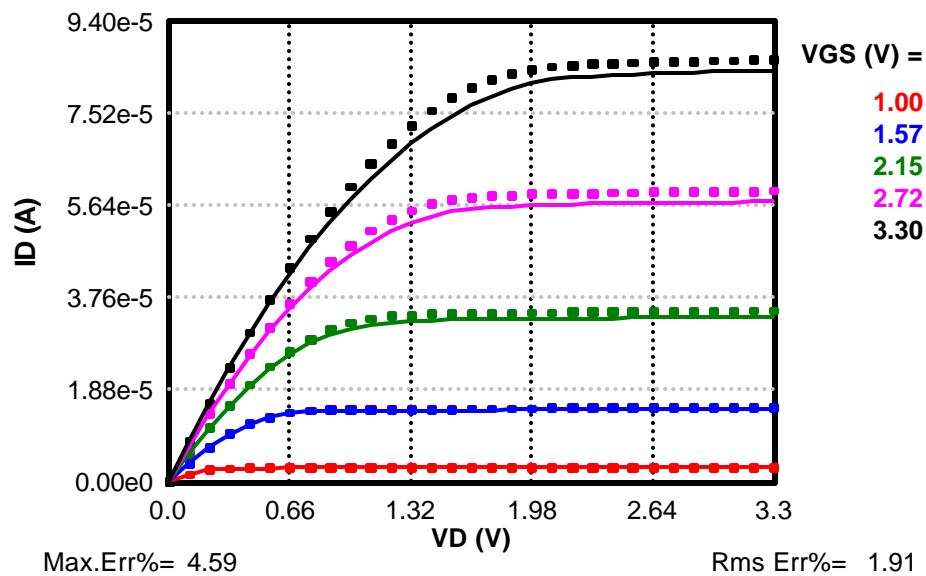
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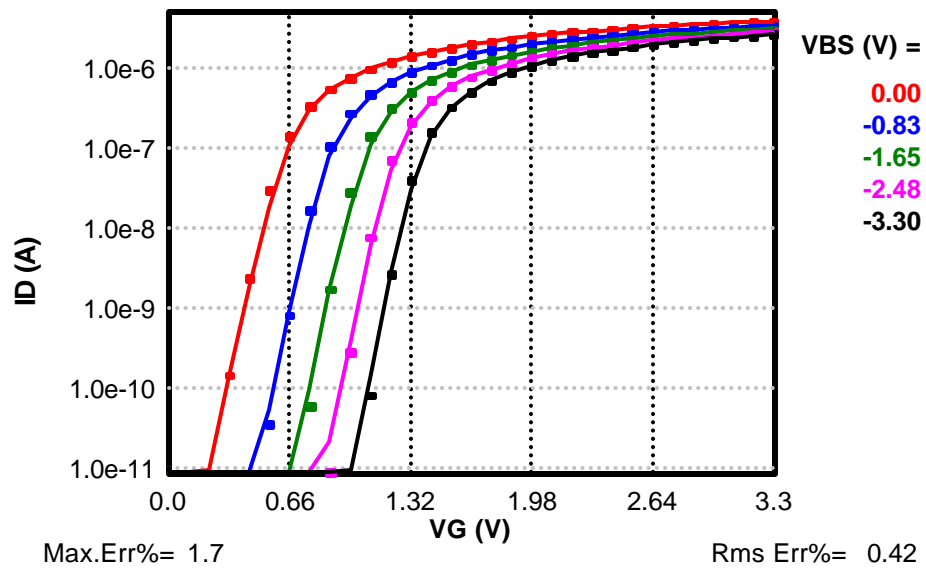
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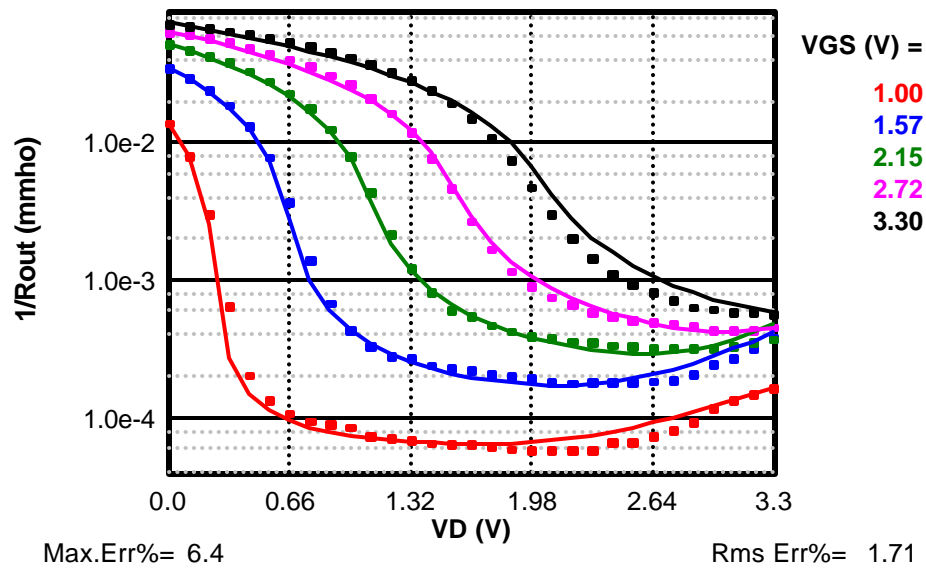
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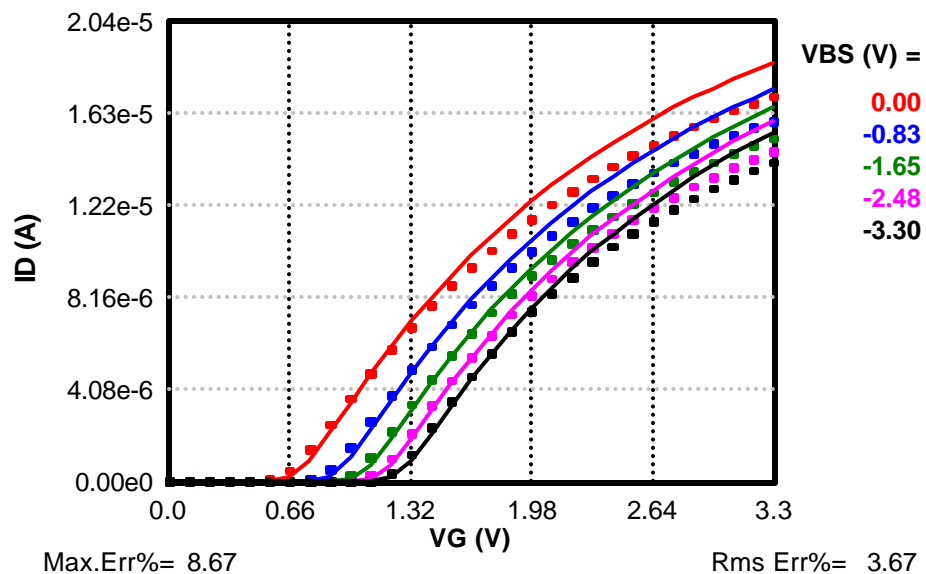
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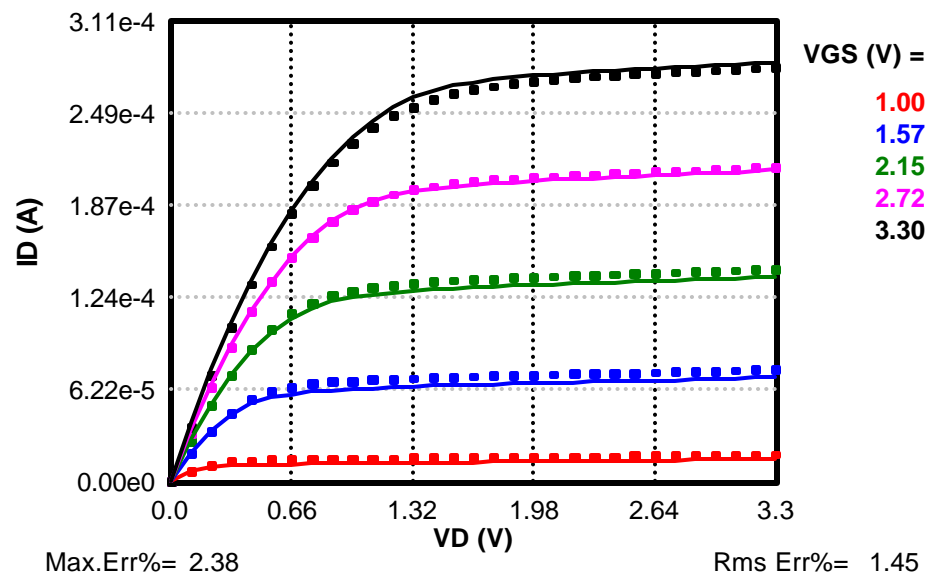
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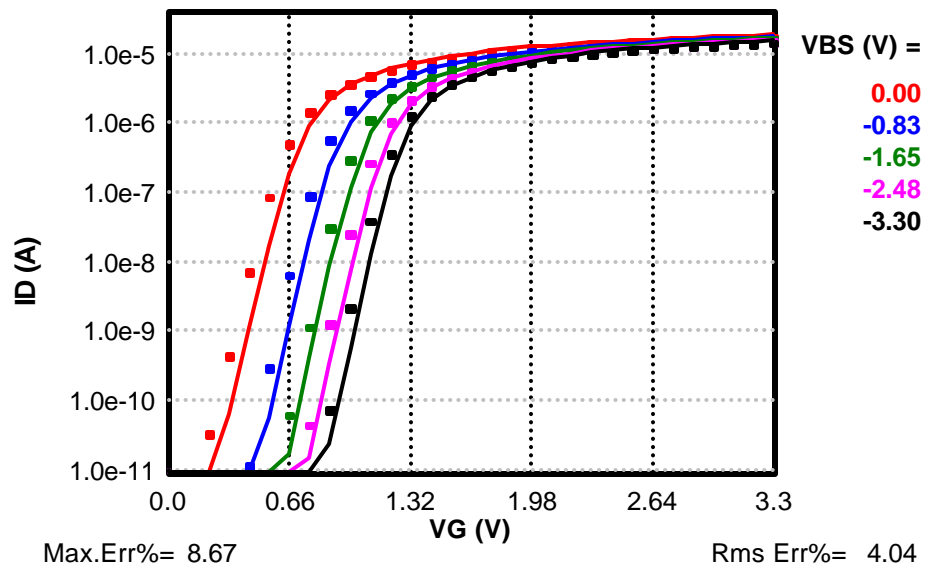
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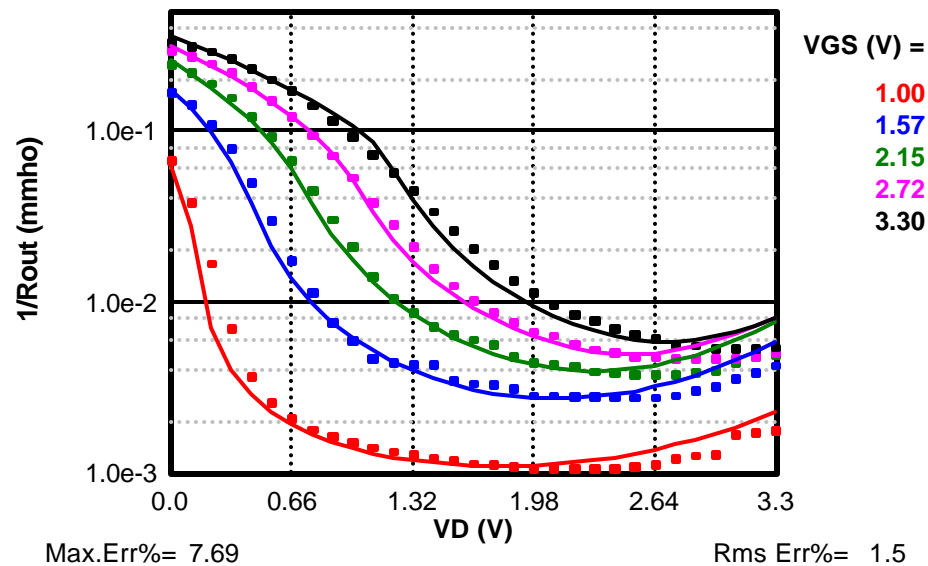
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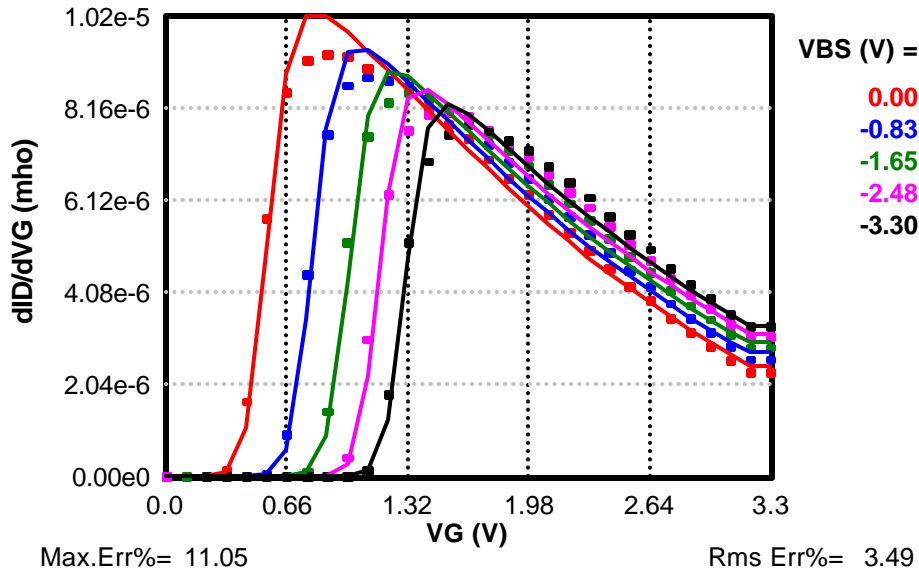
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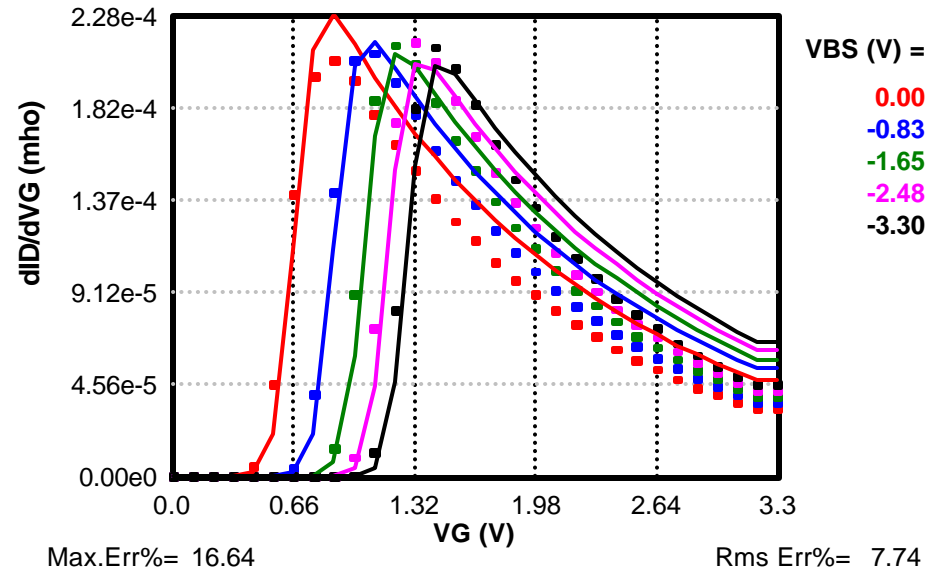
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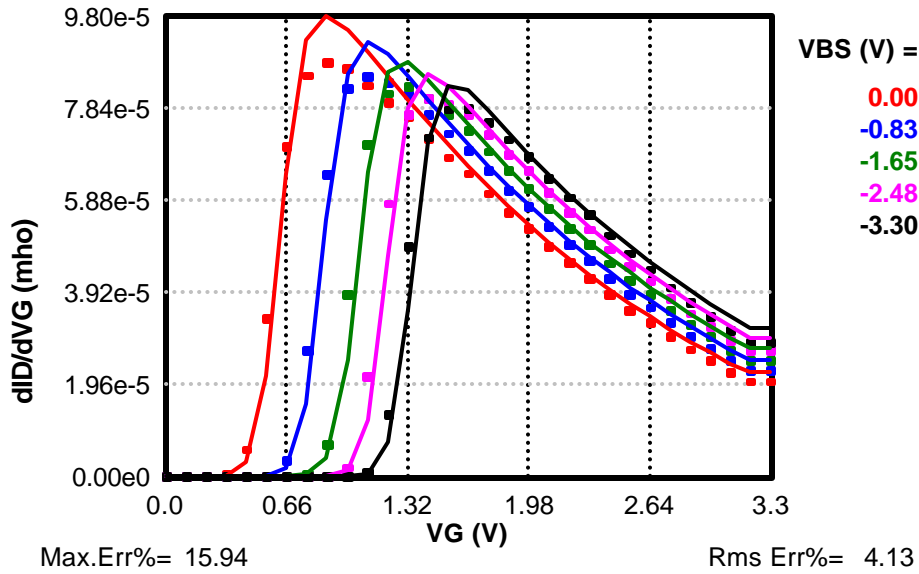
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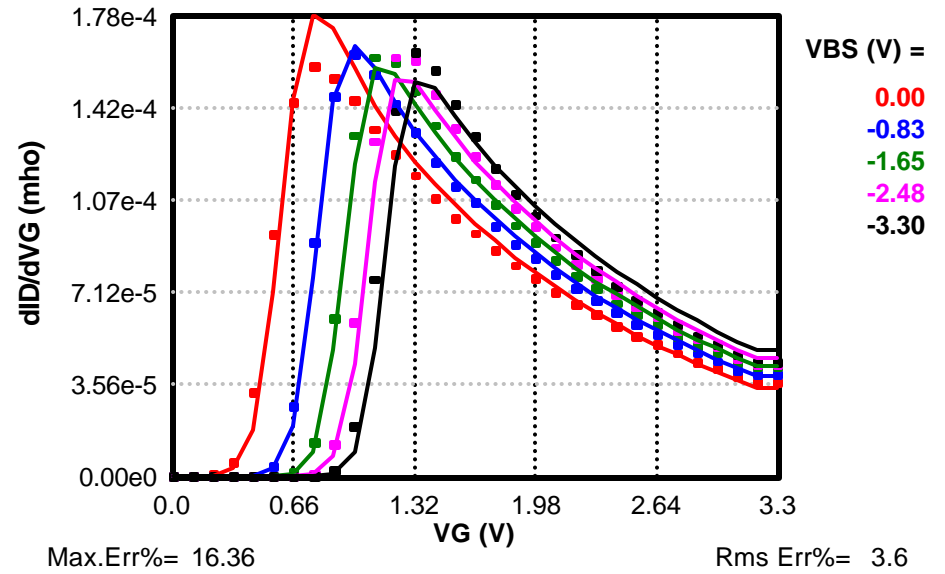
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M3D25R.IV W/L=10.00/1.00 T=25C VD=0.05V

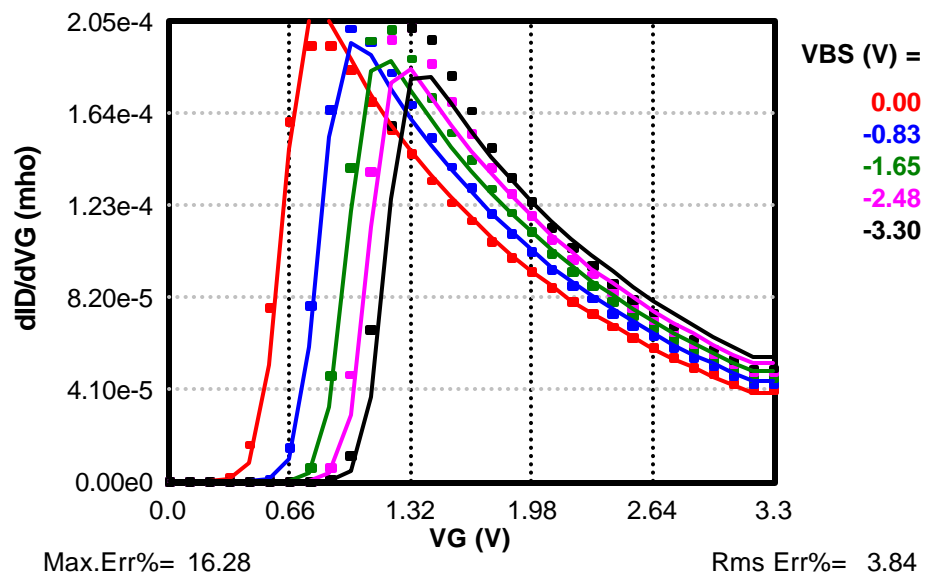


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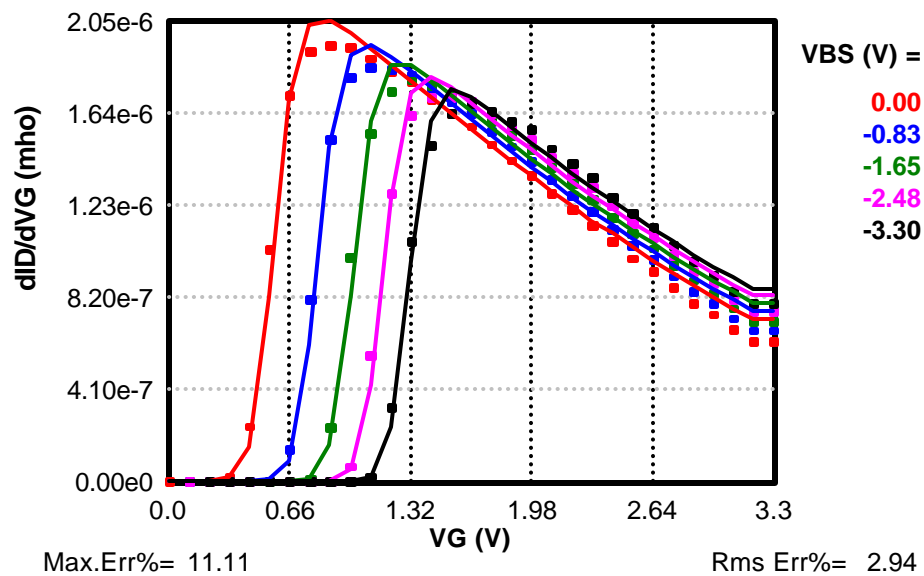




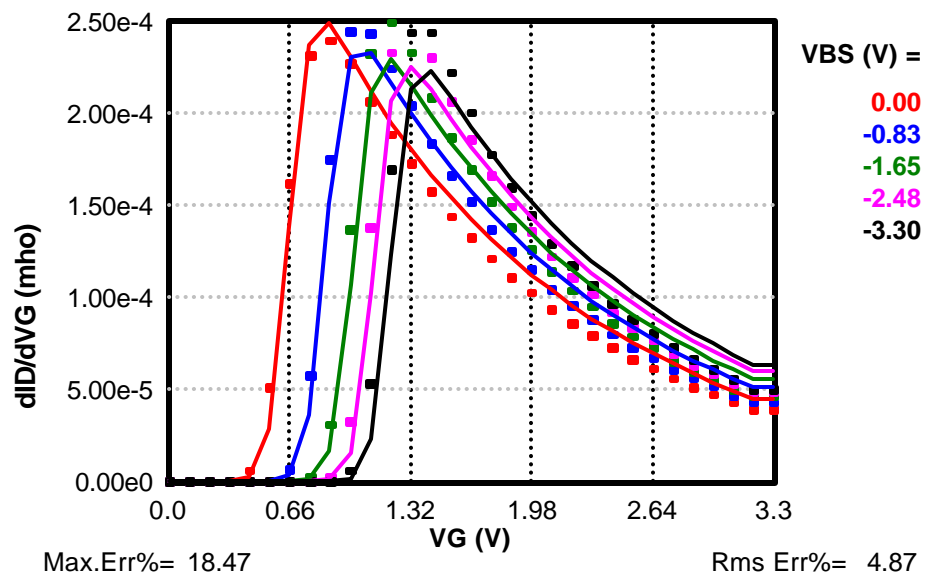
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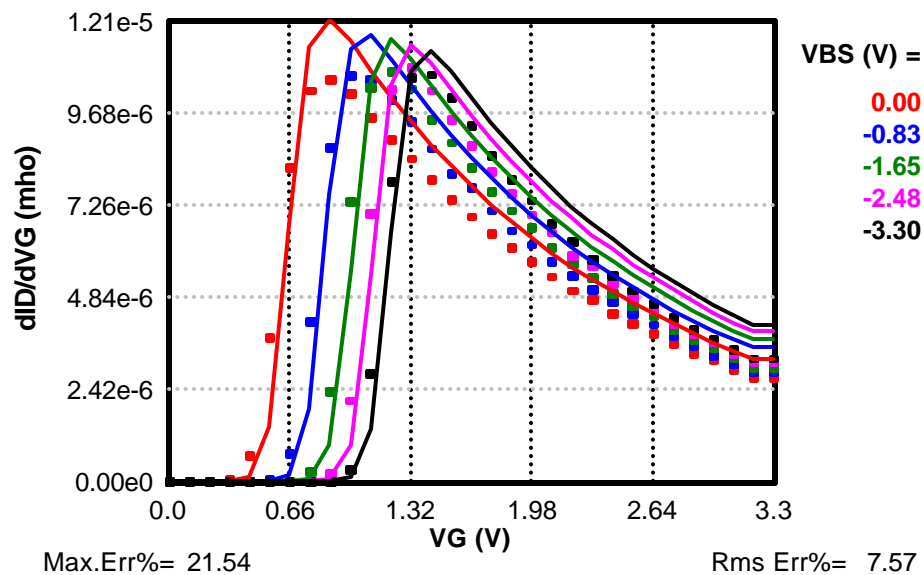
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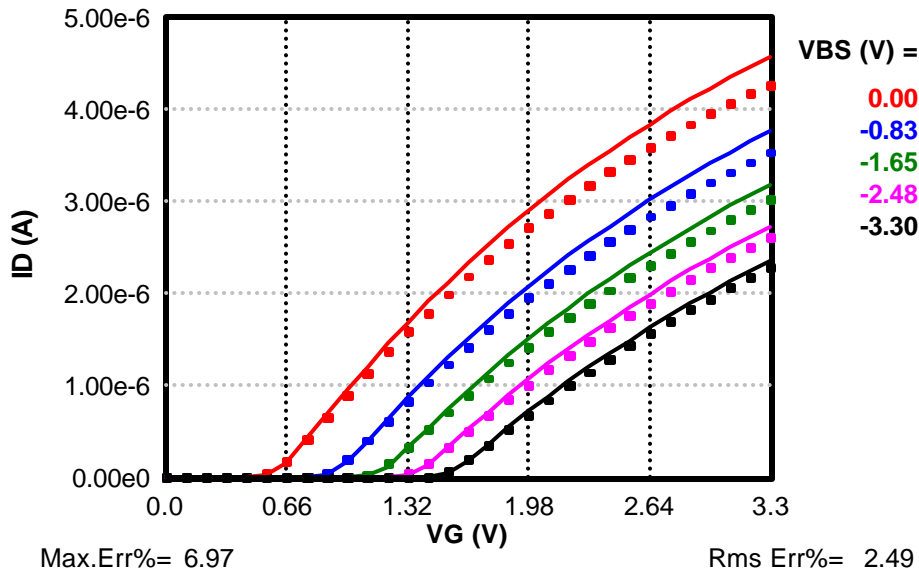
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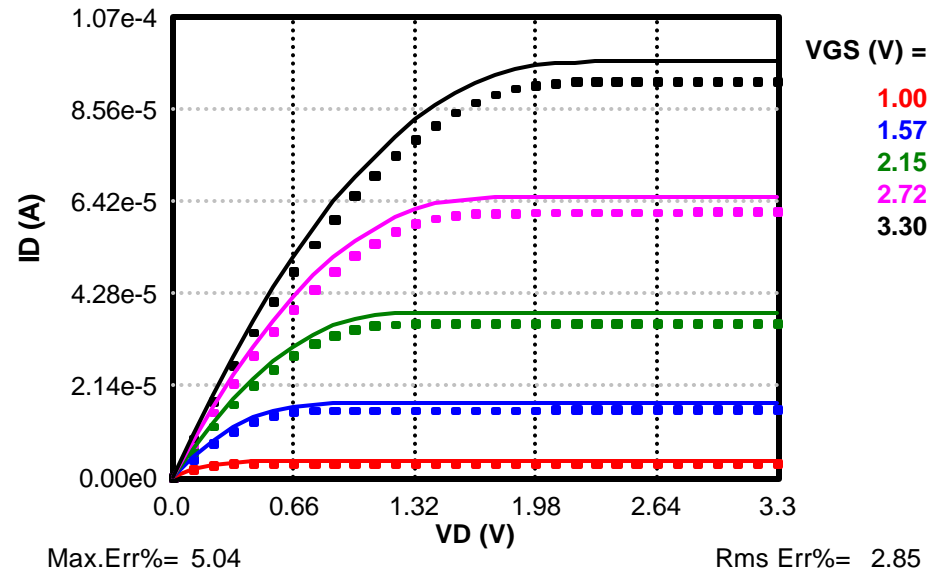
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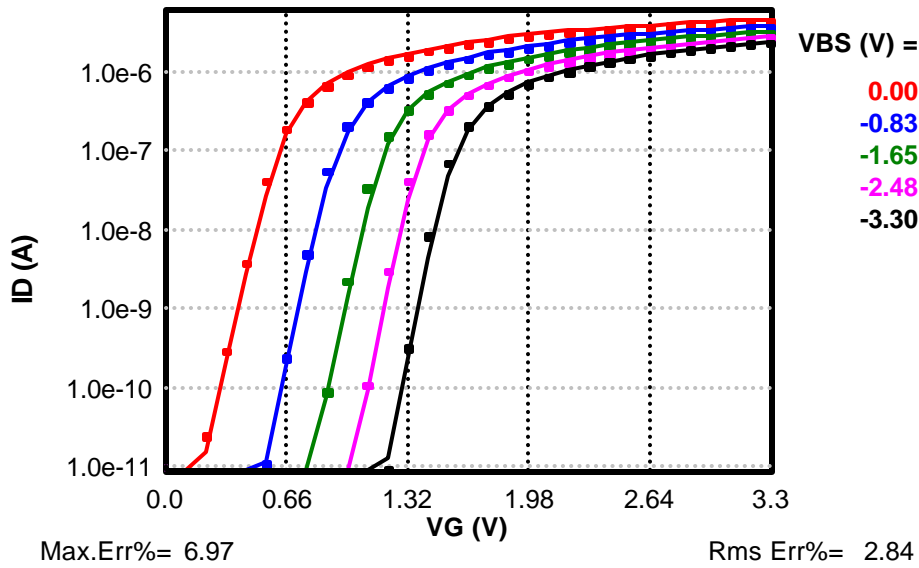
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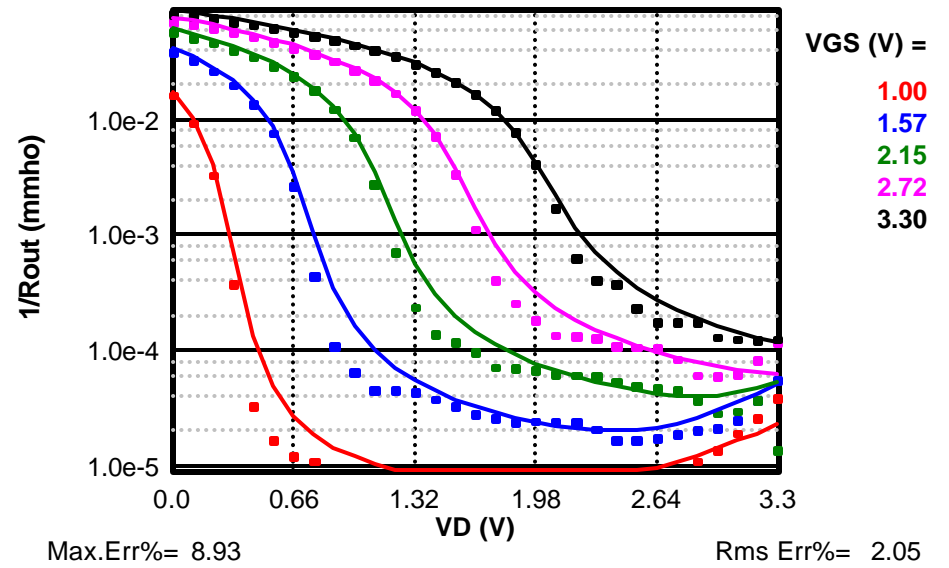
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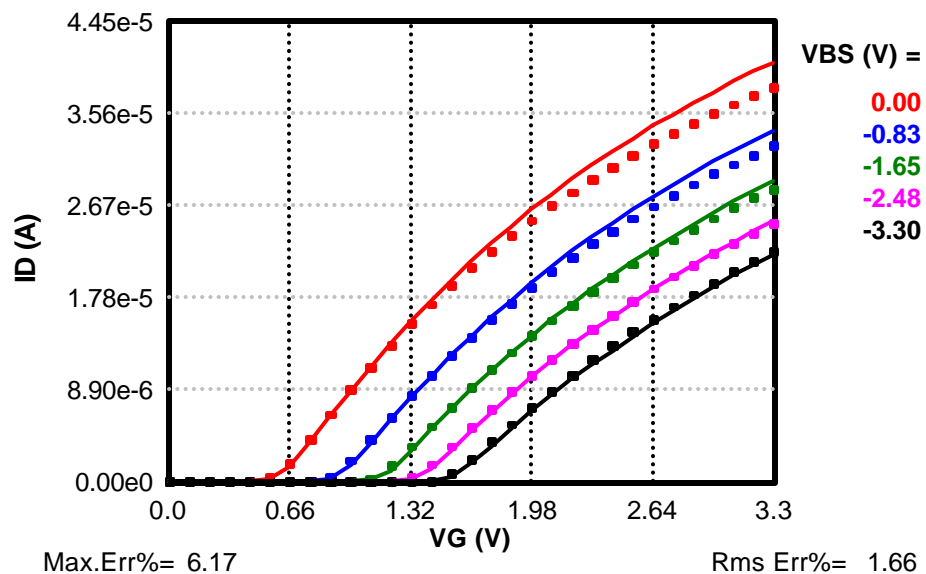
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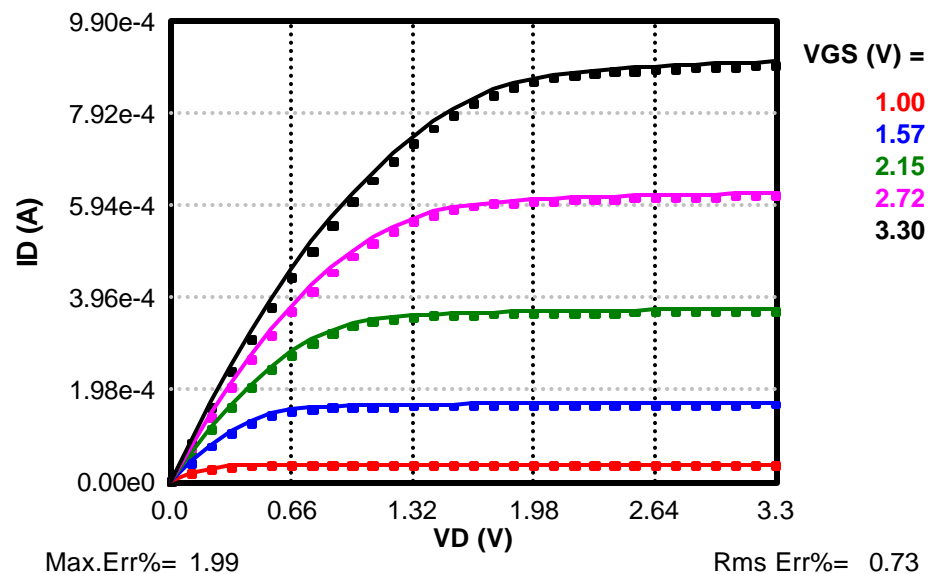
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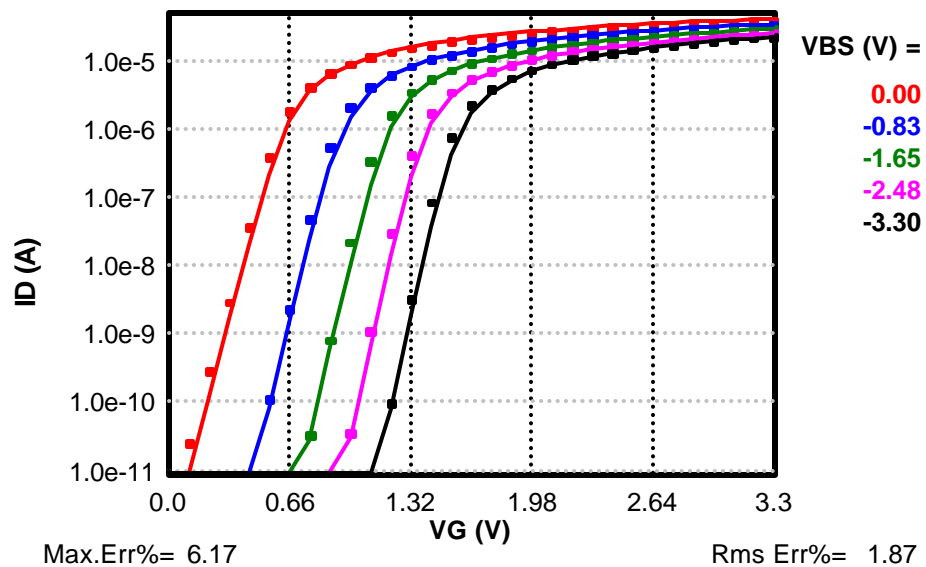
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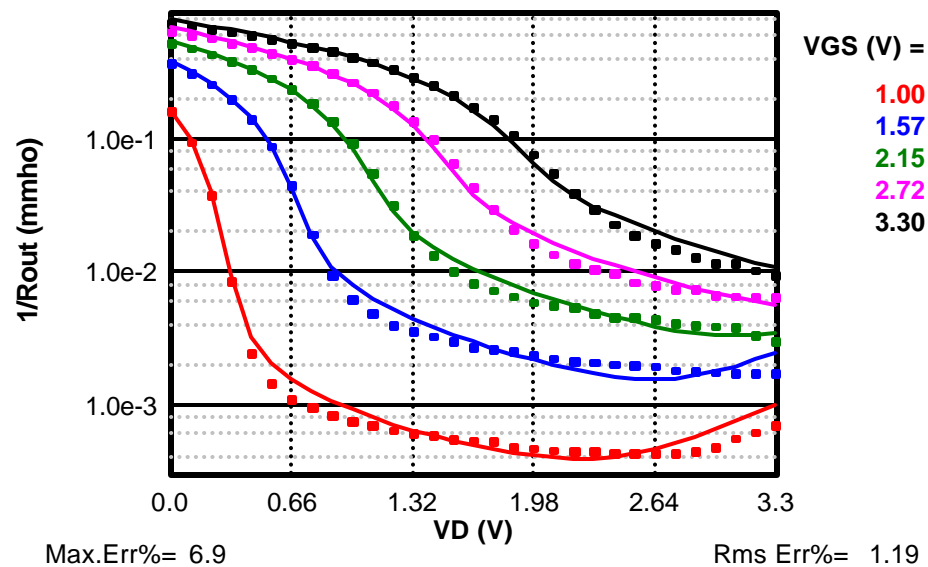
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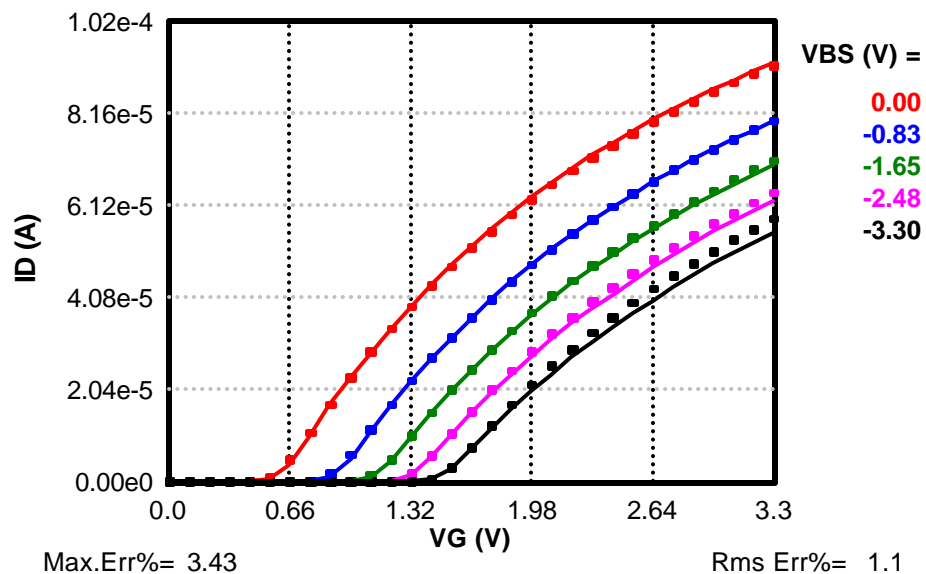
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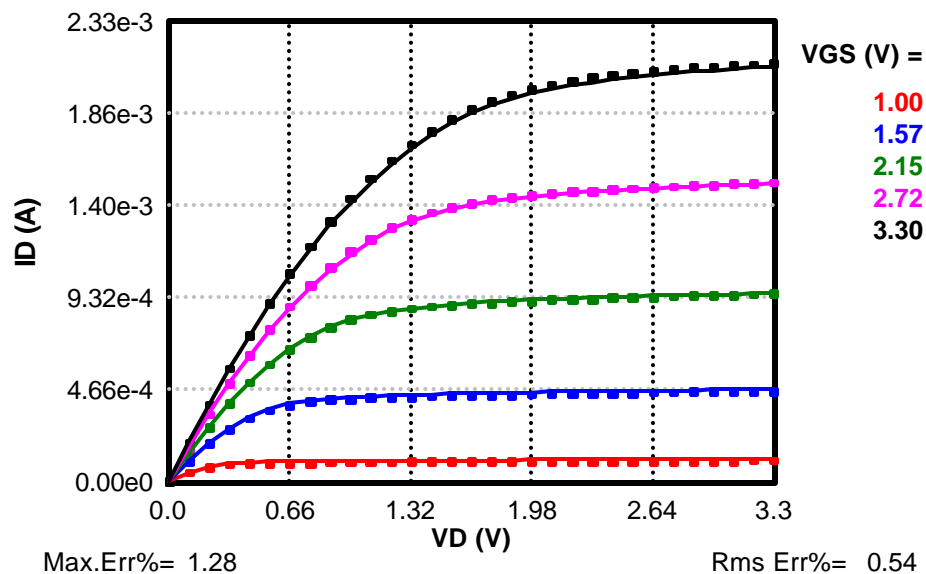
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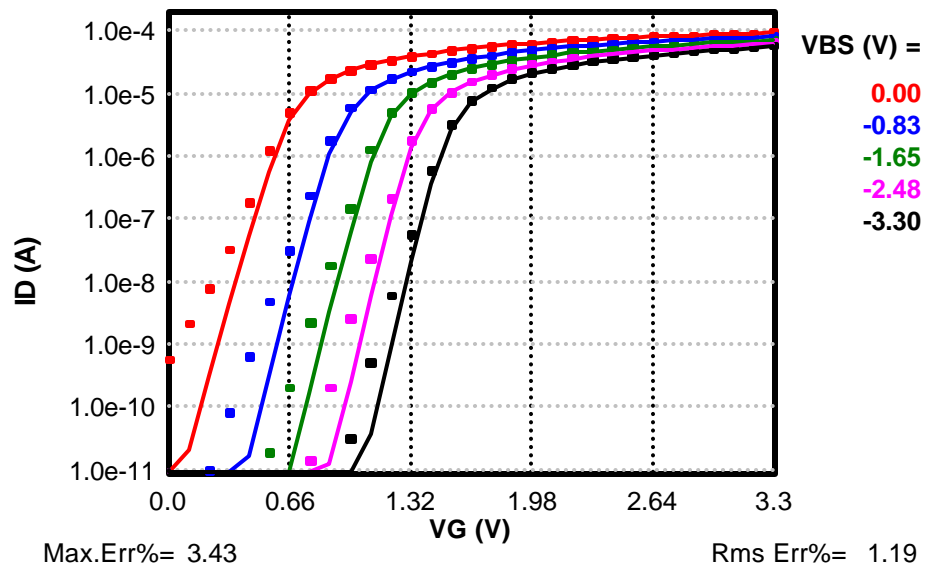
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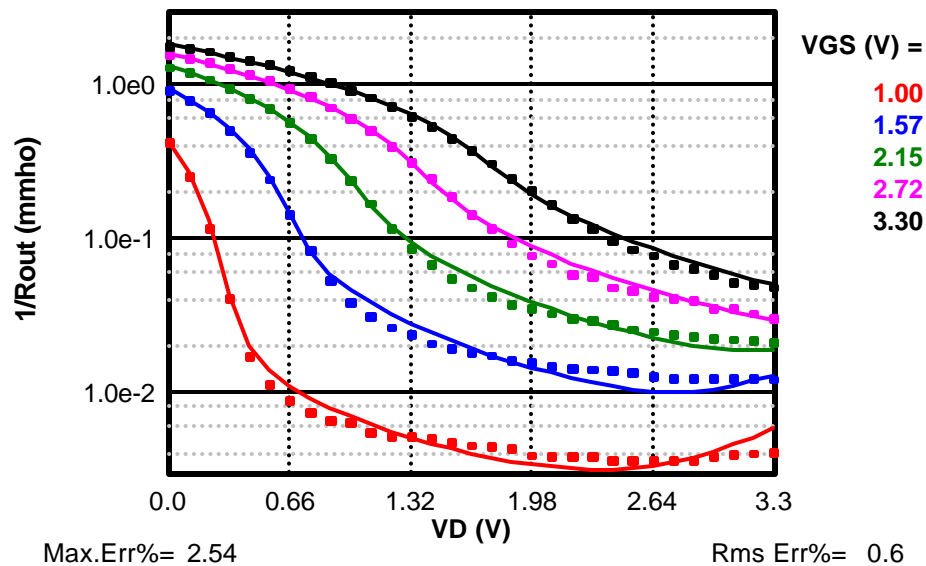
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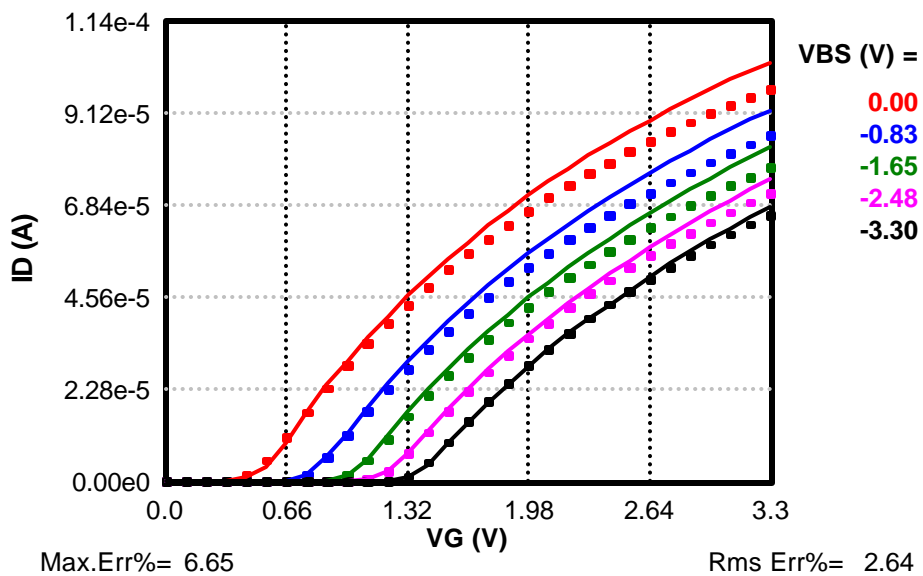
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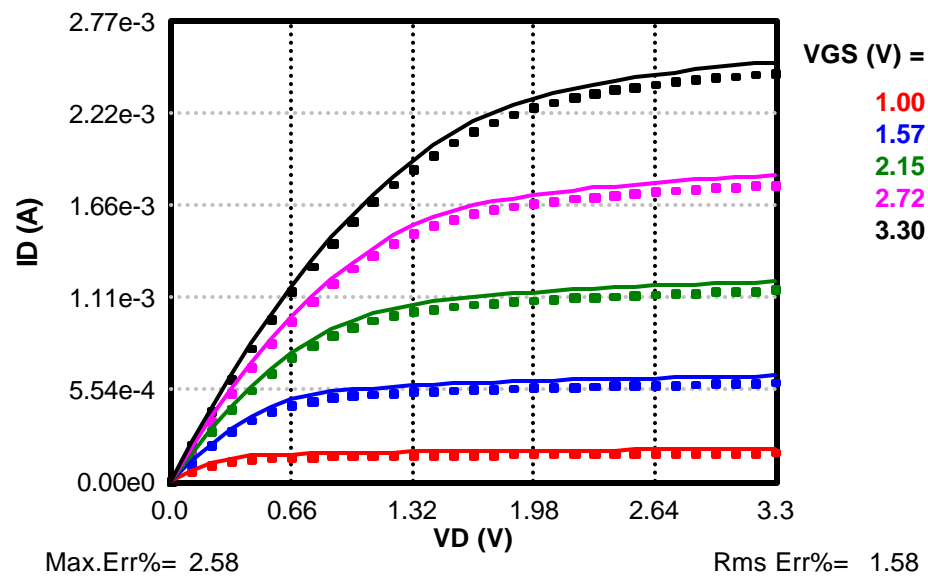
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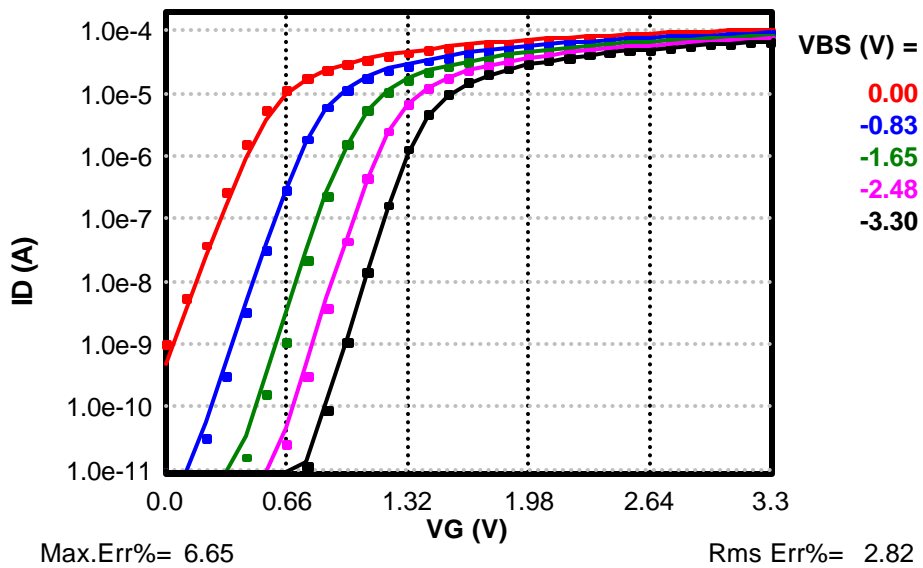
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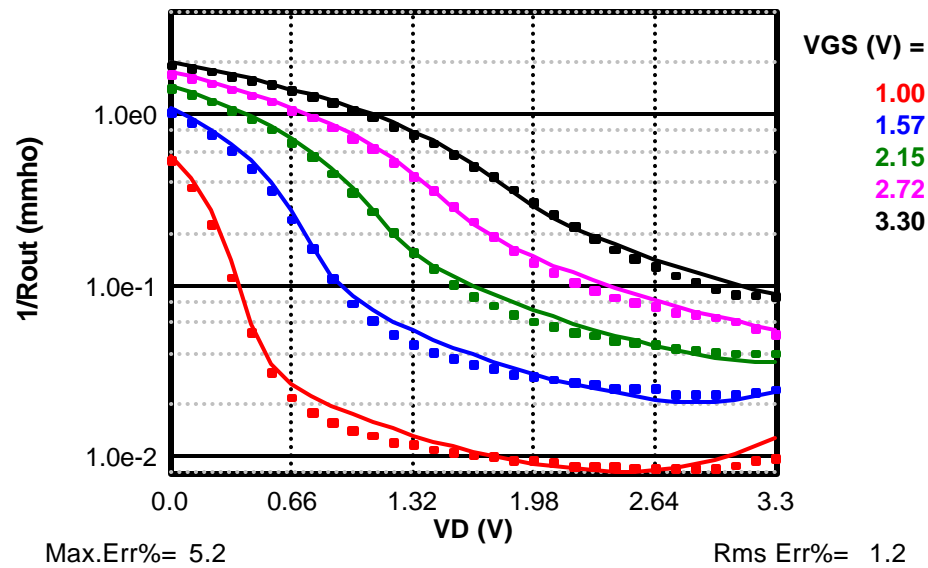
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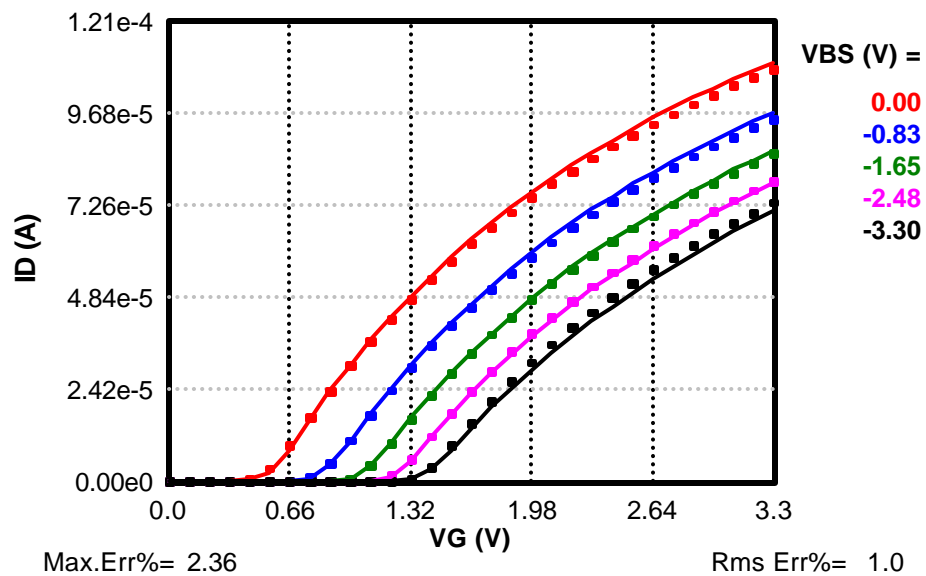
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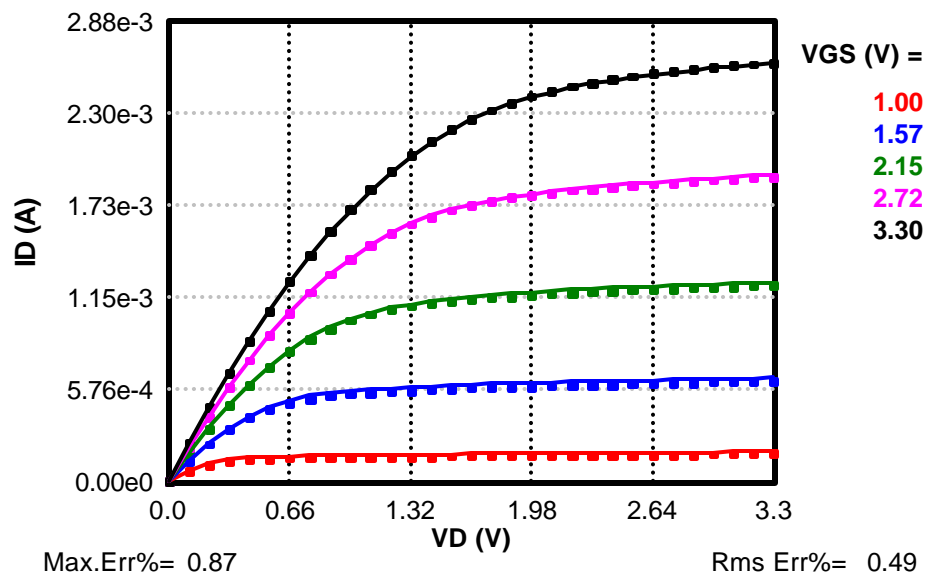
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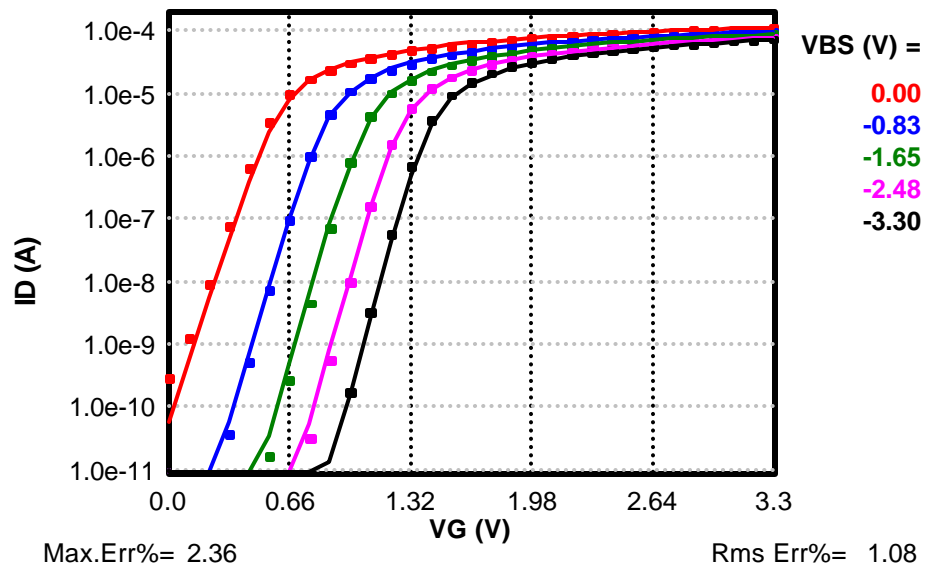
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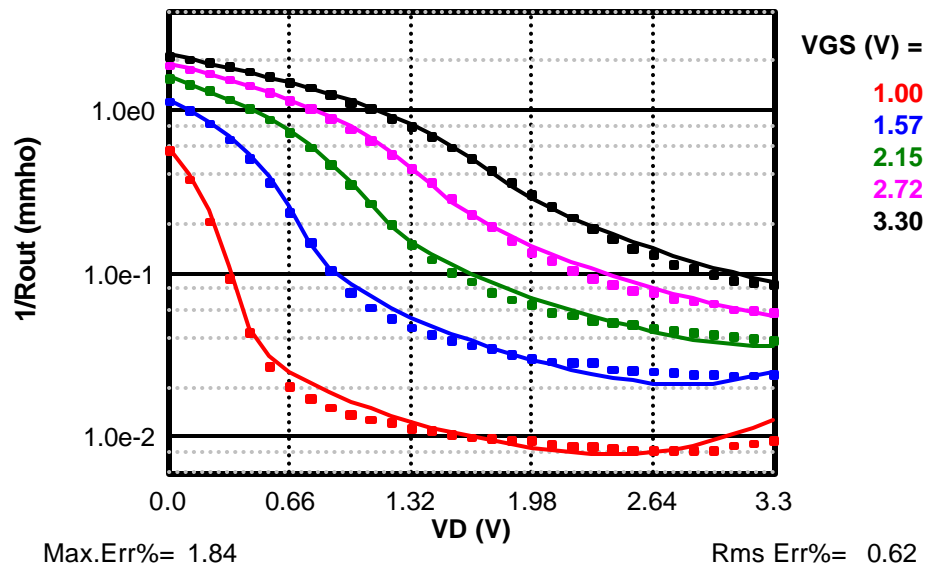
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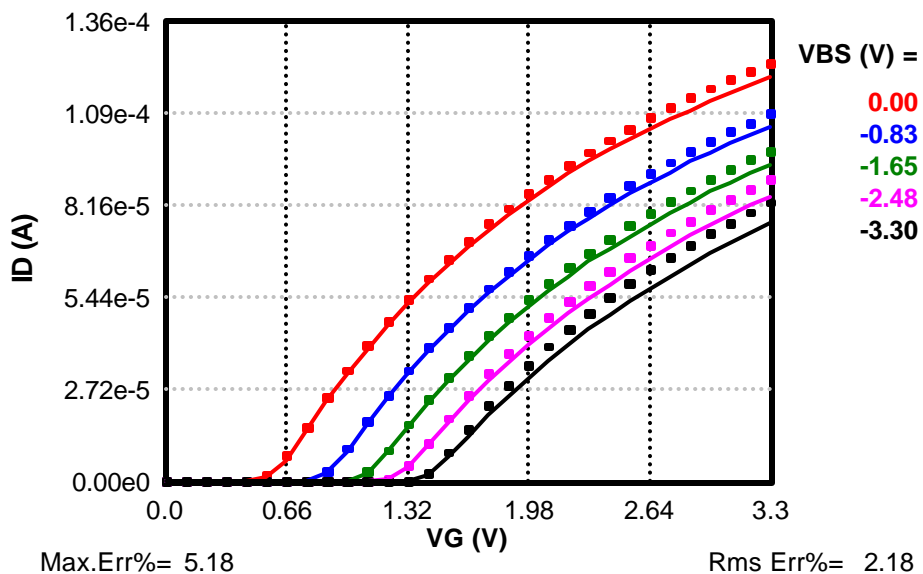
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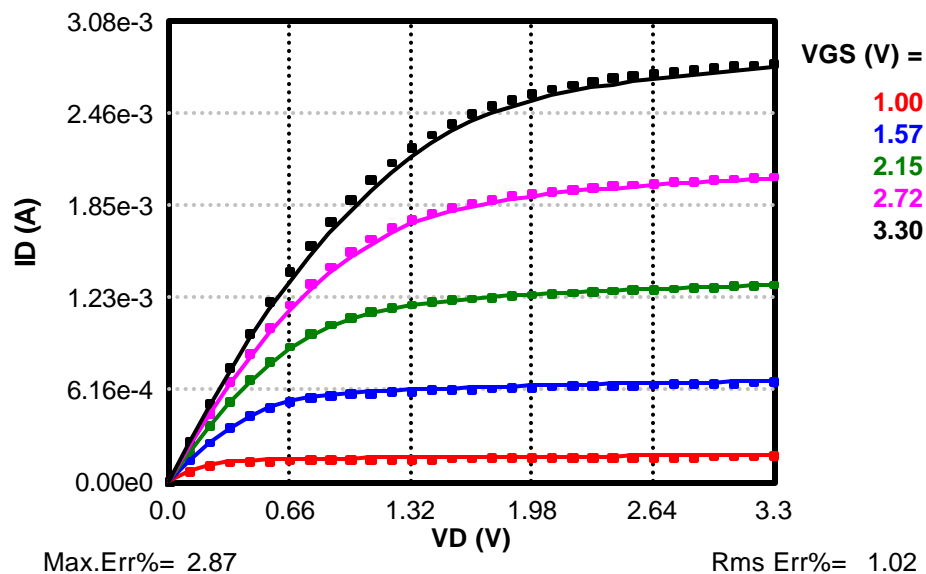
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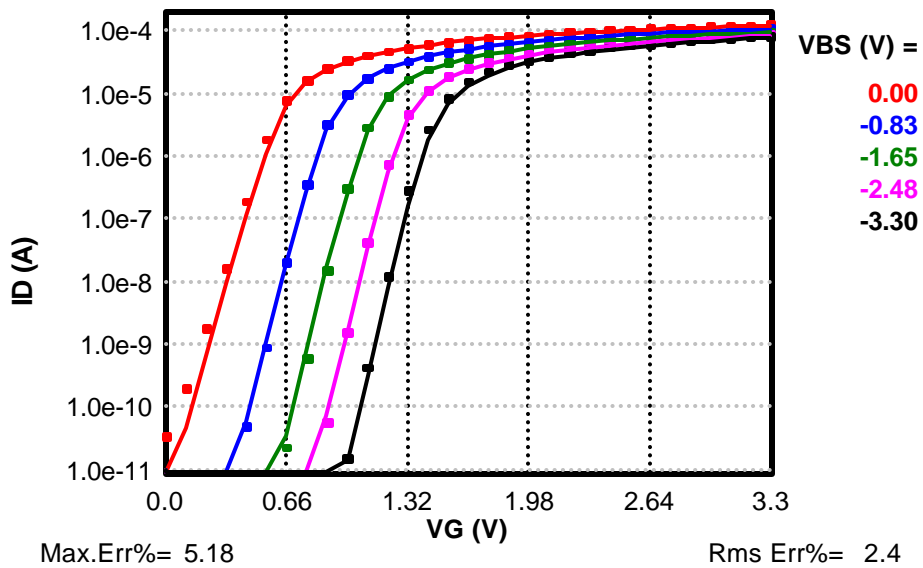
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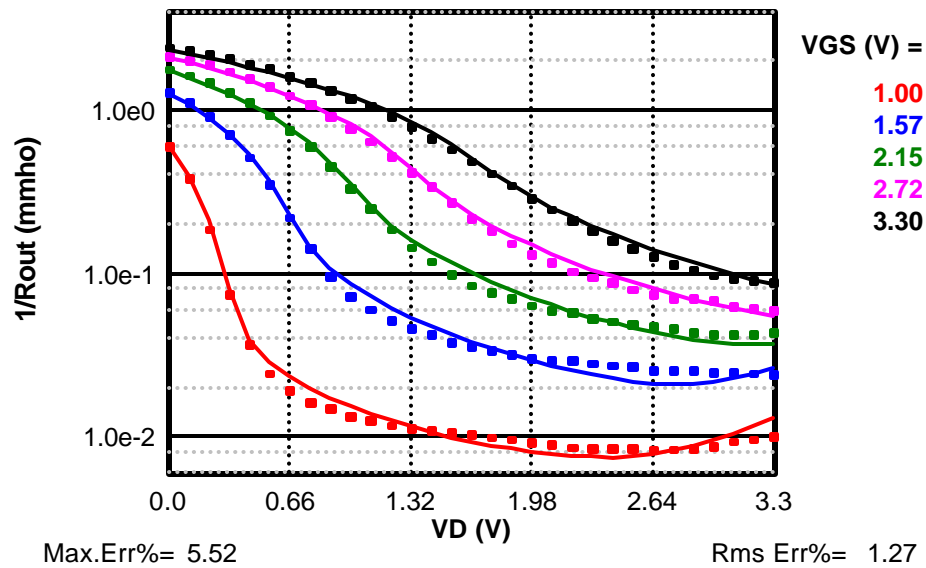
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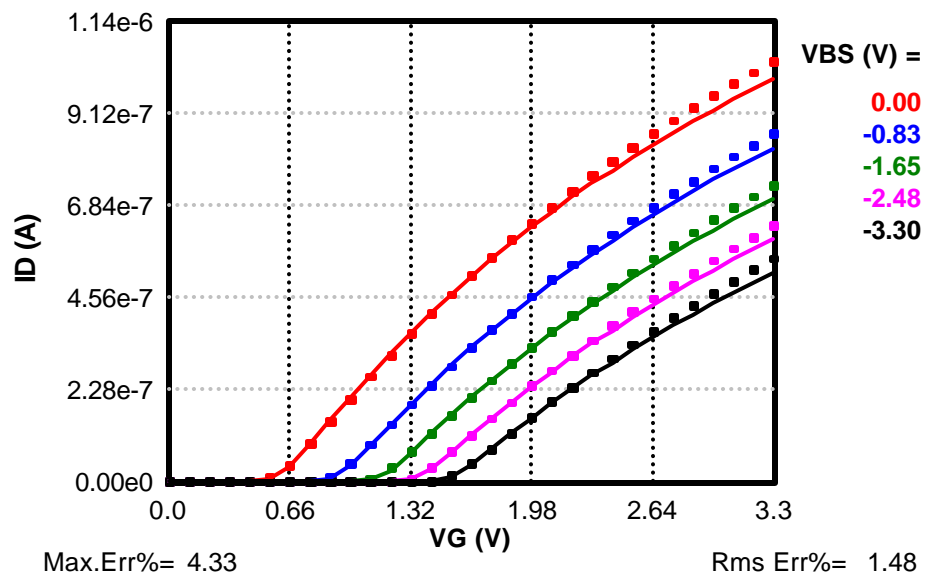
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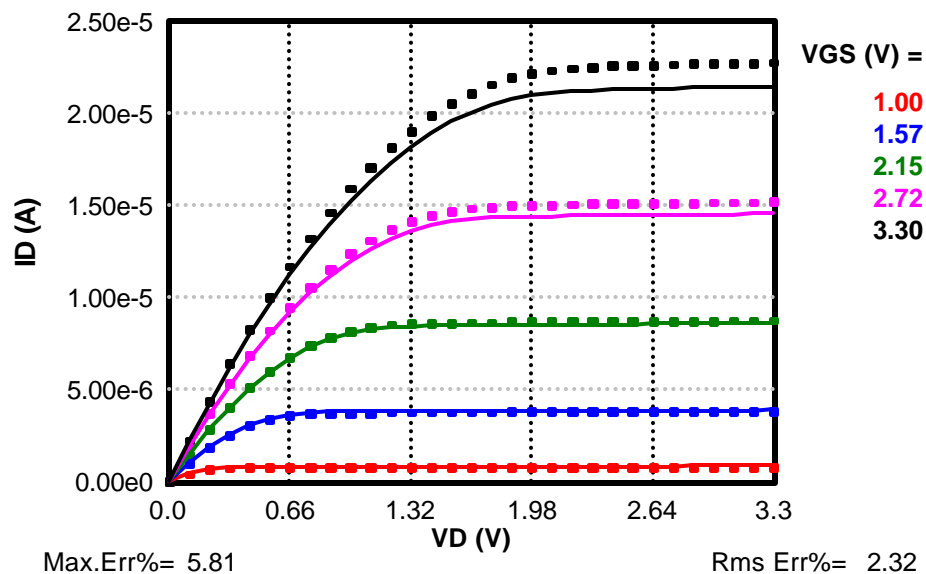
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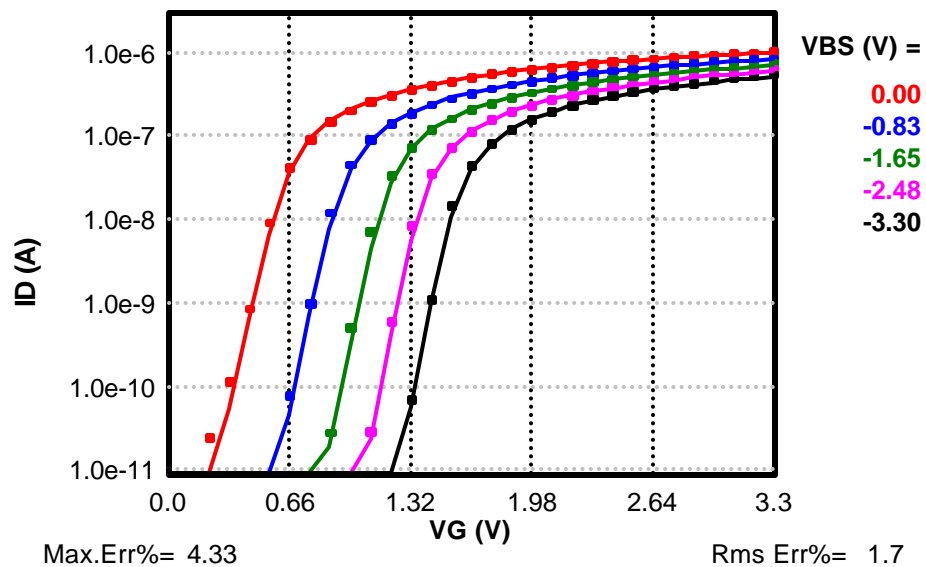
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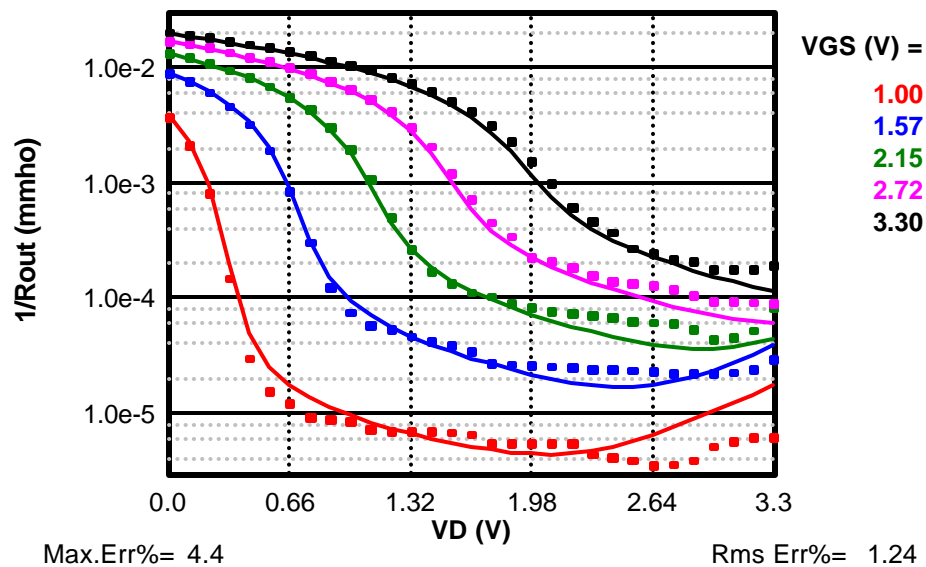
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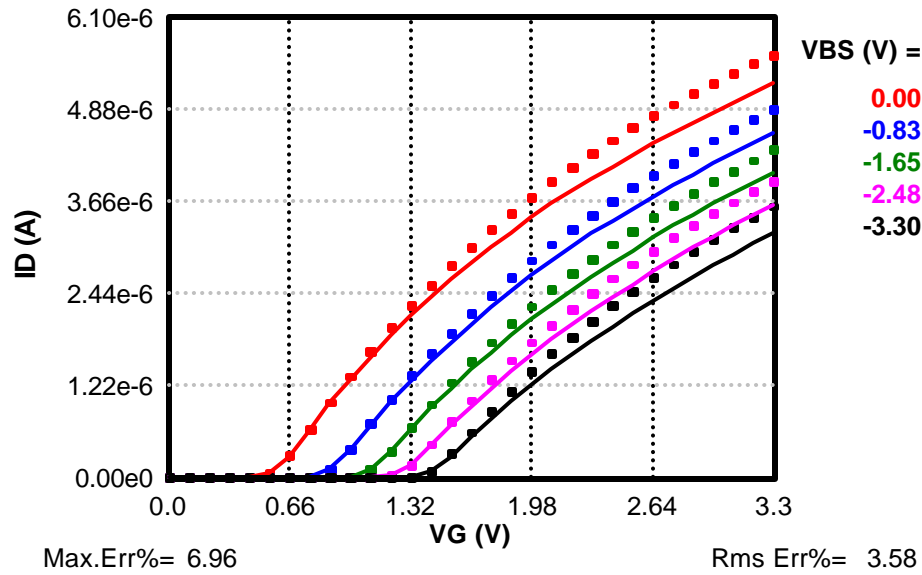


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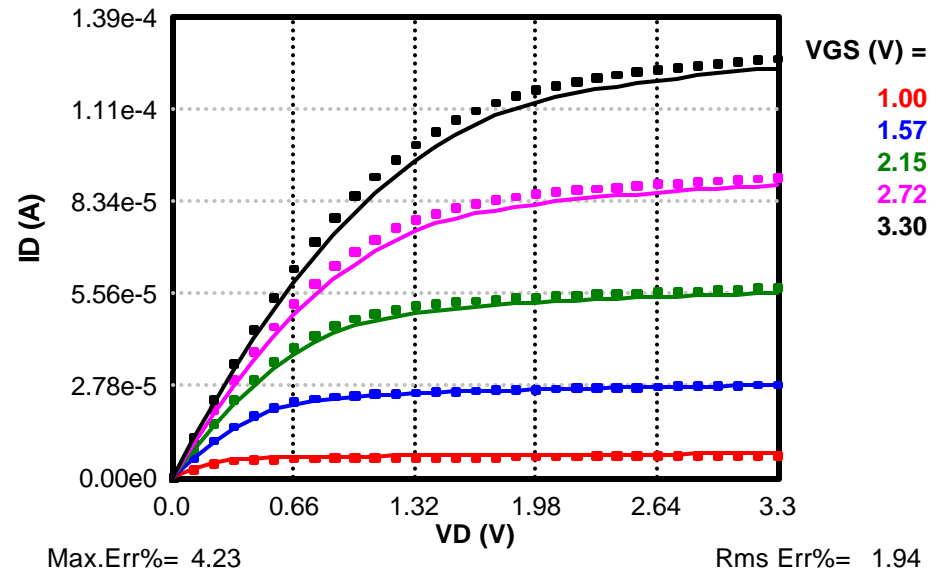




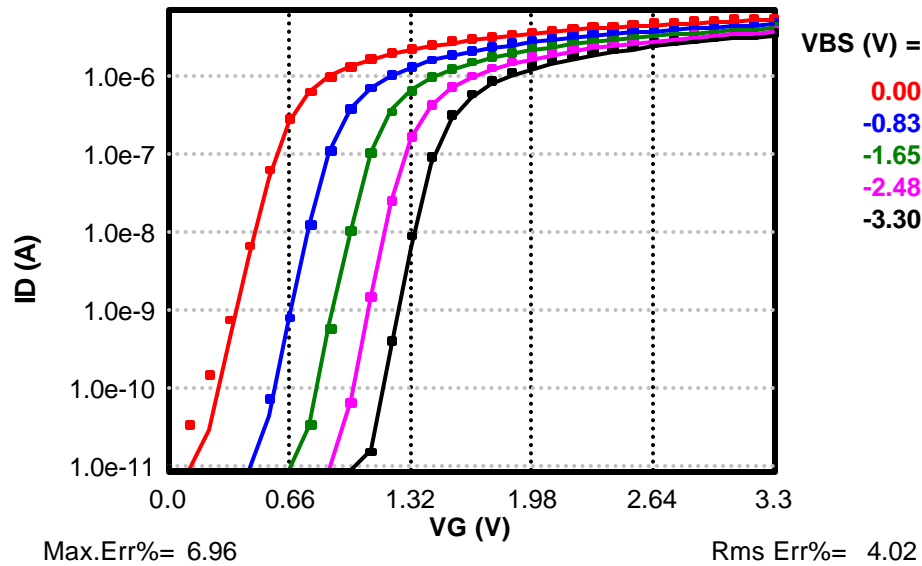
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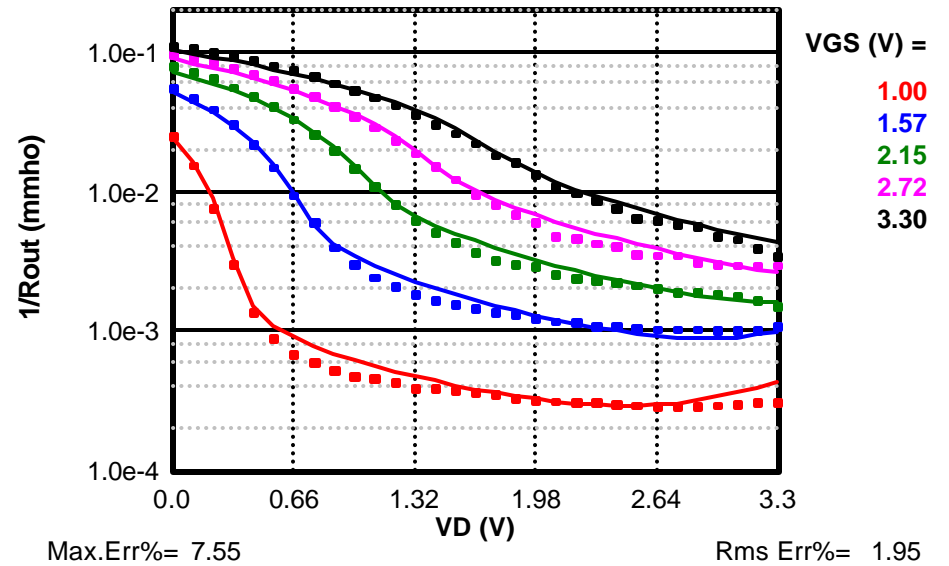
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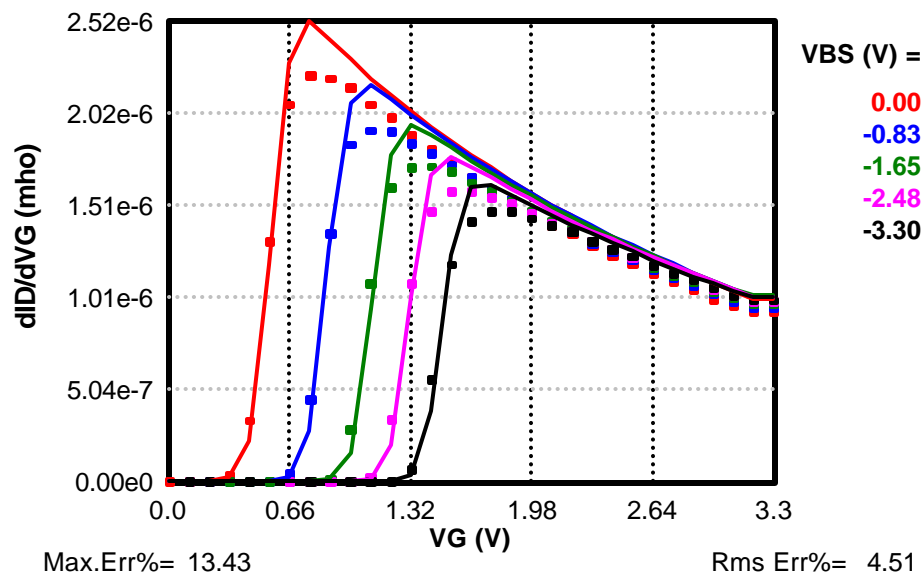
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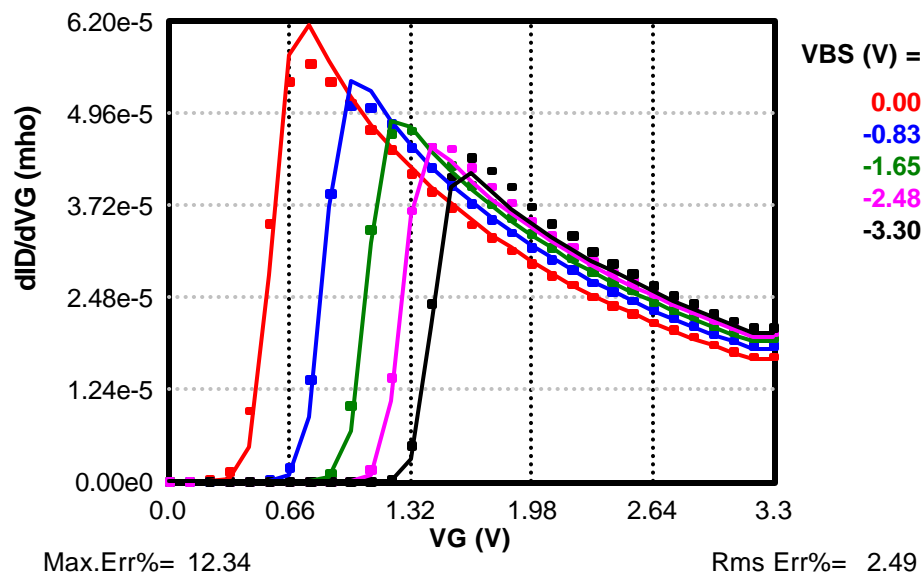
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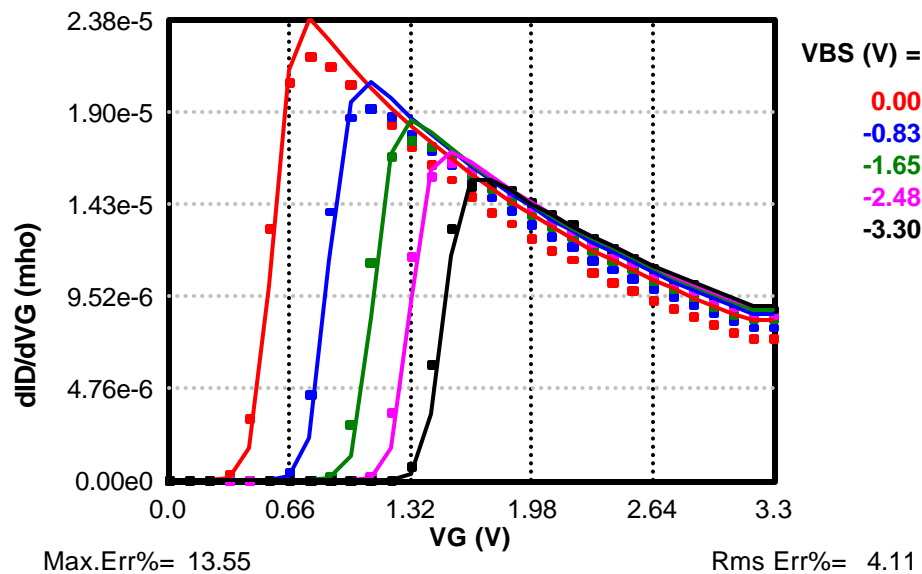
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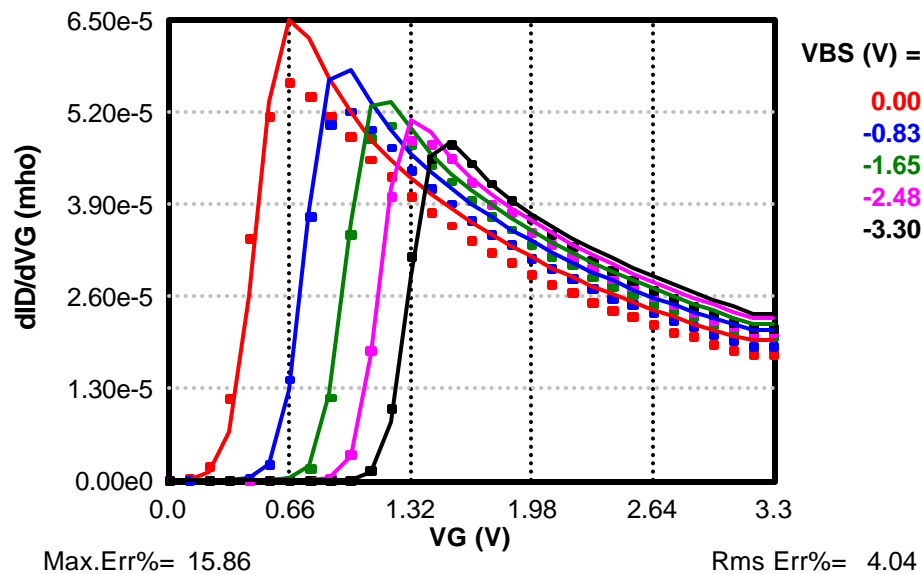
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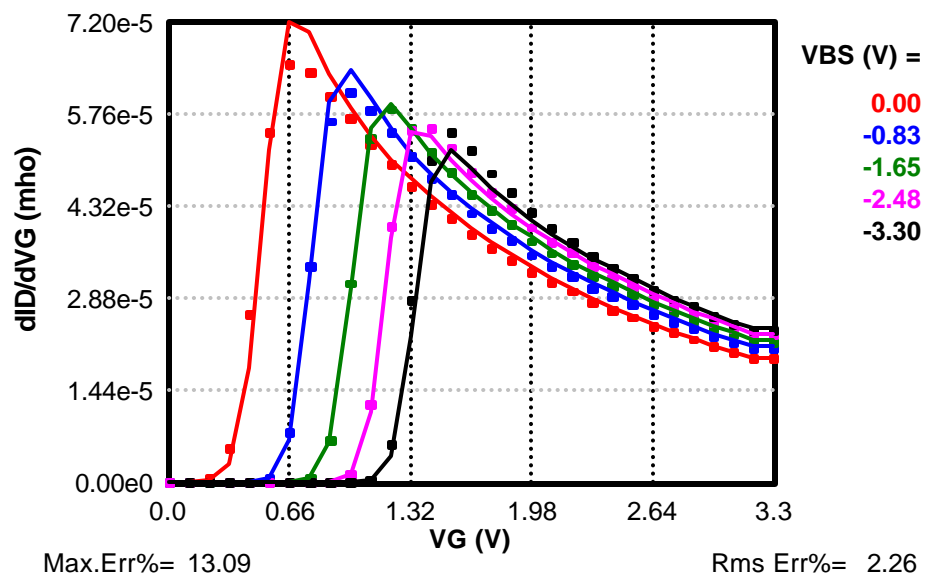
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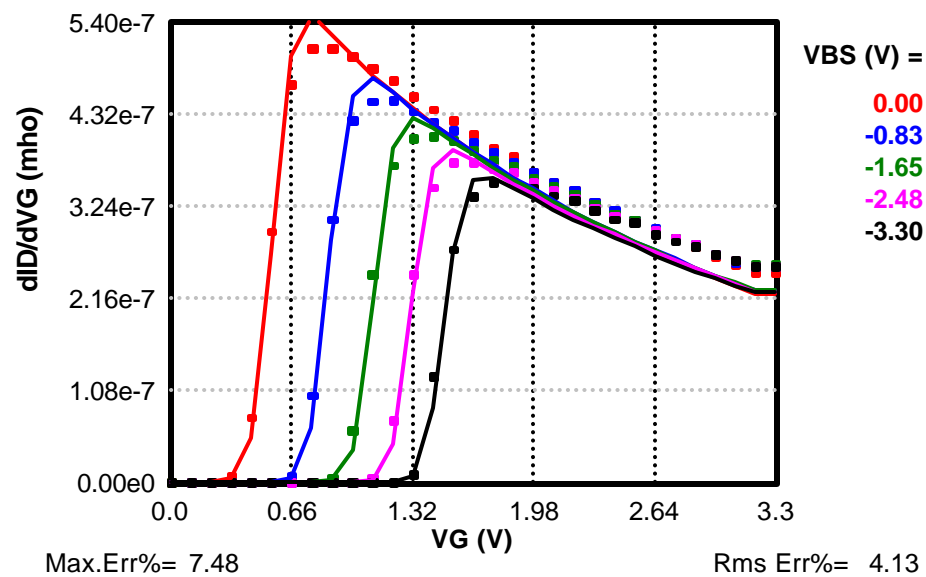
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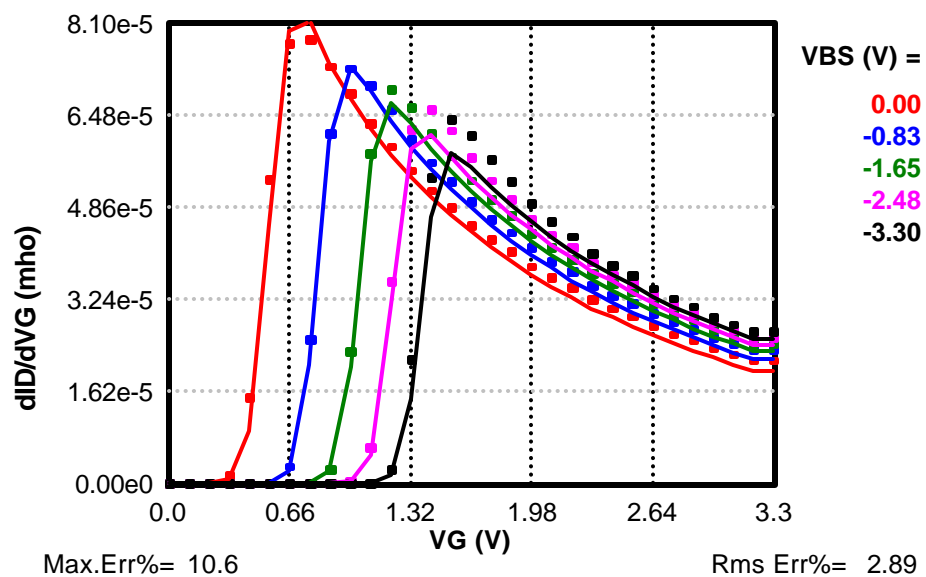
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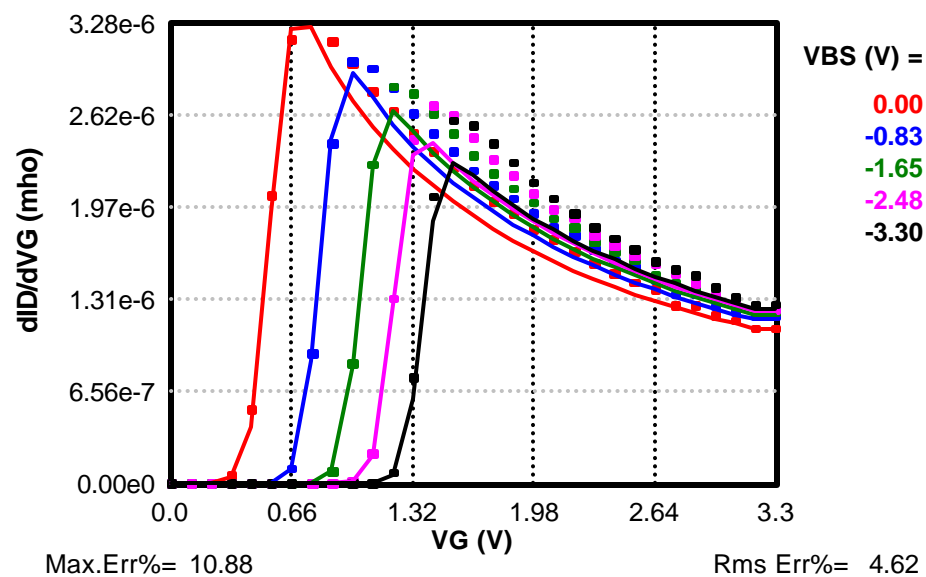
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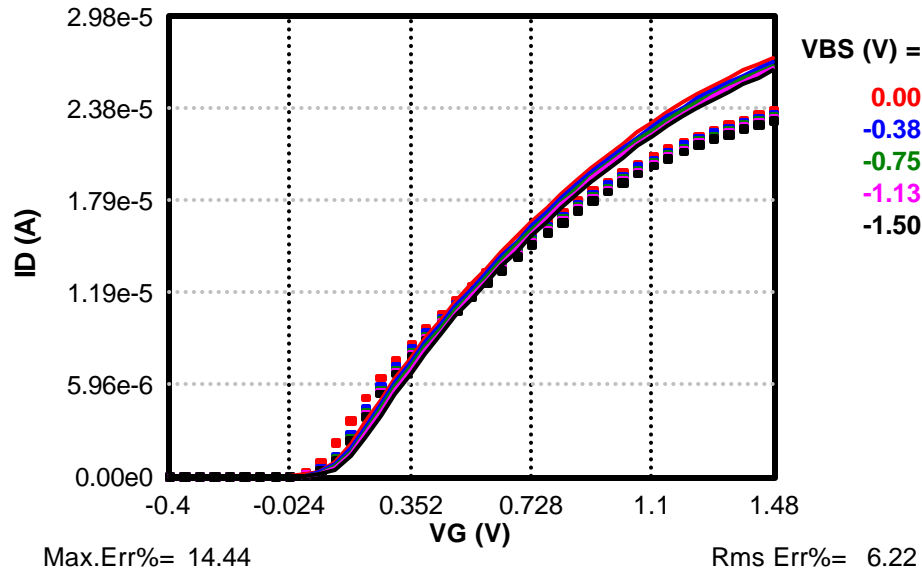
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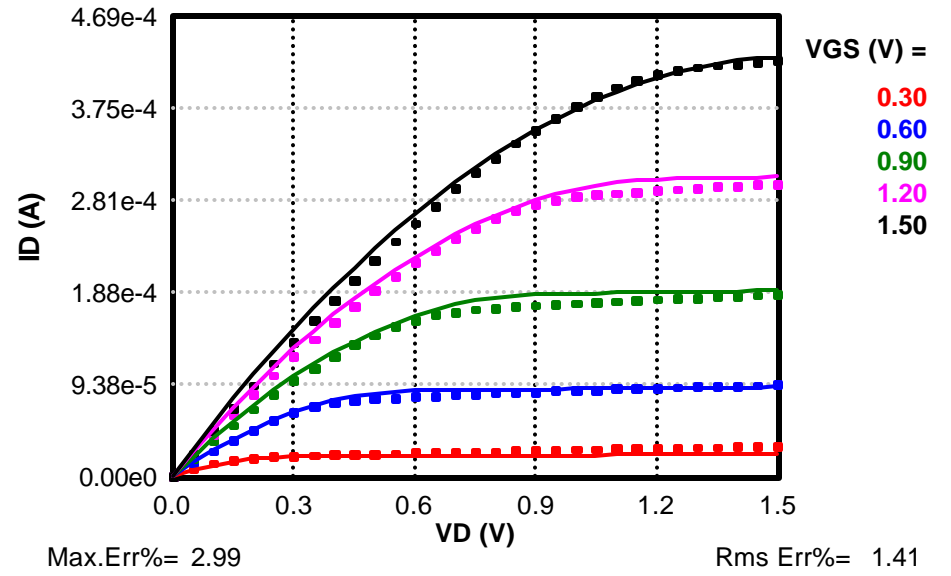
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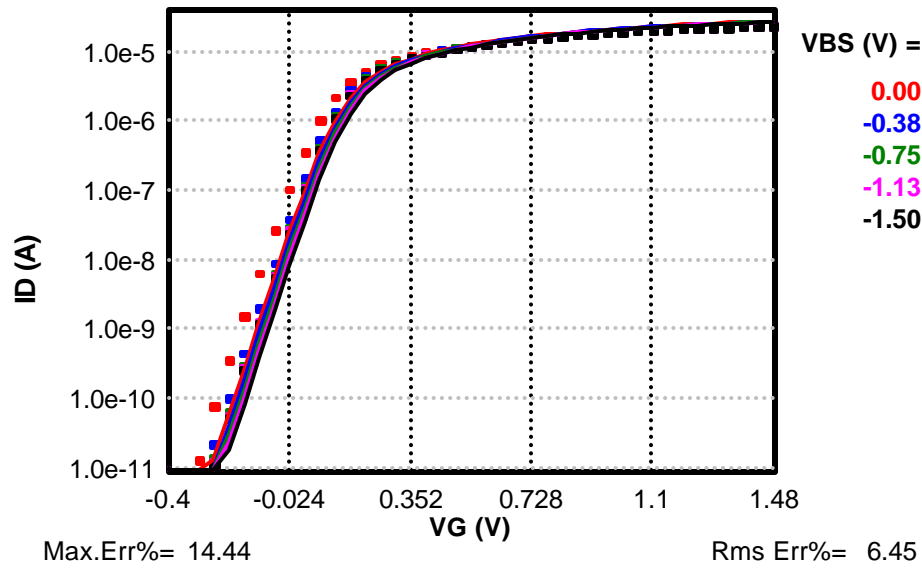
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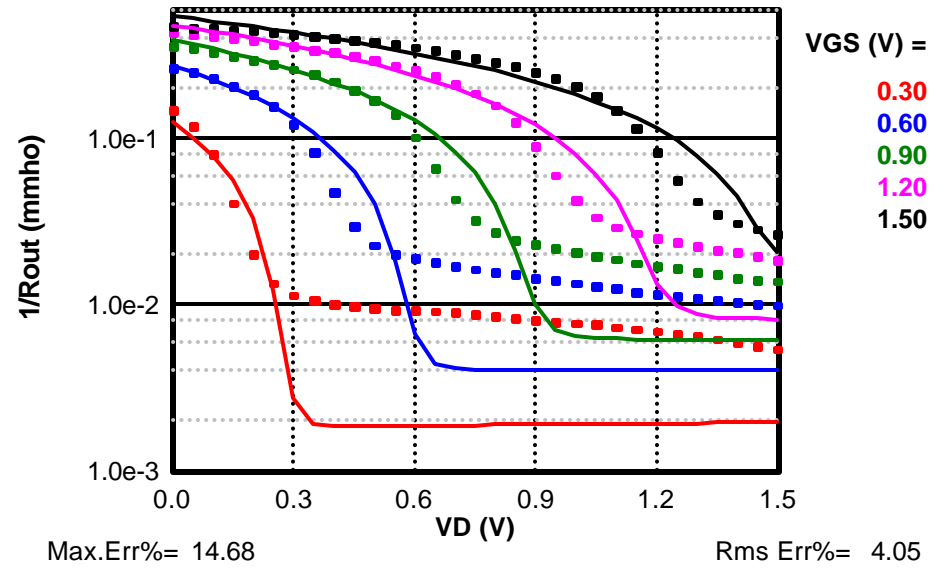
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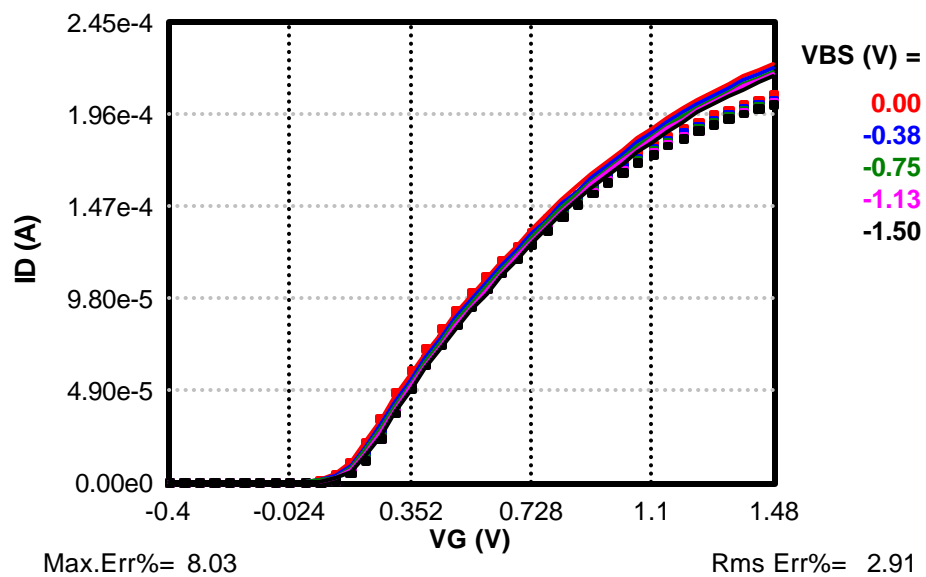
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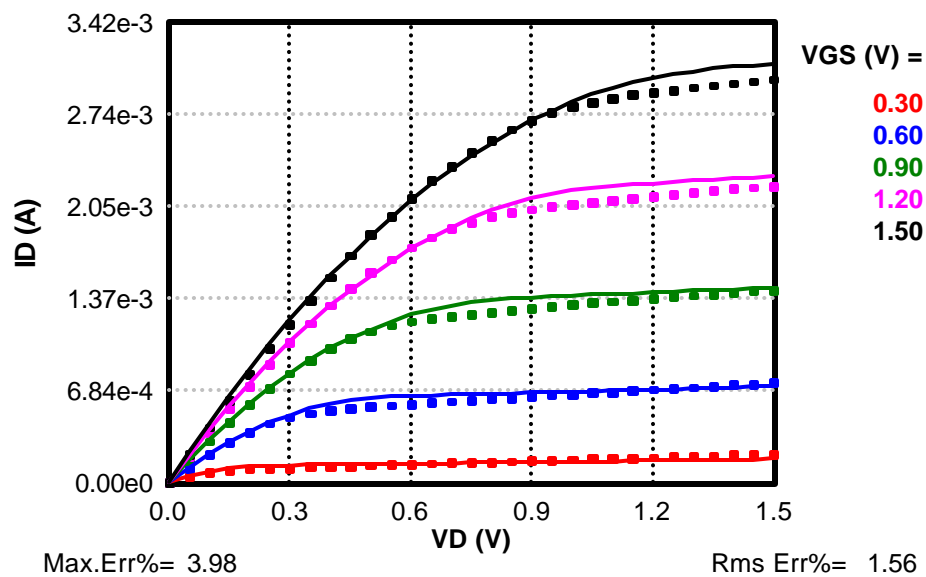
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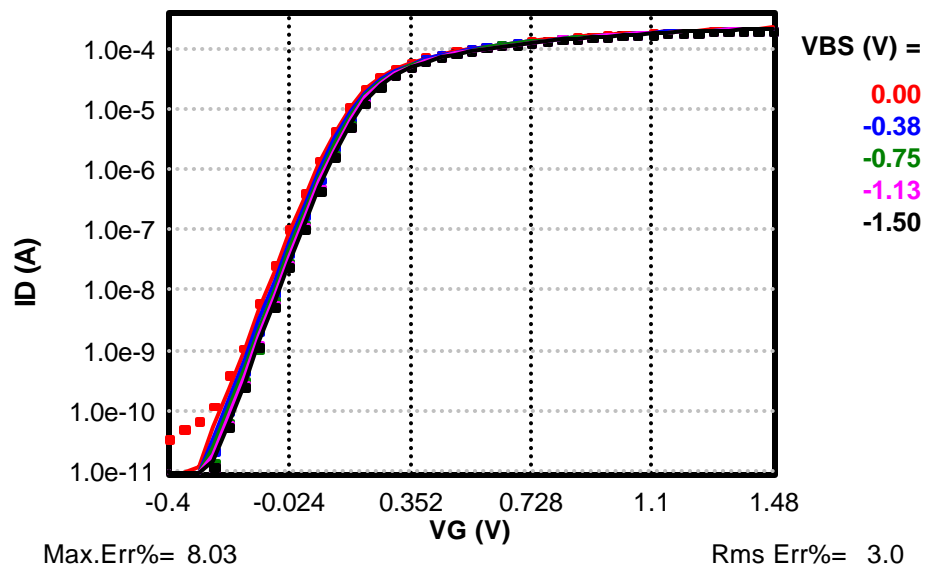
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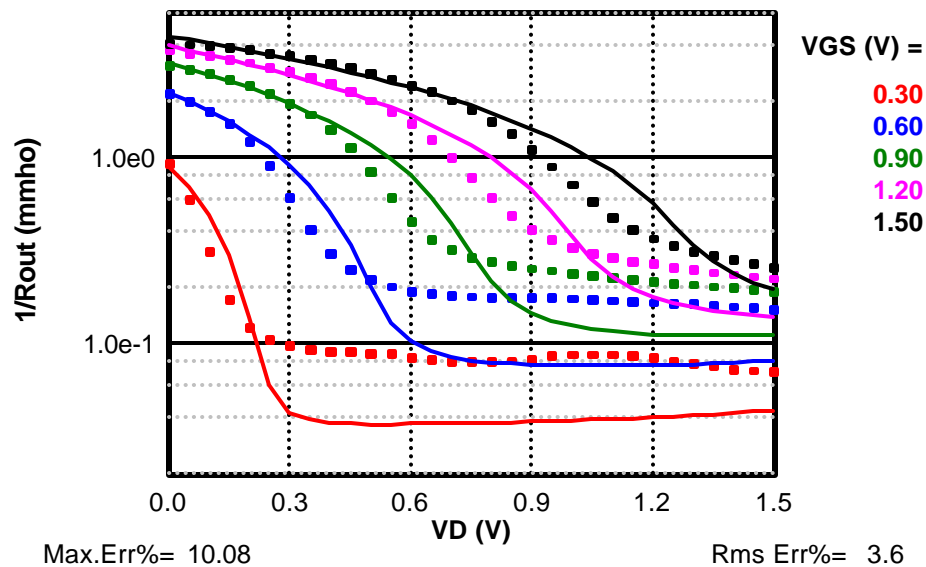
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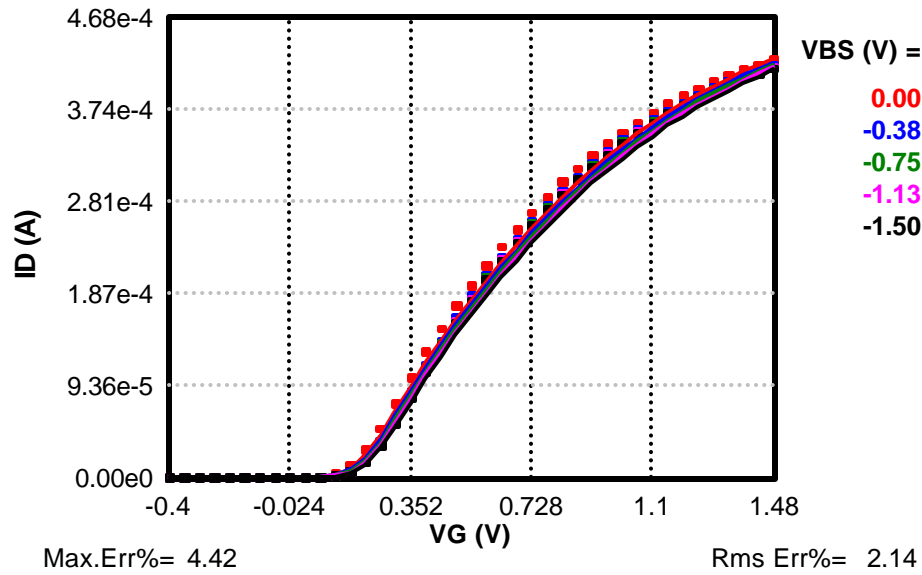
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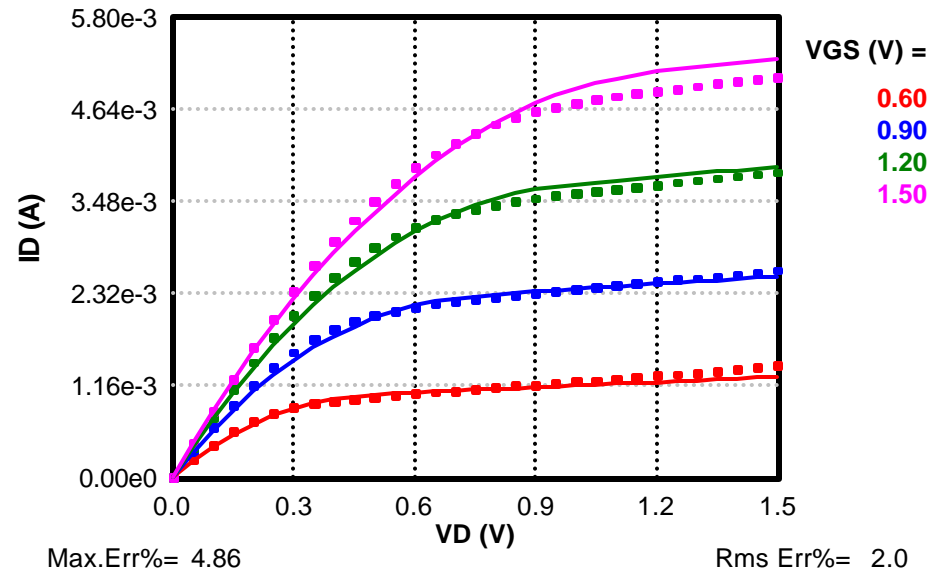
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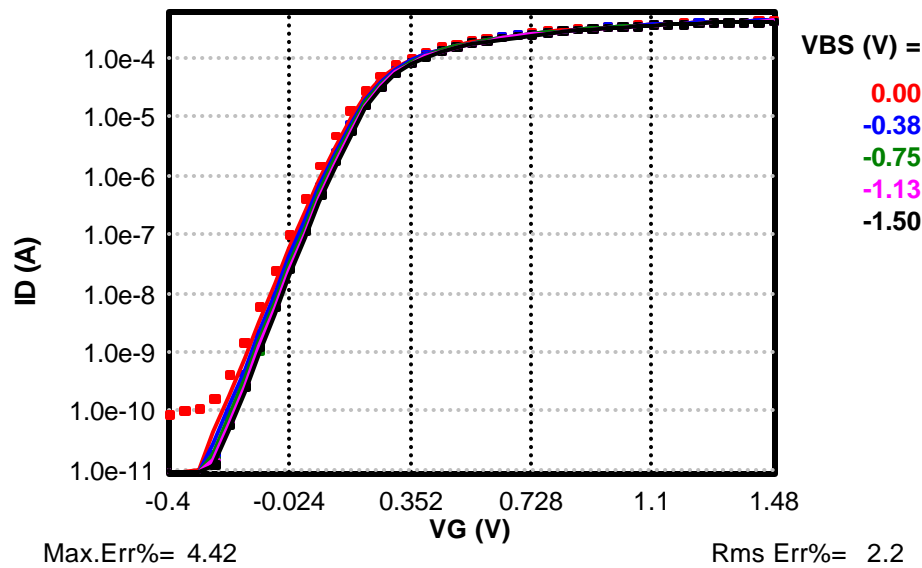
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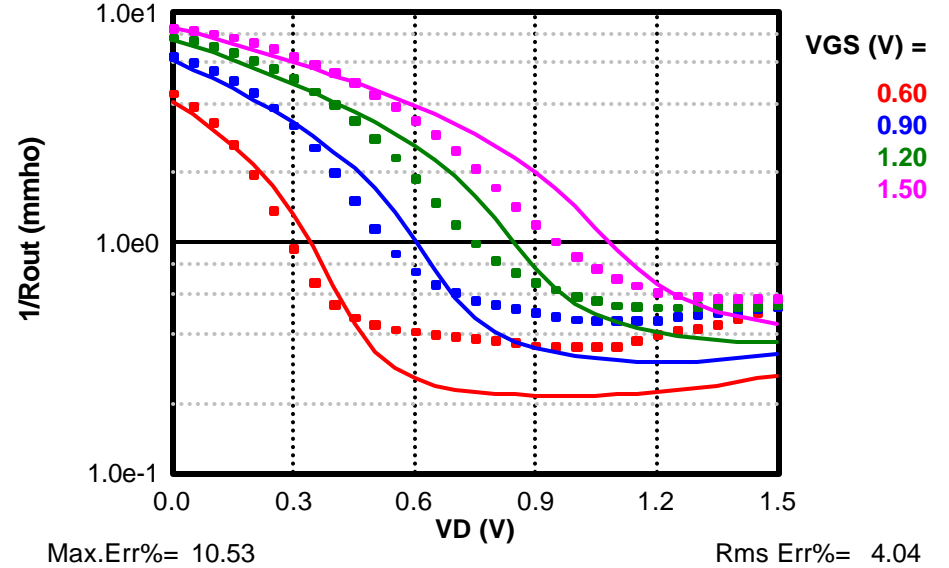
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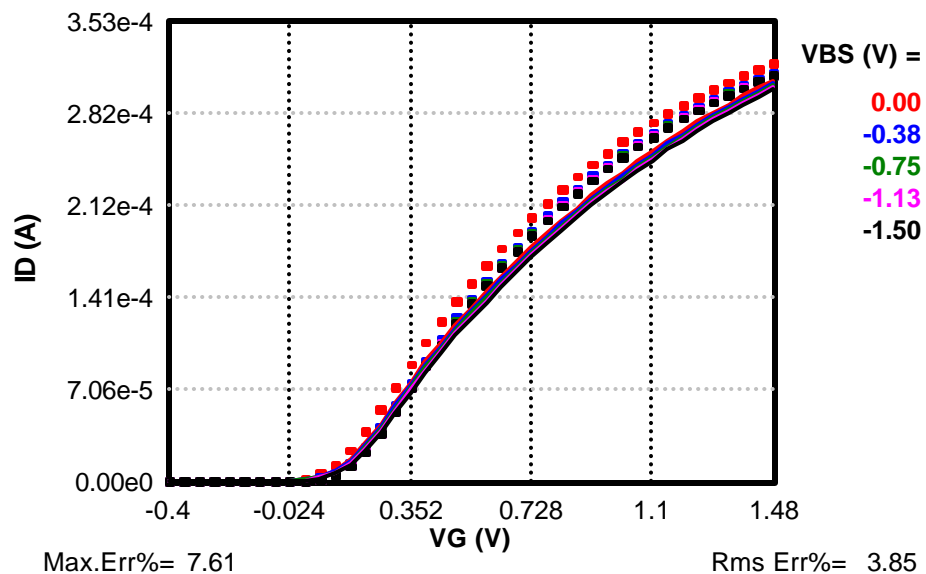
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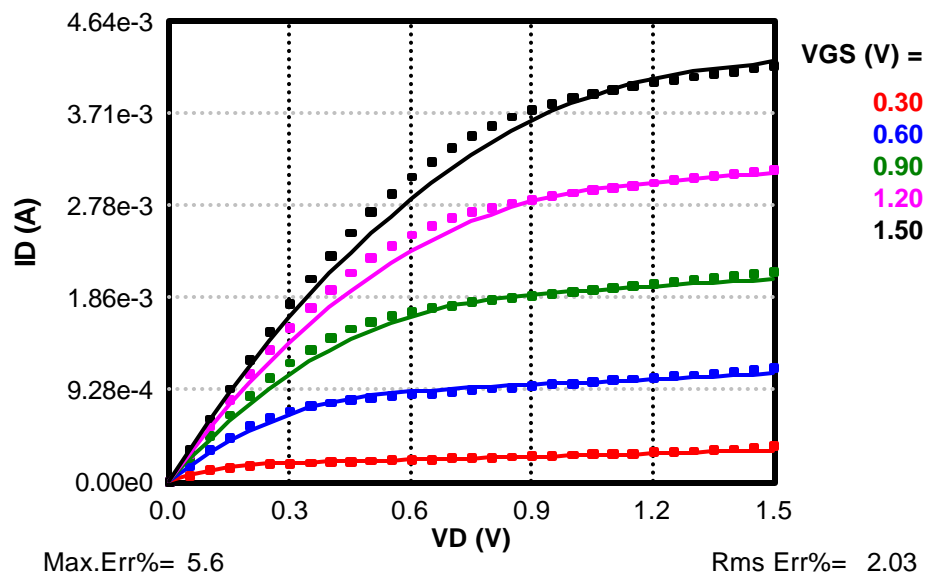
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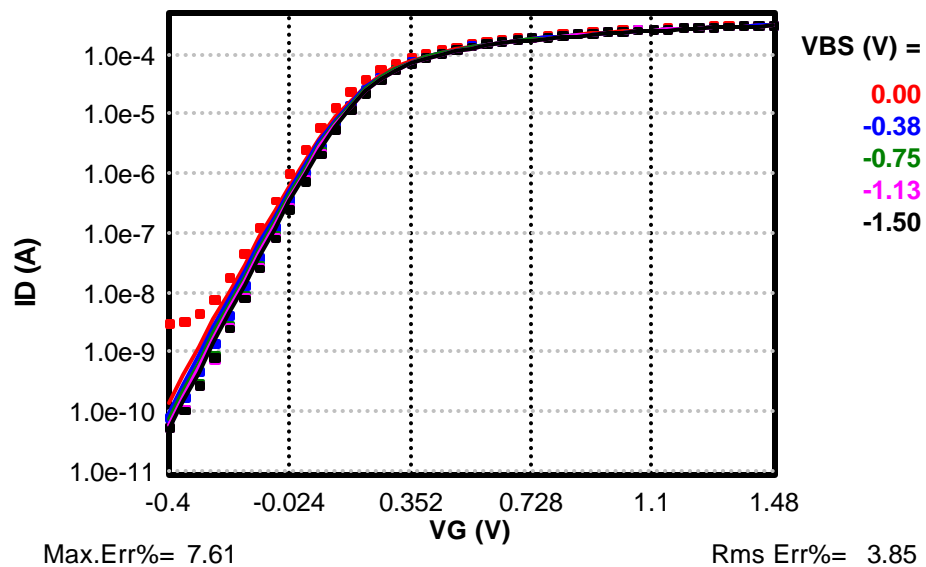
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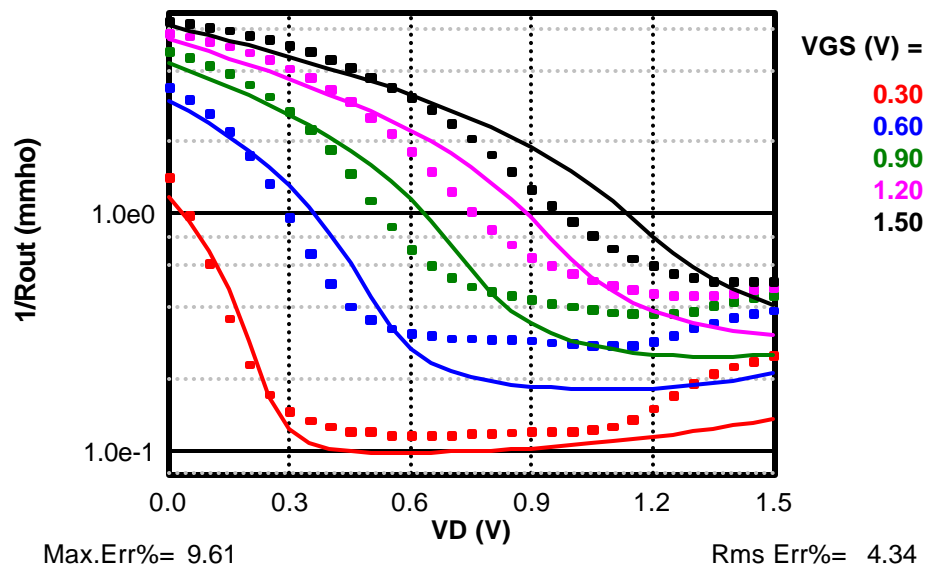
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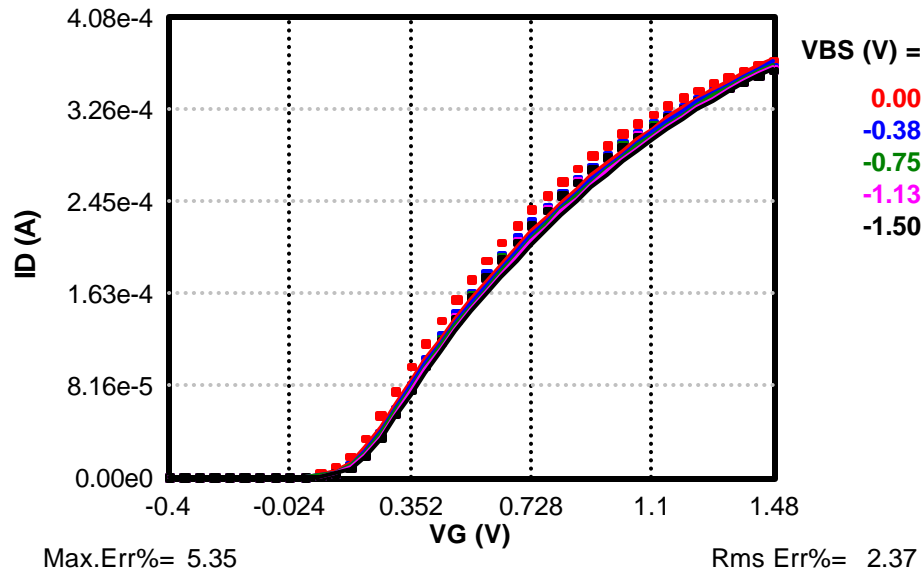
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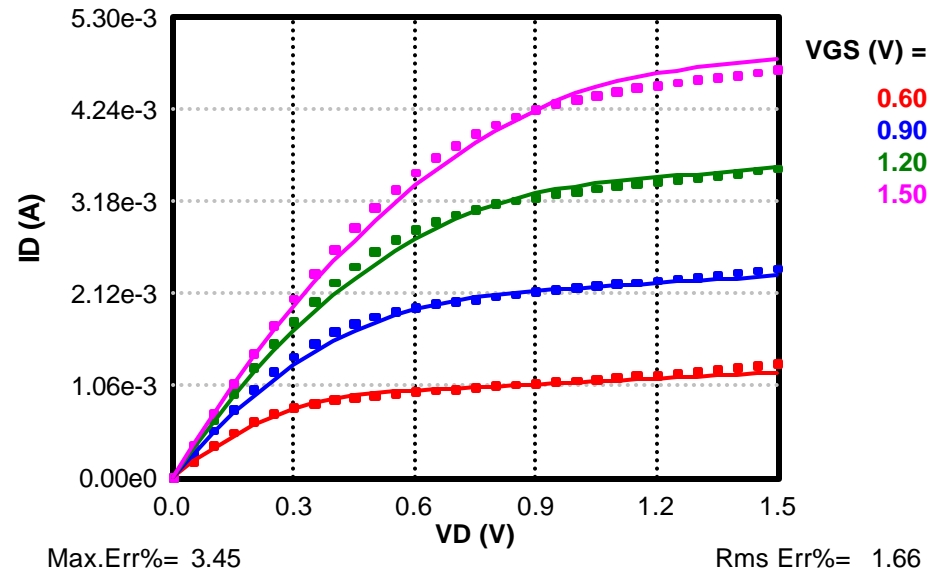
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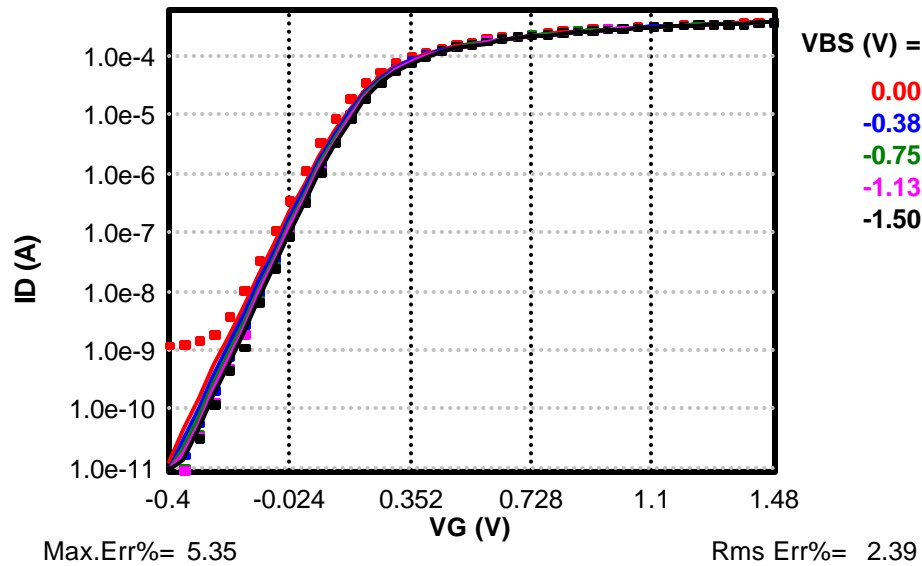
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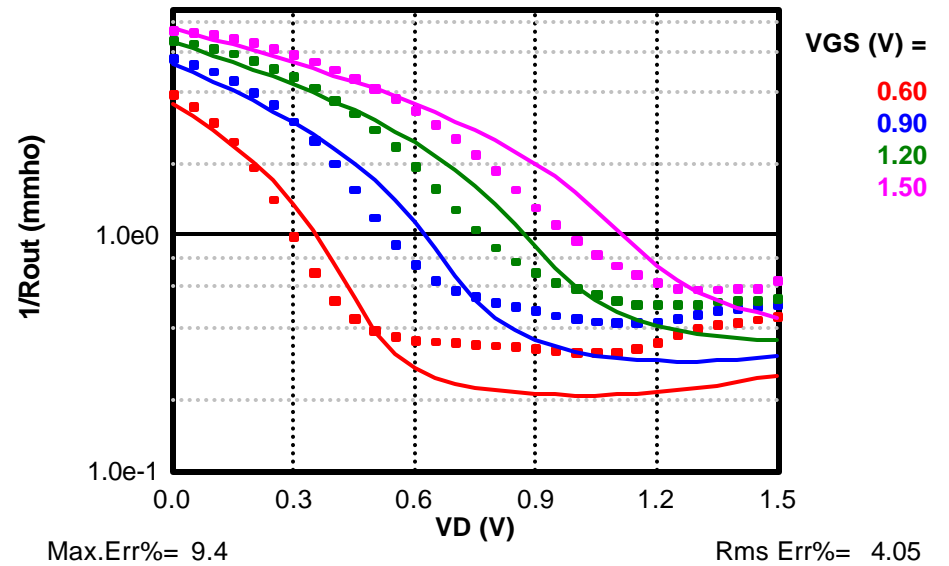
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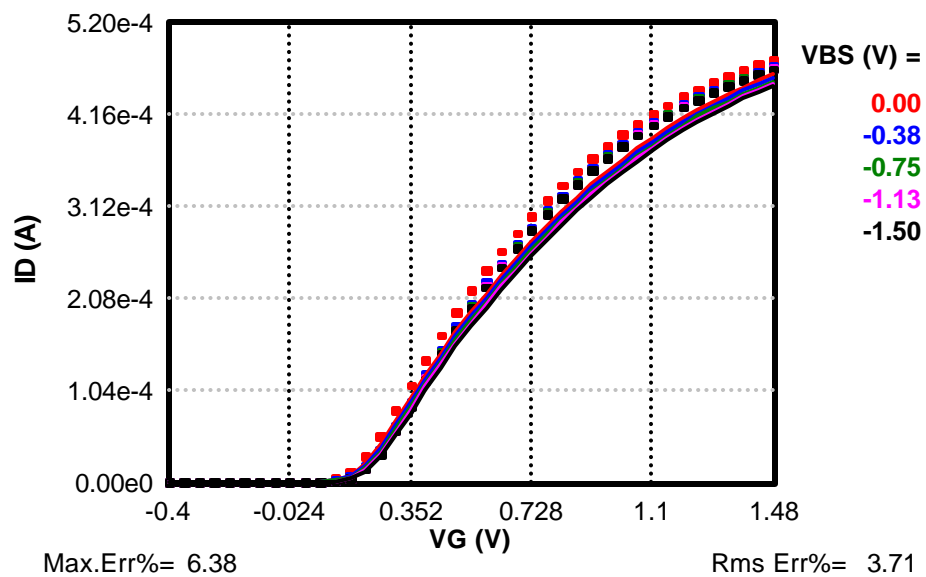


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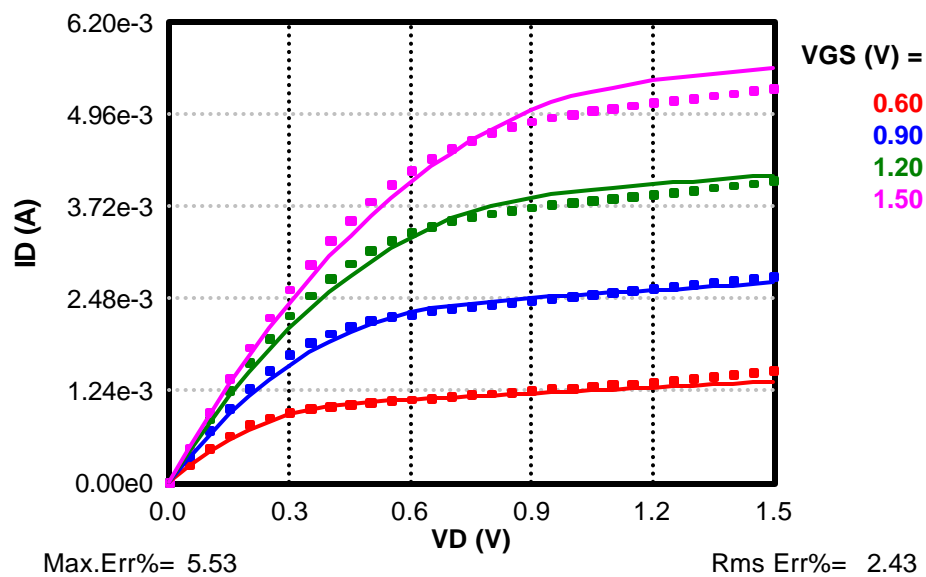




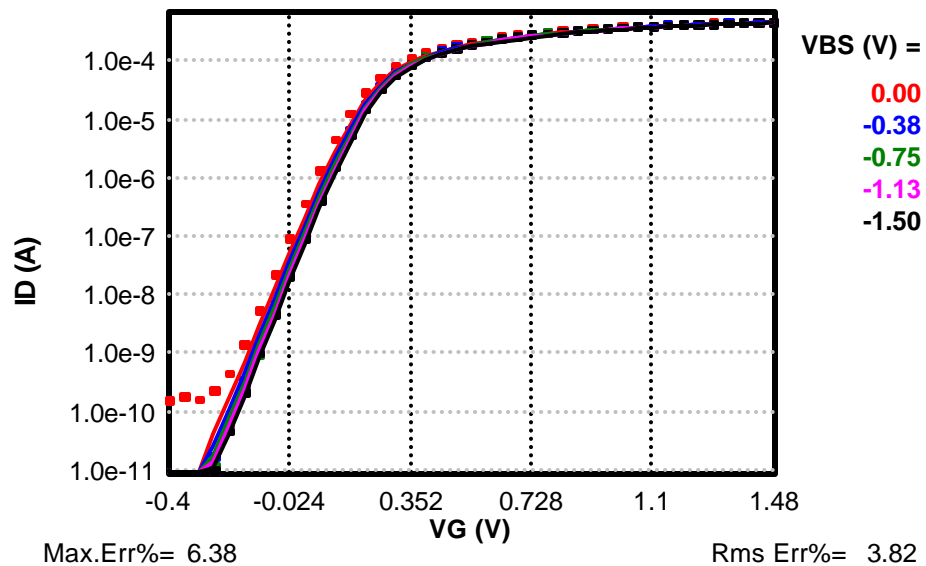
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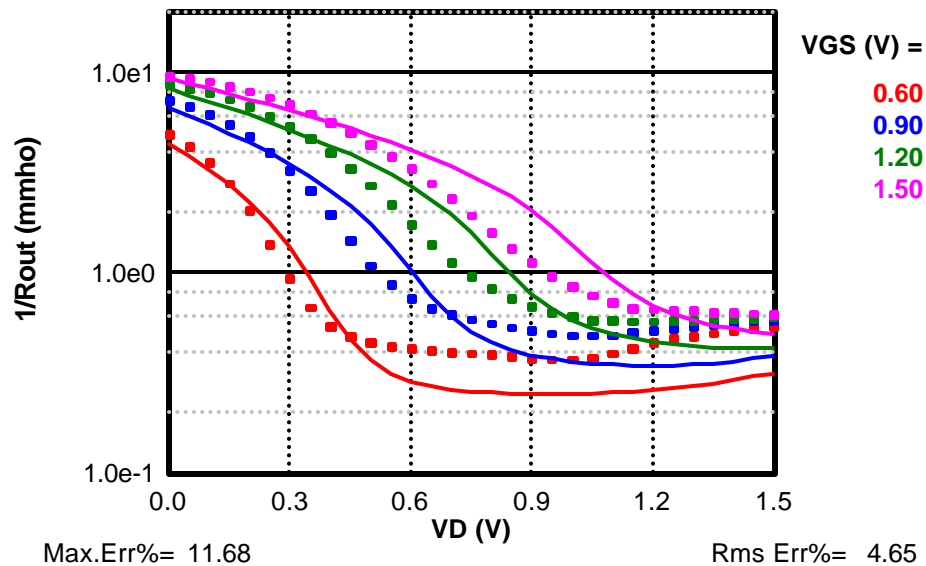
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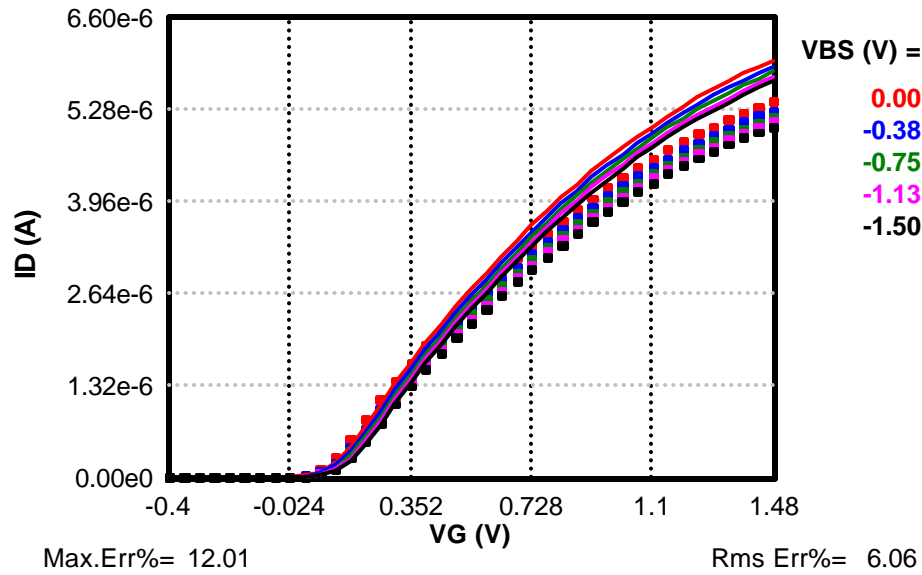
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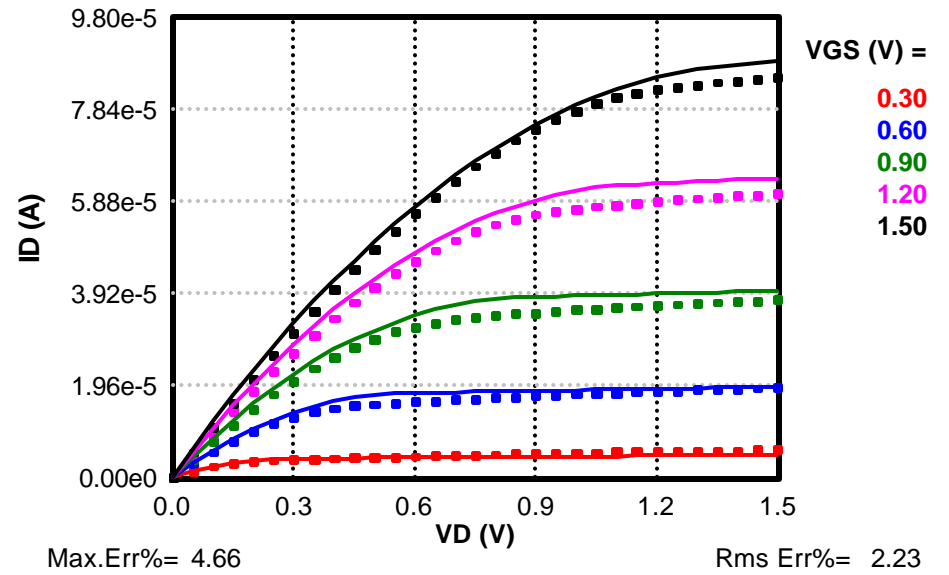
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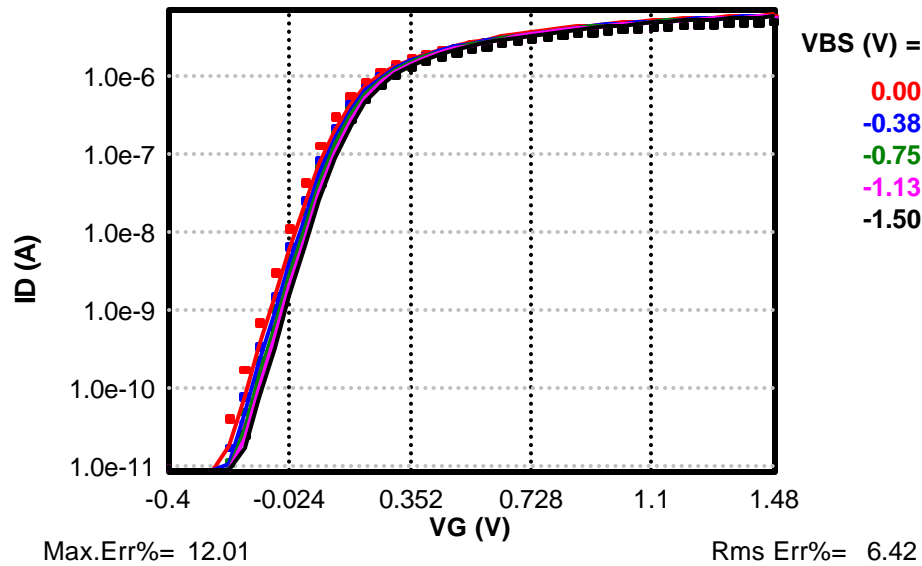
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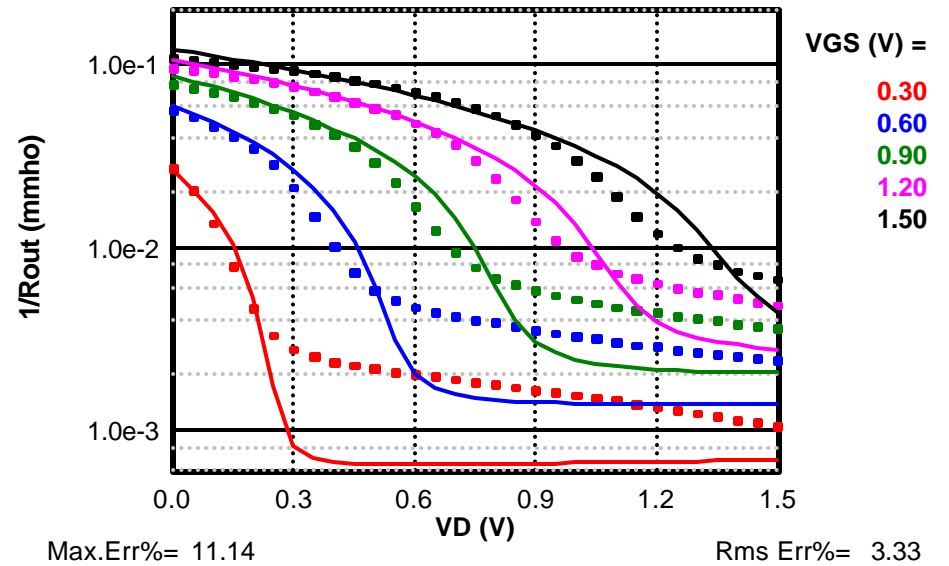
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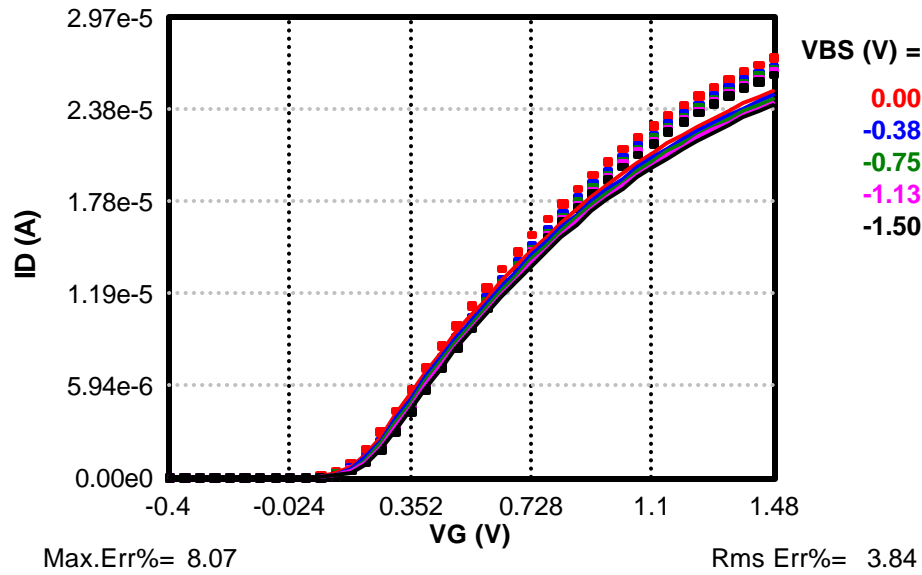
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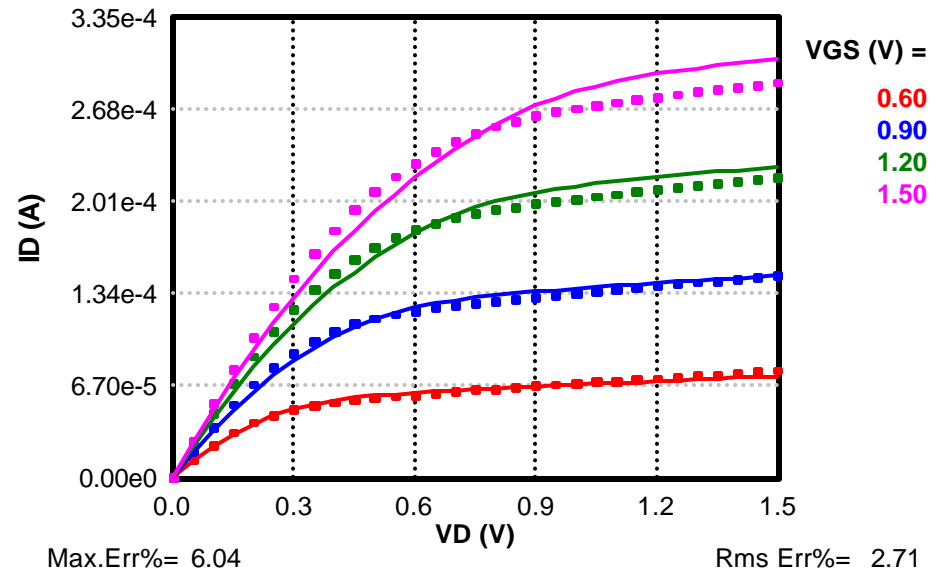
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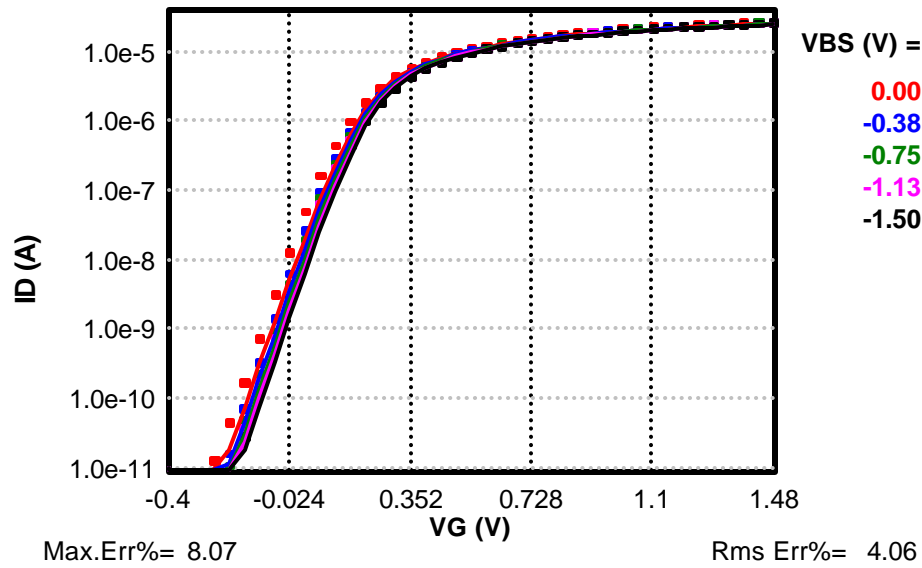
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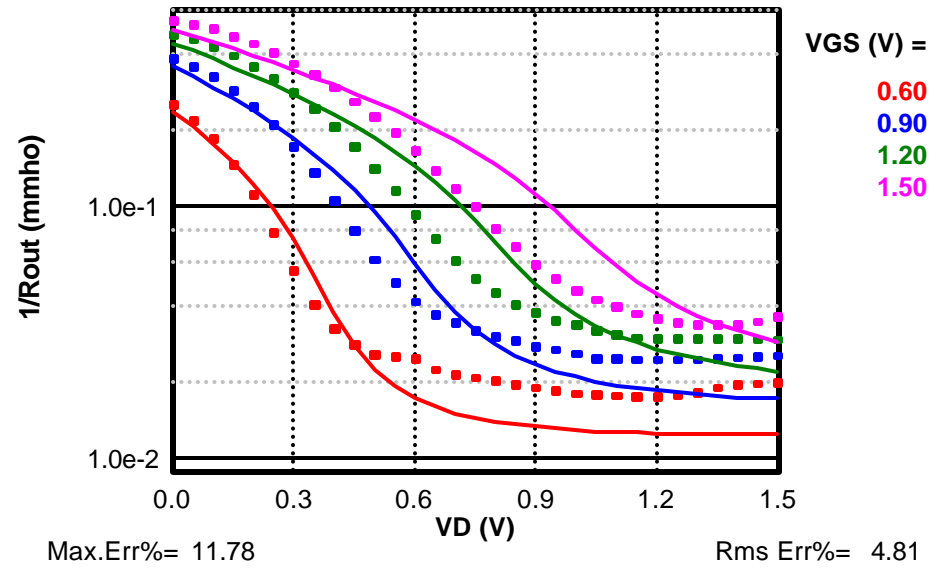
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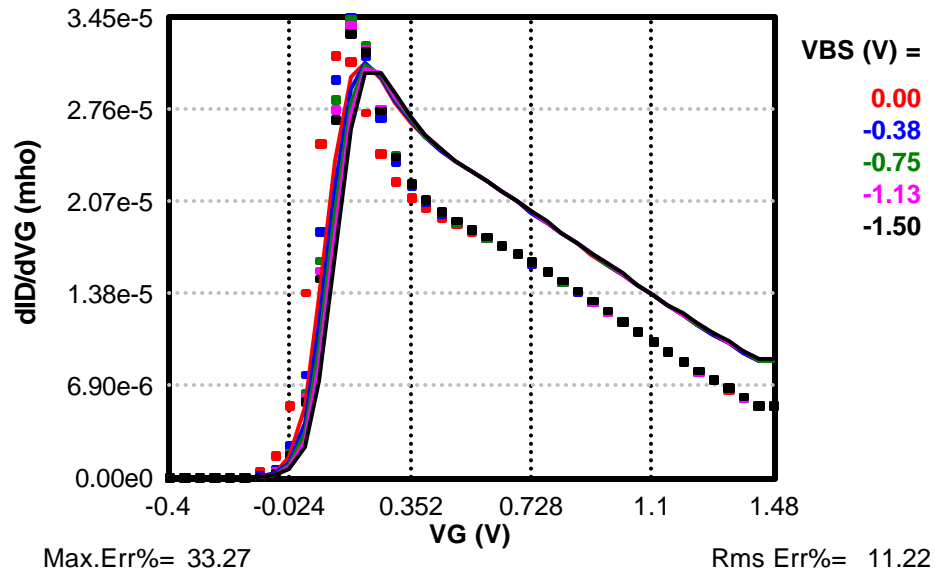
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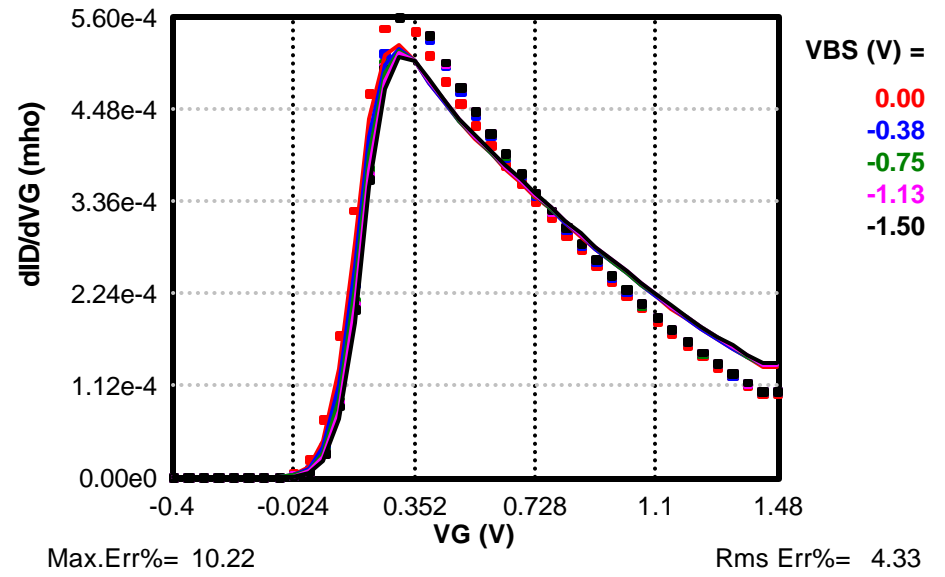
Z21D25.IV W/L=0.42/0.35 T=25C VB=0.00 V



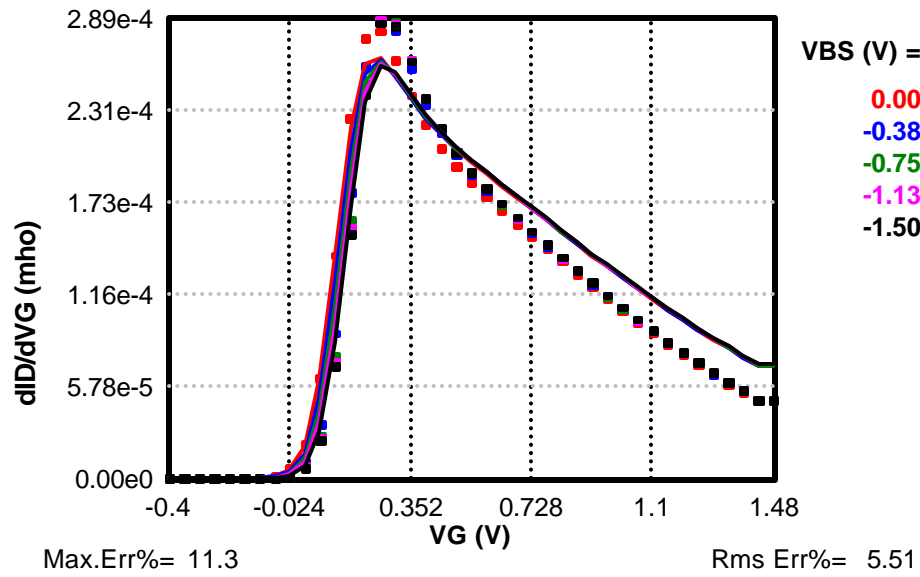
Z1D25.IV W/L=10.00/10.00 T=25C VD=0.05V



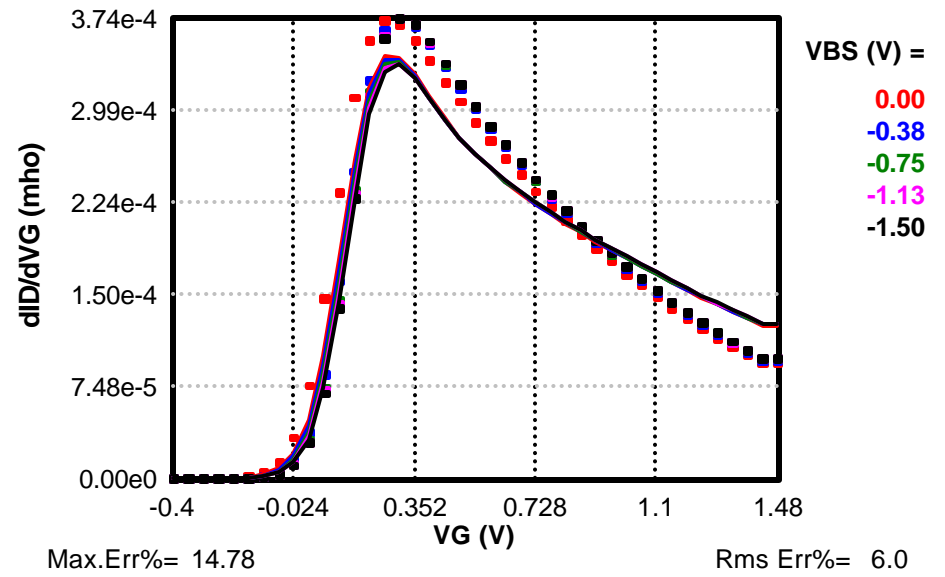
Z8D25.IV W/L=10.00/0.40 T=25C VD=0.05V



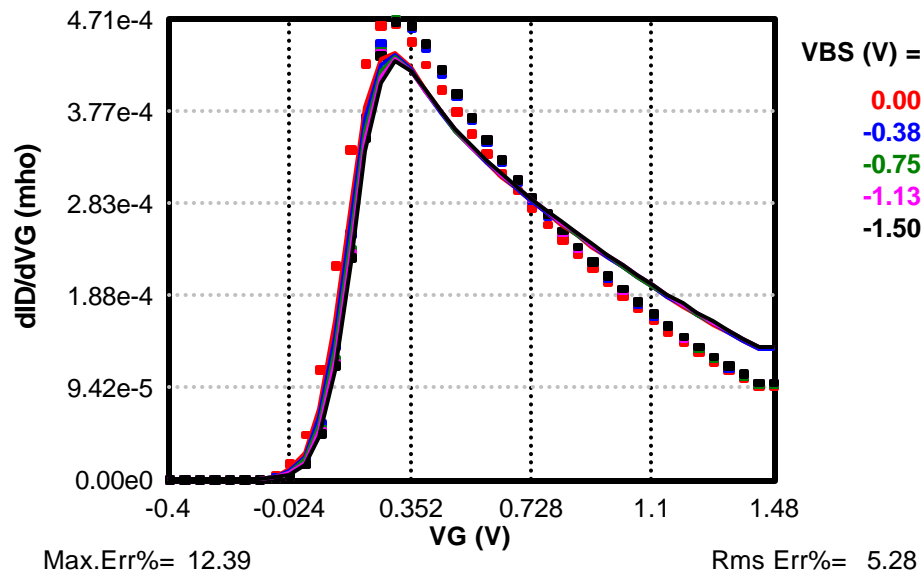
Z3D25.IV W/L=10.00/1.00 T=25C VD=0.05V



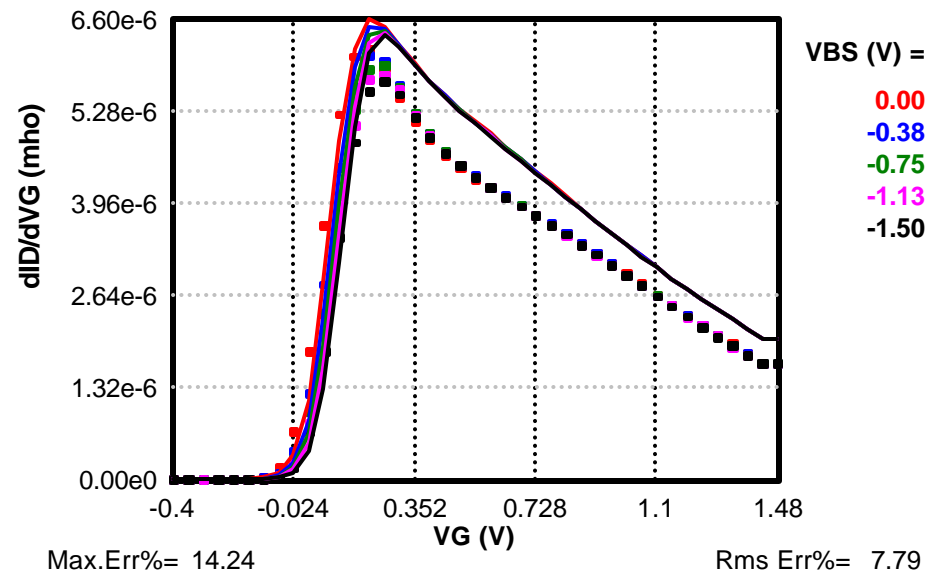
Z9D125.IV W/L=10.00/0.35 T=125C VD=0.05V



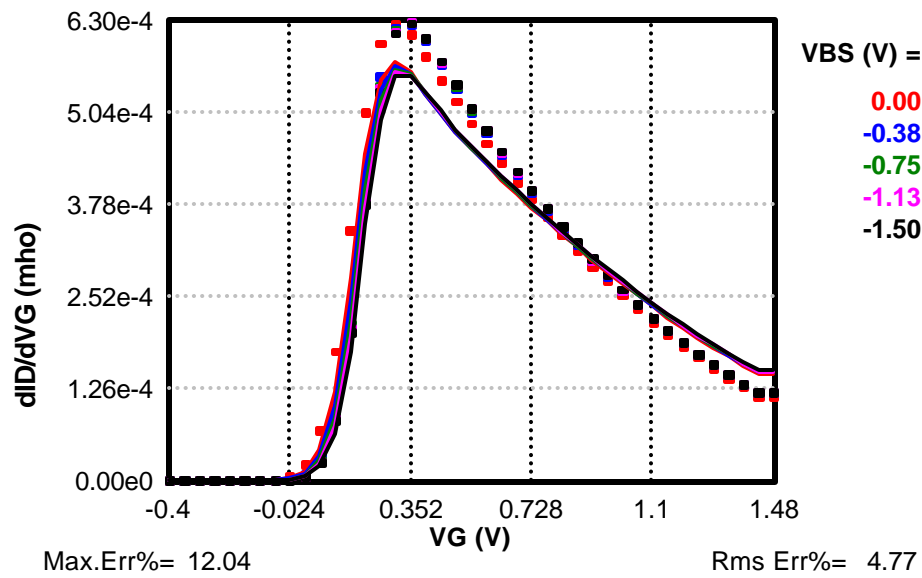
Z9D75.IV W/L=10.00/0.35 T=75C VD=0.05V



Z17D25.IV W/L=0.42/2.00 T=25C VD=0.05V



Z9D25.IV W/L=10.00/0.35 T=25C VD=0.05V



Z21D25.IV W/L=0.42/0.35 T=25C VD=0.05V

