TRACKING TREND

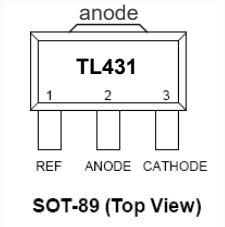
Shunt regulator "Ripple" TL431 U(out)±15V

техническое описание

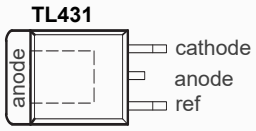
Двуполярный источник питания с параметрической стабилизацией напряжения, расчётное значение величины ослабления напряжения помехи (ripple rejection)< -100дБ *в полосе пропускания каналов стабилизации напряжения* F(-3дБ)≥ 1кГц (CF≤ 820µF). *Защита выхода стабилизаторов от короткого замыкания. Высокая точность выходного напряжения* ИОН (UREF(dev)= 2.495В ±3мВ (тип.)) *и хорошая термостабильность* (αU(ref)< 50ppm/℃) *источников опорного напряжения* (ИОН) *в широком диапазоне значений температуры. Значение динамического и статического выходного импедансов стабилизаторов напряжения* Z(ka)< 0.22Ом (тип.).

Стабилизаторы напряжения (U1,U2) *нагружены отражателями тока* (Q1\D1, Q3\D2) *с коэффициентом отражения тока* ≈ 2 (R4\R1, R11\R12), *выходными импедансами* Z(ср.кэ)≈ 75 кОм *и полюсами на частоте* F(ср)≈ 120 кГц, *входные цепи отражателей* (D1,D2) *питаются током от генератора стабильного тока* (ГСТ) (U3,Q2), *симметричная схемотехника отражателей в сочетании с "плавающим" токовым питанием от* ГСТ *обеспечивает высокую стабильность рабочих точек каскадов и хорошую термостабильность* (ТКН< 5E-03%\℃) *при изменении тока нагрузки, температурных изменений и нестабильности по току и напряжению источников питания* ±35V. *Номиналом резистора* R9 *задаётся выходной ток* ГСТ. *Отношение номиналов резисторов в цепи обратной связи* (R2\R6, R8\R10) *определяет выходное напряжение стабилизаторов напряжения* (U1,U2).
Ёмкостный буфер (CF) (C1\C2, C3\C4) *замыкает нагрузку* (R(L)) *стабилизаторов по переменному току.*

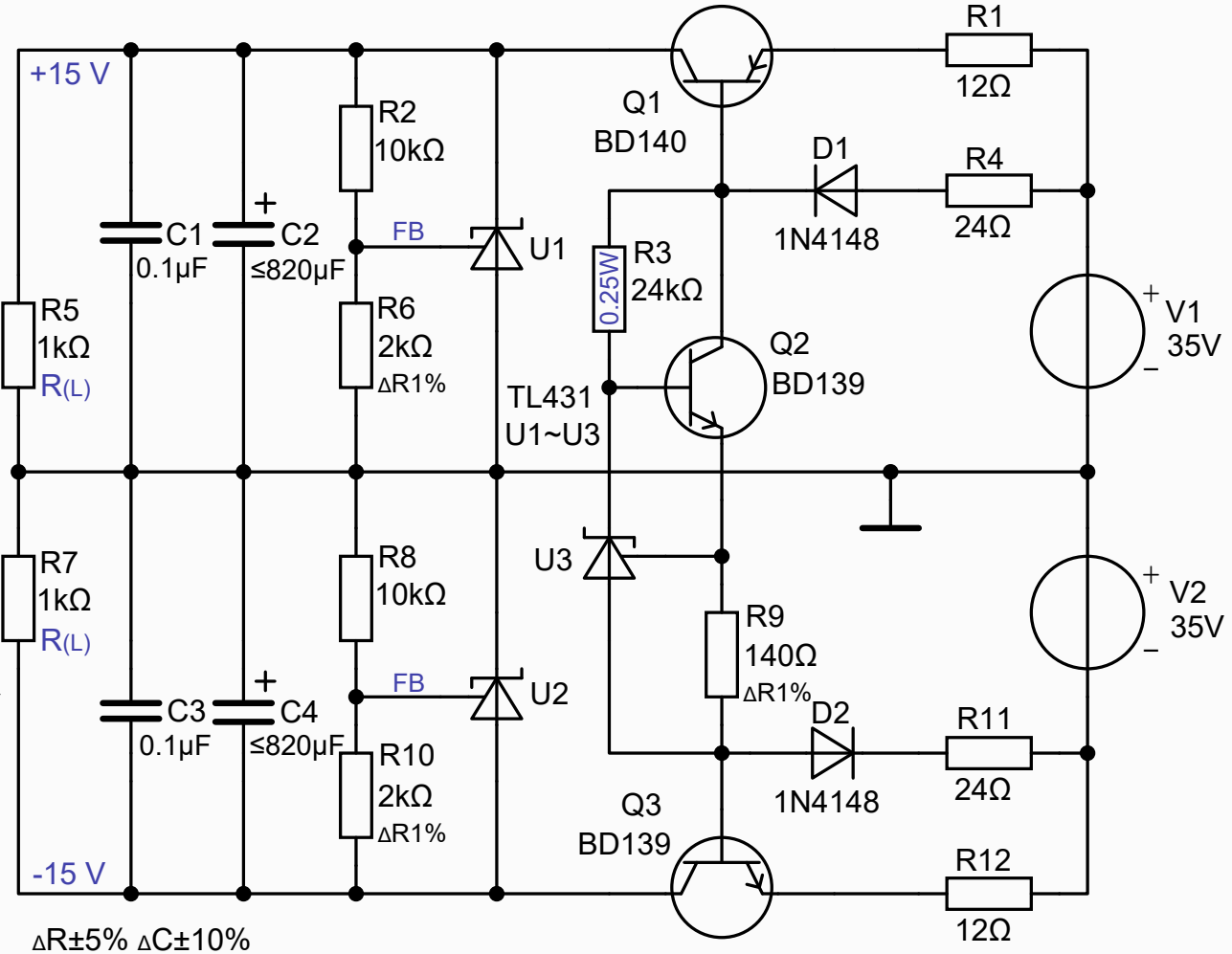
Tracking Trend



SOT-89 (Top View)



TO-252 (Top View)



ΔR±5% ΔC±10%

pairs thermal compensation: Q1\D1, Q3\D2

https://dzen.ru/tracking_trend

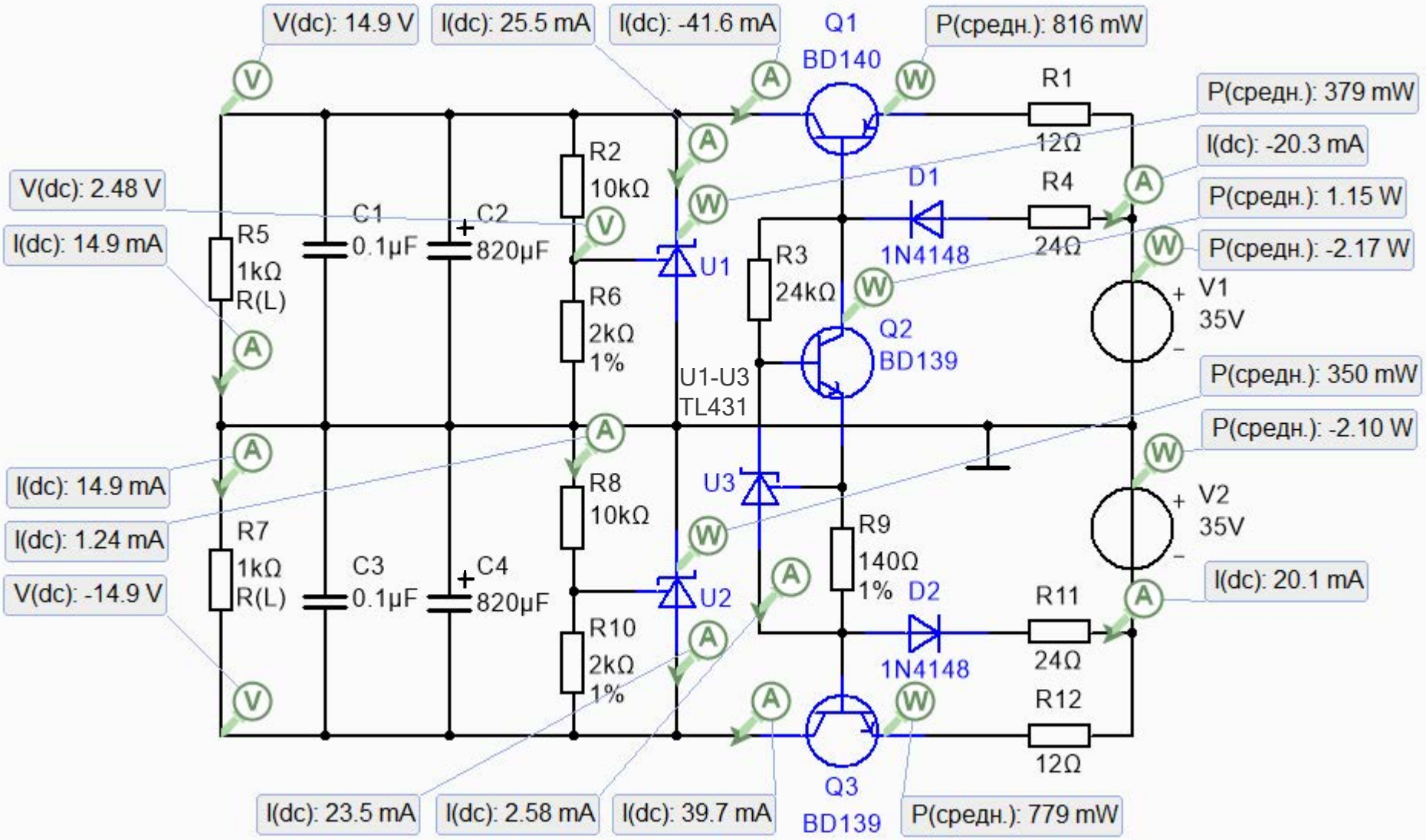
апрель, 2024 год

Shunt regulator "Riple"

ID: 43947596

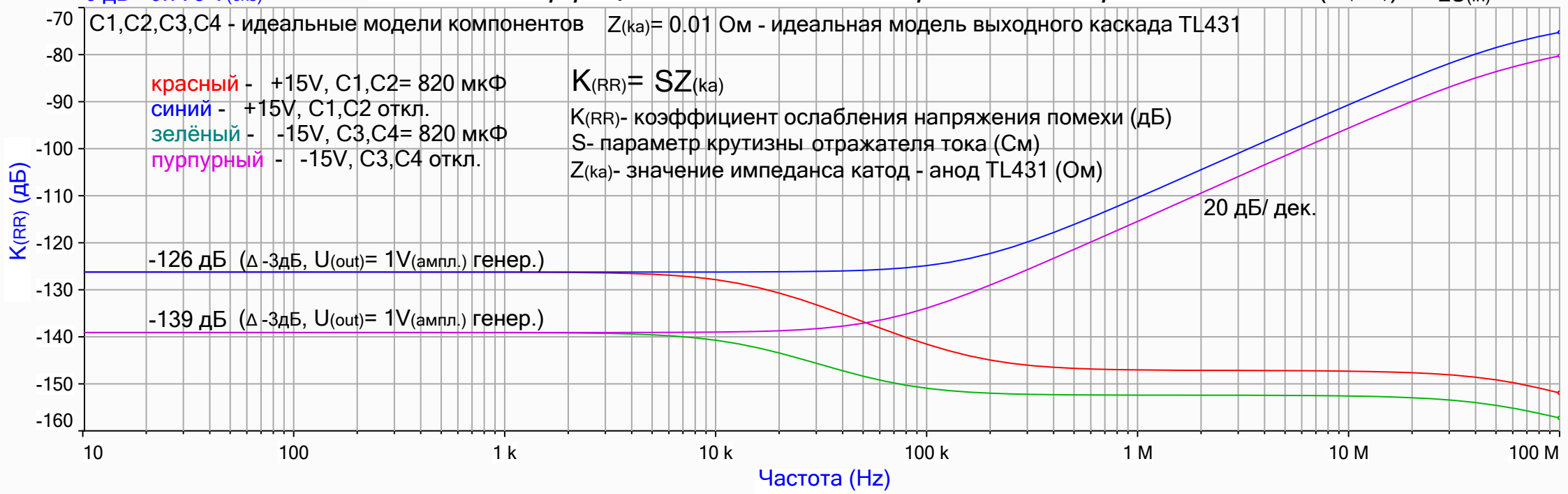
SPICE Models

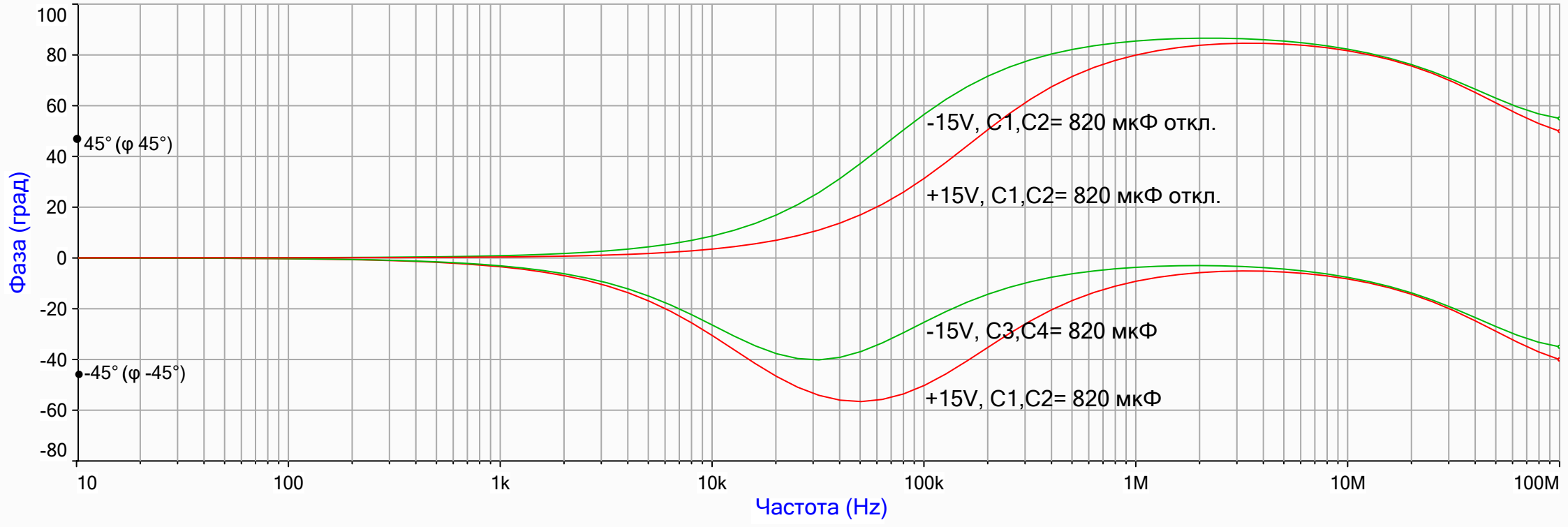
Карта токов, напряжений и мощностей (КНТМ).
Чёрный цвет - идеальные модели компонентов.
Синий цвет - реальные модели компонентов.



Shunt regulator "Riple"

0 дБ= 0.775 V(скз) **Анализ AC** *Коэффициент ослабления напряжения синфазной помехи* ($K_{(RR)}$) $\frac{\Delta U_{(out)}}{\Delta U_{(in)}}$





Shunt regulator "Riple"

Анализ АС *Выходной импеданс* ($Z_{(out)}$) *источников питания* ±15V

$\frac{\Delta U_{(out)}}{\Delta I_{(out)}}$

0 дБ= 1 Ом

C1,C2,C3,C4 - идеальные модели компонентов

$Z_{(ka)}$= 0.01 Ом - идеальная модель выходного каскада TL431

-43

0.01 Ом

0.001 Ом

-20 дБ/ дек.

1E-05 Ом

$$F_{(-3дБ)}=\frac{1}{2\,\pi\,Z_{(ka)}C_{(F)}}$$

$F_{(-3дБ)}$- частота среза по уровню -3 дБ, (φ -45°) (Гц)

$Z_{(ka)}$- значение импеданса катод - анод TL431 (Ом)

$C_{(F)}$- значение ёмкости буфера (Ф)

$Z_{(out)}$ (дБ\Ом)

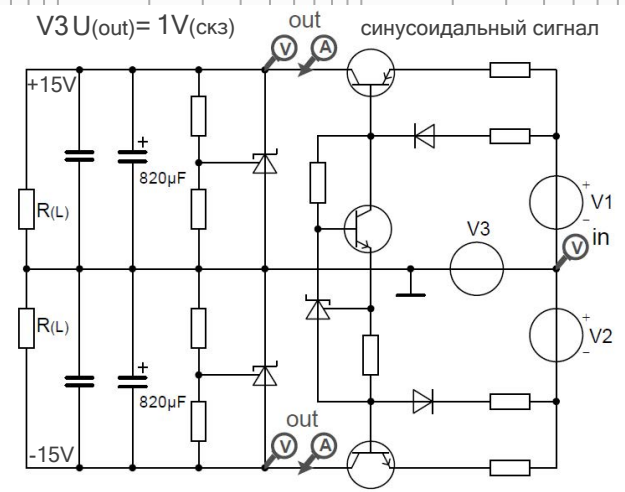
-30 -40 -50 -60 -70 -80 -90 -100 -110 -120

10 100 1k 10k 100k 1M 10M 100M

Частота (Hz)

схема измерений параметра "$K_{(RR)}$", "$Z_{(out)}$"

анализ амплитуды АС (-3дБ) $U_{(out)}$= 1V(ампл.)



Фаза (град)

190 180 170 160 150 140 130 120 110 100 90 80

135° (φ -45°)

10 100 1k 10k 100k 1M 10M 100M

Частота (Hz)

Shunt regulator "Riple"

Анализ АС *Передаточная хар-ка крутизны* (S) *отражателей тока* (Q1\D1, Q3\D2) $\frac{\Delta I(out)}{\Delta U(in)}$

0 дБ= 1 См

красный - +15 V
зелёный - -15 V

S (дБ\См)

-30 -40 -50 -60 -70 -80 -90 -100 -110

-89 дБ 3.67E-05 См

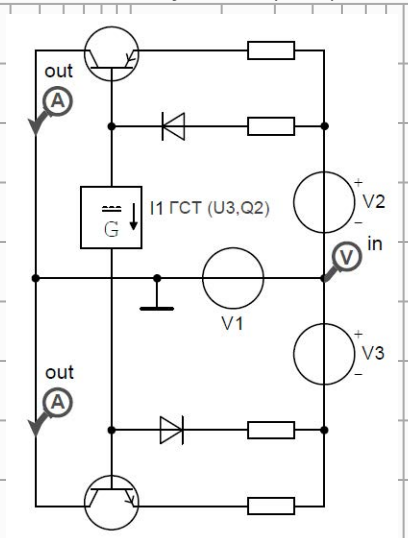
-102 дБ 7.94E-06 См

20 дБ/ дек.

10 10k 100k 1M 10M 100M

Частота (Hz)

схема измерения параметра "S" отражателя тока
V1 U(out)= 1V(скз) синусоидальный сигнал
анализ амплитуды АС (-3дБ) U(out)= 1V(ампл.)



Фаза (град)

-80 -90 -100 -110 -120 -130 -140 -150 -160 -170 -180 -190

-135°(φ -45°)

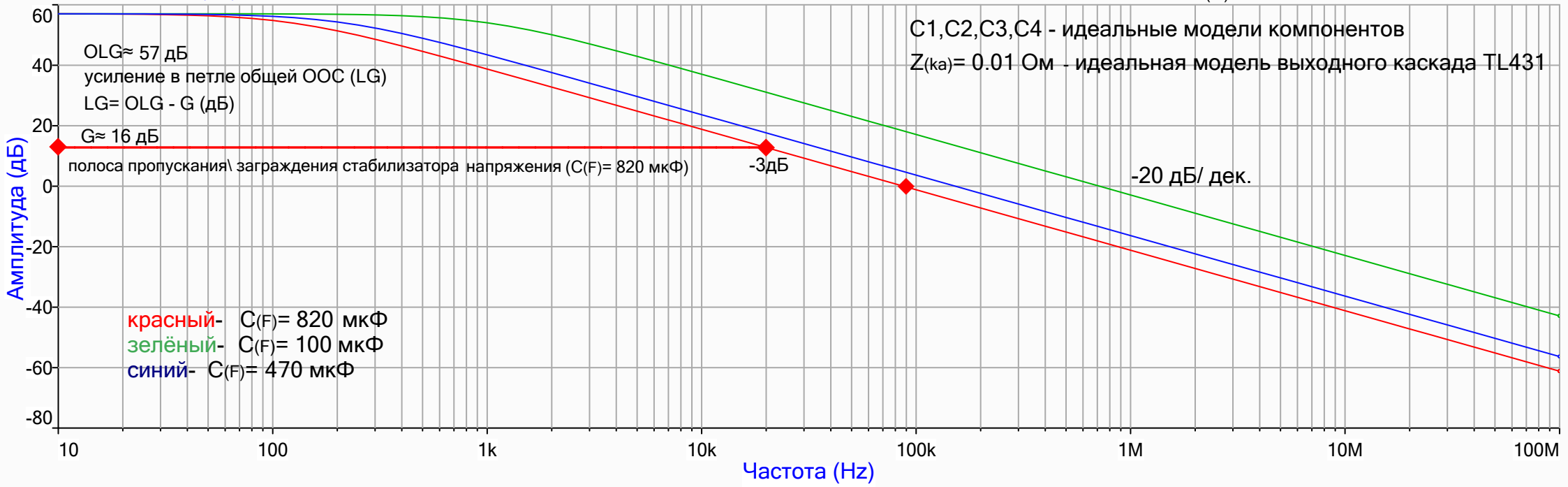
10 100 1k 10k 100k 1M 10M 100M

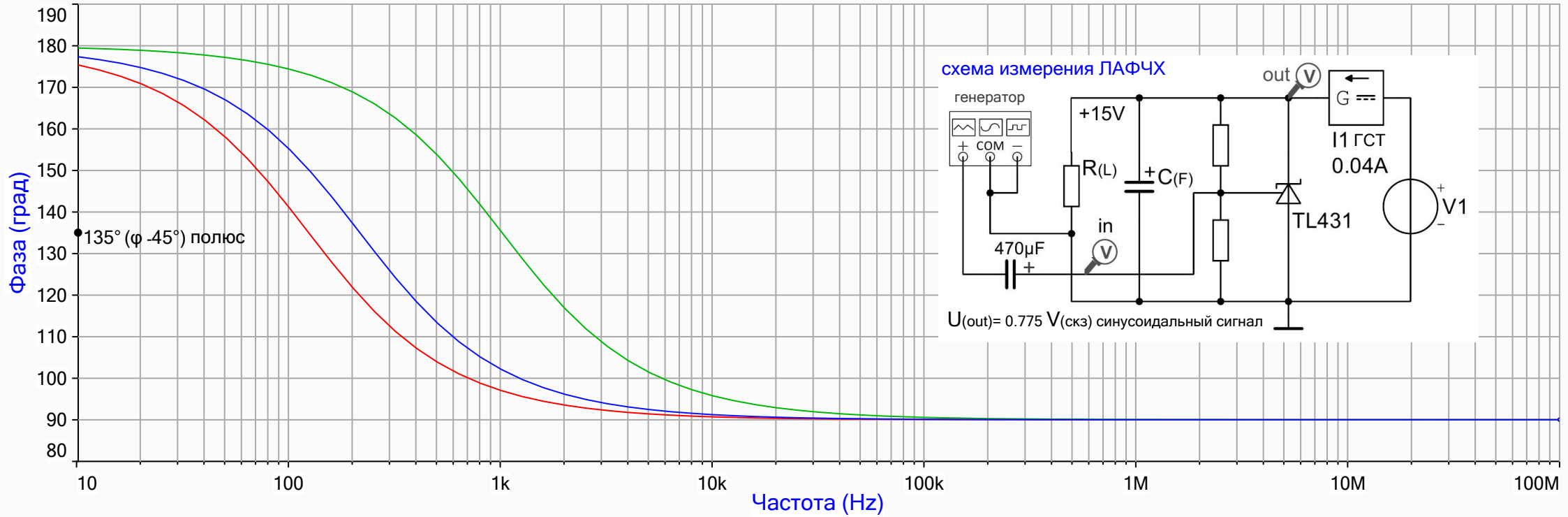
Частота (Hz)

Shunt regulator "Riple"

0 дБ= 0.775 V(скз)

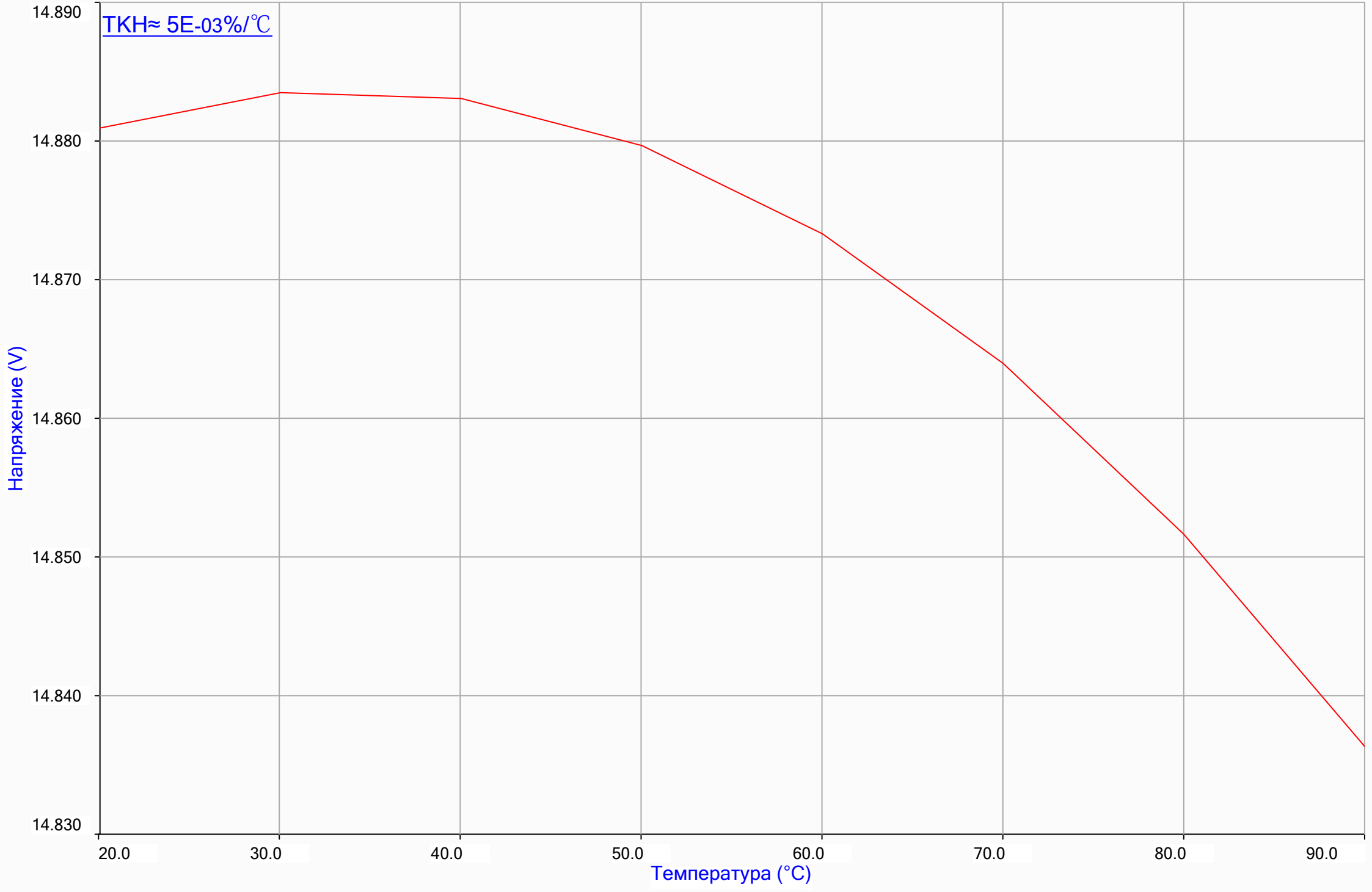
Анализ АС ЛАФЧХ (график Боде) *источник питания* +15V $\frac{\Delta U(out)}{\Delta U(in)}$





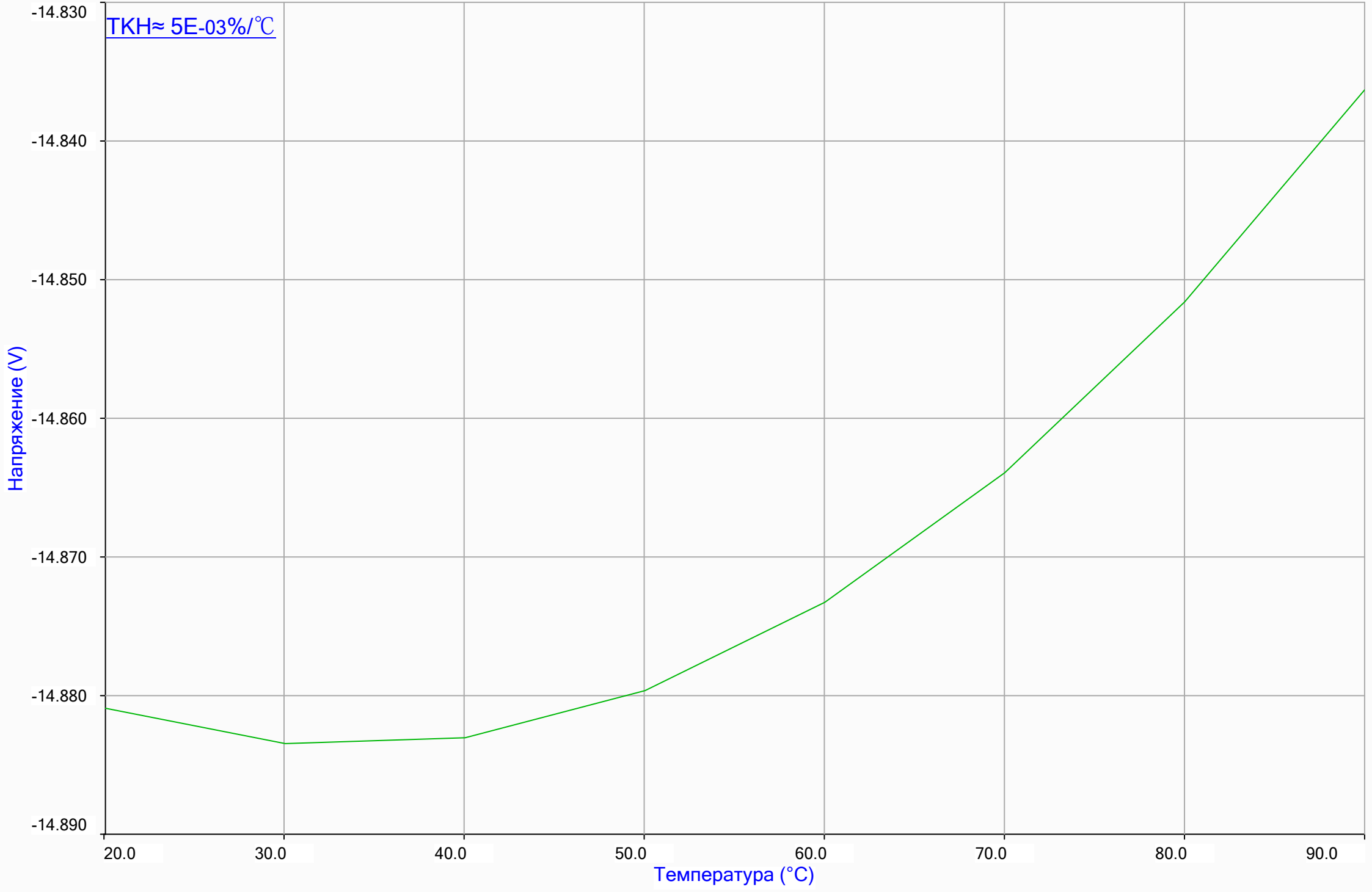
Shunt regulator "Riple"

Изменение температуры *Выходное напряжение* (U(out)) *источника питания* +15V ΔU(out)@T(℃)



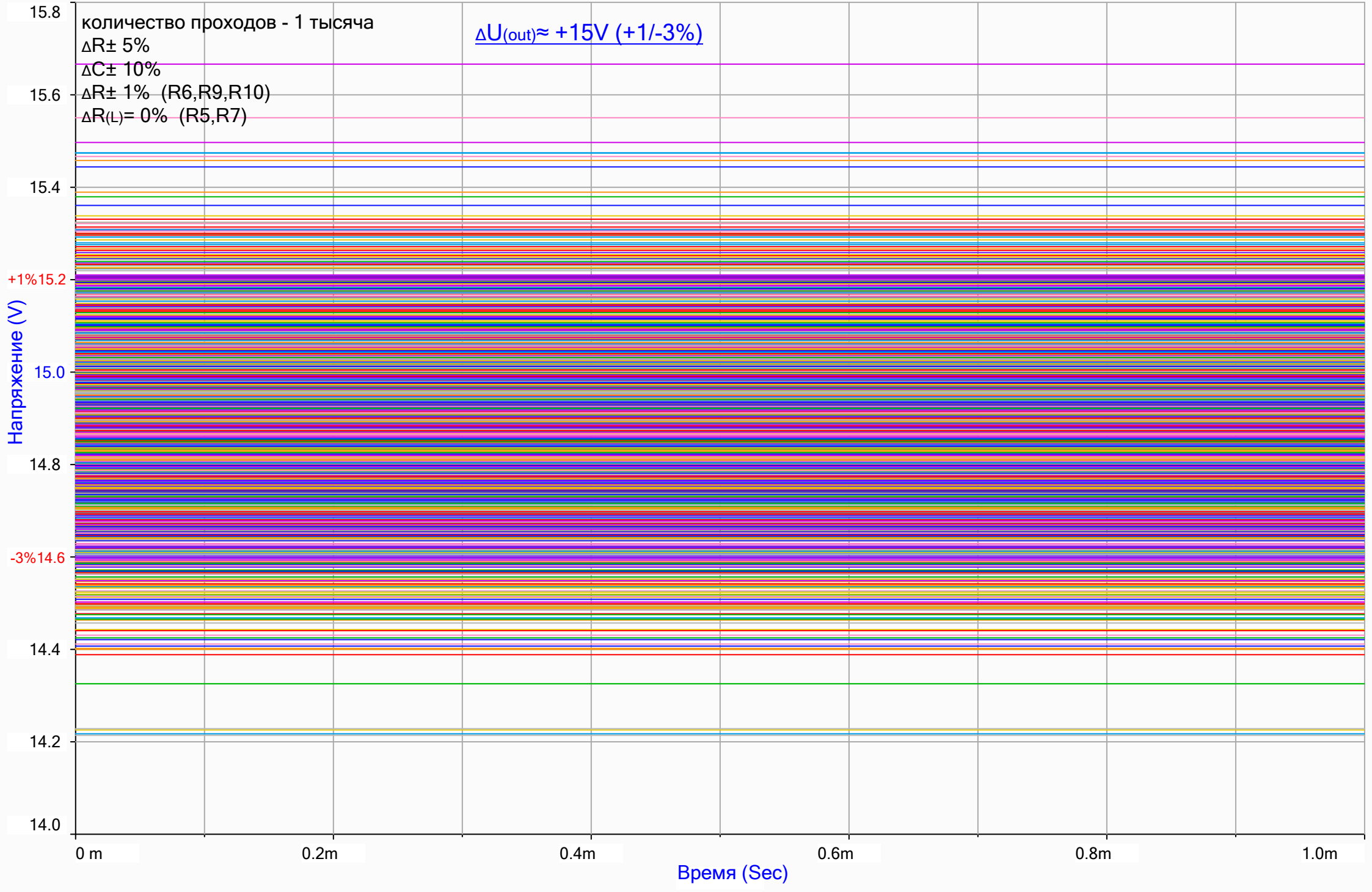
Shunt regulator "Riple"

Изменение температуры *Выходное напряжение* (U(out)) *источника питания* -15V ΔU(out)@T(℃)



Shunt regulator "Riple"

Анализ Monte Carlo *Вероятность отклонения выходного напряжения* ($U_{(out)}$) *источника питания* +15V



Наименование	Описание	Параметр	Единицы	По умолчанию
Level	Уровень модели	Gummel-Poon (Level 1)		
IS	Transport saturation current	4.815E-14	A	
BF	Ideal maximum forward beta	124.2		
NF	Forward current emission coefficient	0.9897		
VAF	Forward Early voltage	222	V	
IKF	Corner for forward beta high current roll-off	1.6	A	
ISE	B-E leakage saturation current	1.389E-14	A	
NE	B-E leakage emission coefficient	1.6		
BR	Ideal maximum reverse beta	13.26		
NR	Reverse current emission coefficient	0.9895		
VAR	Reverse Early voltage	81.4	V	
IKR	Corner for reverse beta high current roll-off	0.29	A	
ISC	B-C leakage saturation current	1.295E-13	A	
NC	B-C leakage emission coefficient	1.183		
RB	Zero-bias base resistance	0.5	Ω	
IRB	Current where base resistance falls halfway to its minimum value	1E-06	A	
RBM	Minimum base resistance at high currents	0.5	Ω	
RE	Emitter resistance	0.165	Ω	
RC	Collector resistance	0.096	Ω	
CJE	B-E zero-bias depletion capacitance	1.243E-10	F	
VJE	B-E built in potential	0.7313	V	
MJE	B-E junction exponential factor	0.3476		
TF	Ideal forward transit time	6.478E-10	sec	
XTF	Coefficient for bias dependence of TF	29		
VTF	Voltage describing VBC dependence of TF	2.648	V	
ITF	High-current parameter for effect on TF	3.35	A	
PTF	Excess phase at freq=1.0/(TF*2PI) Hz	0	Deg	
CJC	B-C zero-bias depletion capacitance	3.04E-11	F	
VJC	B-C built in potential	0.5642	V	
MJC	B-C junction exponential factor	0.4371		
XCJC	Fraction of B-C depletion capacitance connected to internal base node	1		
TR	Ideal reverse transit time	1E-32	sec	
CJS	Zero-bias substrate capacitance	0	F	
VJS	Substrate junction built-in potential	0.75	V	
MJS	Substrate junction exponential factor	0.333		
XTB	Forward and reverse beta temperature exponent	0		
EG	Energy gap for temperature effect on IS	1.11	eV	
XTI	Temperature exponent for effect on IS	3		
FC	Coefficient for forward-bias depletion capacitance formula	0.9359		
TNOM	Parameter measurement temperature	27	°C	
KF	Flicker noise coefficient	0		
AF	Flicker noise exponent	1		
NK	High-current roll-off coefficient	0.5		
ISS	Substrate saturation current	0	A	
NS	Substrate emission coefficient	1		
XCJC2	Fraction of CJC connected internally to Rb	1		
XCJS	Fraction of CJS connected internally to Rc	1		
TRB1	RB linear temperature coefficient	0	1/°C	
TRB2	RB quadratic temperature coefficient	0	1/°C²	
TRC1	RC linear temperature coefficient	0	1/°C	
TRC2	RC quadratic temperature coefficient	0	1/°C²	
TRE1	RE linear temperature coefficient	0	1/°C	
TRE2	RE quadratic temperature coefficient	0	1/°C²	
TRM1	RBM linear temperature coefficient	0	1/°C	
TRM2	RBM quadratic temperature coefficient	0	1/°C²	
CN	Quasi-saturation temperature coefficient for hole mobility	2.2		
D	Quasi-saturation temperature coefficient for scattering-limited hole carrier velocity	0.52		
GAMMA	Epitaxial region doping factor	1.0e-11		
QCO	Epitaxial region charge factor	0		
QUASIMOD	Quasi-saturation model flag for temperature dependence	0		
RCO	Epitaxial region resistance	0	Ω	
VG	Quasi-saturation extrapolated bandgap voltage at 0 K	1.206	V	
VO	Carrier mobility knee voltage	10	V	
T_MEASURED	Parameter measurement temperature	27	°C	
T_ABS	Model operating temperature	27	°C	

Наименование	Описание	Параметр	Единицы	По умолчанию
Level	Уровень модели	Gummel-Poon (Level 1)		
IS	Transport saturation current	7.401E-14	A	
BF	Ideal maximum forward beta	336.5		
NF	Forward current emission coefficient	0.9938		
VAF	Forward Early voltage	22.47	V	
IKF	Corner for forward beta high current roll-off	0.1689	A	
ISE	B-E leakage saturation current	4.104E-16	A	
NE	B-E leakage emission coefficient	1.054		
BR	Ideal maximum reverse beta	13.91		
NR	Reverse current emission coefficient	0.9913		
VAR	Reverse Early voltage	30.00	V	
IKR	Corner for reverse beta high current roll-off	9.888E-2	A	
ISC	B-C leakage saturation current	1.290E-14	A	
NC	B-C leakage emission coefficient	1.100		
RB	Zero-bias base resistance	0.500	Ω	
IRB	Current where base resistance falls halfway to its minimum value	1E-06	A	
RBM	Minimum base resistance at high currents	0.500	Ω	
RE	Emitter resistance	0.208	Ω	
RC	Collector resistance	5.526E-02	Ω	
CJE	B-E zero-bias depletion capacitance	1.066E-10	F	
VJE	B-E built in potential	0.6900	V	
MJE	B-E junction exponential factor	0.3676		
TF	Ideal forward transit time	2.578E-10	sec	
XTF	Coefficient for bias dependence of TF	13.56		
VTF	Voltage describing VBC dependence of TF	2.366	V	
ITF	High-current parameter for effect on TF	1.3040	A	
PTF	Excess phase at freq=1.0/(TF*2PI) Hz	0	Deg	
CJC	B-C zero-bias depletion capacitance	5.234E-11	F	
VJC	B-C built in potential	0.6431	V	
MJC	B-C junction exponential factor	0.4436		
XCJC	Fraction of B-C depletion capacitance connected to internal base node	0.440		
TR	Ideal reverse transit time	1E-25	sec	
CJS	Zero-bias substrate capacitance	0	F	
VJS	Substrate junction built-in potential	0.75	V	
MJS	Substrate junction exponential factor	0.333		
XTB	Forward and reverse beta temperature exponent	0		
EG	Energy gap for temperature effect on IS	1.11	eV	
XTI	Temperature exponent for effect on IS	3		
FC	Coefficient for forward-bias depletion capacitance formula	0.990		
TNOM	Parameter measurement temperature	27	°C	
KF	Flicker noise coefficient	0		
AF	Flicker noise exponent	1		
NK	High-current roll-off coefficient	0.5		
ISS	Substrate saturation current	0	A	
NS	Substrate emission coefficient	1		
XCJC2	Fraction of CJC connected internally to Rb	1		
XCJS	Fraction of CJS connected internally to Rc	1		
TRB1	RB linear temperature coefficient	0	1/°C	
TRB2	RB quadratic temperature coefficient	0	1/°C²	
TRC1	RC linear temperature coefficient	0	1/°C	
TRC2	RC quadratic temperature coefficient	0	1/°C²	
TRE1	RE linear temperature coefficient	0	1/°C	
TRE2	RE quadratic temperature coefficient	0	1/°C²	
TRM1	RBM linear temperature coefficient	0	1/°C	
TRM2	RBM quadratic temperature coefficient	0	1/°C²	
CN	Quasi-saturation temperature coefficient for hole mobility	2.2		
D	Quasi-saturation temperature coefficient for scattering-limited hole carrier velocity	0.52		
GAMMA	Epitaxial region doping factor	1.0e-11		
QCO	Epitaxial region charge factor	0		
QUASIMOD	Quasi-saturation model flag for temperature dependence	0		
RCO	Epitaxial region resistance	0	Ω	
VG	Quasi-saturation extrapolated bandgap voltage at 0 K	1.206	V	
VO	Carrier mobility knee voltage	10	V	
T_MEASURED	Parameter measurement temperature	27	°C	
T_ABS	Model operating temperature	27	°C	

1N4148

Наименование	Описание	Параметр	Единицы	По умолчанию
IS	Saturation current	0.1p	A	
RS	Parasitic resistance	1.6	Ω	
N	Emission Coefficient	1.0		
TT	Transit Time	12n	sec	
CJO	Zero-bias junction capacitance	2p	F	
VJ	Junction potential	1.0	V	
M	Junction grading coefficient	0.5		
EG	Activation energy	1.11	eV	
XTI	Saturation-current temperature exponent	3.0		
KF	Flicker noise coefficient	0.0		
AF	Flicker noise exponent	1.0		
FC	Forward-bias depletion capacitance coefficient	0.5		
BV	Reverse breakdown knee voltage	100	V	
IBV	Reverse breakdown knee current	0.1p	A	
IBVL	Low-level reverse breakdown knee current	1.0	A	
IKF	High-injection knee current	1e30	A	
ISR	Recombination current parameter	0.0	A	
NBV	Reverse breakdown ideality factor	1.0		
NBVL	Low-level reverse breakdown ideality factor	1.0		
NR	Emission coefficient for ISR	2.0		
TBV1	BV linear temperature coefficient	0.0	1/°C	
TBV2	BV quadratic temperature coefficient	0.0	1/°C²	
TIKF	IKF linear temperature coefficient	0.0	1/°C	
TRS1	RS linear temperature coefficient	0.0	1/°C	
TRS2	RS quadratic temperature coefficient	0.0	1/°C²	
TNOM	Parameter measurement temperature	27	°C	
T_MEASURED	Parameter measurement temperature	27	°C	
T_ABS	Model operating temperature	27	°C	
T_REL_GLOBAL	Change relative to global temperature	0	°C	

TL431

*Note: This only models DC characteristics. Dynamic characteristics are not modeled.

```
V1  6  7  DC  1.4V
I1  2  4  1E-3
R1  1  2  1.2E6
R2  4  2  2.495E3 RMOD
R3  5  7  .2
D1  3  6  DMOD1
D2  2  3  DMOD1
D3  2  7  DMOD2
E1  5  2  POLY(2)  (4,2)  (1,2)  0  710  -710
.MODEL RMOD R(TC1=1.4E-5 TC2=-1E-6)
.MODEL DMOD1 D (RS=.3)
.MODEL DMOD2 D (RS=1E-6)
.ENDS
```