What Sets the Gain Is Neither the Device nor the Current but the Voltage Dropped Across the Load

— a bipolar gain is V_{RL}/V_T, staying at **193.408635** however current and resistance change as long as the voltage across the load does — the separator is whether the denominator is a constant of physics (the thermal voltage **0.025852** V) or a voltage the designer picks — [Paper 823]

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— *From thinking to syncing.* —

Abstract

The gain of an amplifier looks as though it is set by the quality of the device.This paper counts that in a single stage the gain is set neither by the current nor by the resistance, but by their product: the voltage dropped across the load.No new theorem or law is claimed. First, and this is the core. Change current and resistance; if the voltage across the load is the same, the gain is the same——193.408635 at 0.1 mA with 50 kΩ, at 1 mA with 5 kΩ, and at 10 mA with 500 Ω (Section 2). **Second, the gain is proportional to that voltage——193.408635 at 5 V and 386.817271 at 10 V** (Section 2). **Third, its denominator is a constant of physics——the thermal voltage $V_T = kT/q = 0.025852$ V at 300 K, which no designer chooses** (Section 2). **Fourth, in a field-effect device the denominator becomes a chosen quantity——the gain is $2V_{RL}/V_{ov}$: 100.000000 at $V_{ov} = 0.1$ V, 50.000000 at 0.2 V, 20.000000 at 0.5 V** (Section 3). **Fifth, there is a point where the two meet——at $V_{ov} = 0.051704$ V ($= 2V_T$) the gains are equal for the same V_{RL}** (Section 3). **Sixth, the separator is whether the denominator is a constant of physics or a voltage the designer picks——"more current gives more gain" is undecided until one says which device is meant** (Section 4). **Keywords**: transconductance, gain, thermal voltage, load resistance, overdrive voltage, small signal.

Scope of this paper (scope note): **No new theorem or law is claimed——that a bipolar transconductance is I_c/V_T, that a field-effect transconductance is $2I_d/V_{ov}$, and that a single-stage gain is g_mR_L, are all standard.Only small signals ——distortion, large swings and saturation are not treated.No real device is discussed——the Early effect, parasitic capacitance, frequency response, noise and temperature drift are not the subject.No design method is given——how to set the operating point or choose a topology is not treated.The values are examples——$V_{RL} = 5$ V and V_{ov} from 0.1 to 0.5 V are values for comparison.Relation to earlier papers**: **Paper 326 showed that the square-cube "law" is an identity, not a law——this paper stands beside it: here too the gain is not a performance to be measured but a ratio of two quantities.Paper 300 showed that whether two things share a root is decidable——V_T and V_{ov} sit in the same place in the formula but are distinct roots, one a constant of physics and the other a chosen quantity.**What is added is **confirming that the gain stays at 193.408635 under three combinations of current and resistance**, **showing the proportionality with 386.817271**, **locating the crossing at $V_{ov} = 0.051704$ V**, and **placing the separator on constant versus chosen denominator**.

1. Notation and the Question

Setting: **the gain of a single amplifying stage is the transconductance times the load resistance.**

$$A = g_m R_L, \qquad g_m^{\text{bipolar}} = \frac{I_c}{V_T}, \qquad g_m^{\text{field-effect}} = \frac{2I_d}{V_{ov}}, \qquad V_T = \frac{kT}{q}$$

At 300 K, $V_T = 0.025852$ V.Write $V_{RL} = IR_L$ for the voltage dropped across the load.

Question: **is the gain set by the current, by the resistance, or by something else?**

2. Bipolar: Only the Dropped Voltage Matters

Computation 2.1: **the gain was computed for several currents and resistances.**

I_c	R_L	g_m (S)	dropped voltage	gain
0.1 mA	50 kΩ	0.003868	5.000000 V	193.408635
1 mA	5 kΩ	0.038682	5.000000 V	193.408635
10 mA	500 Ω	0.386817	5.000000 V	193.408635
1 mA	10 kΩ	0.038682	10.000000 V	386.817271

Observation 2.2

this is the core. Raise the current a hundredfold and lower the resistance to match, and the gain does not move.g_m runs from 0.003868 to 0.386817, a factor of 100, while the gain stays at 193.408635——since $g_m R_L = (I_c/V_T)R_L = V_{RL}/V_T$, current and resistance enter only as a product.

Observation 2.3

the denominator is a constant of physics.$V_T = kT/q = 0.025852$ V depends only on temperature and is not the designer's to choose——so "I want more gain" means "I want more voltage dropped".

3. Field-Effect: The Denominator Becomes a Choice

Computation 3.1: **at the same $V_{RL} = 5$ V, the overdrive voltage was varied.**

V_{ov}	gain ($2V_{RL}/V_{ov}$)
0.1 V	100.000000
0.2 V	50.000000
0.5 V	20.000000

Observation 3.2

the denominator becomes a chosen quantity.The bipolar 193.408635 is 3.868173 times the field-effect value at $V_{ov} = 0.2$ V, and the two meet at $V_{ov} = 0.051704$ V ($= 2V_T$)——lowering the overdrive raises the gain, but how far it can be lowered is limited by other things.

4. The Separator

Observation 4.1

the separator is whether the denominator is a constant of physics or a chosen voltage.V_T sits in the denominator for the bipolar device and V_{ov} for the field-effect one——"more current gives more gain" is true for the bipolar device if the resistance is held, and false if the resistance is lowered to match.

Observation 4.2

placed beside Papers 326 and 300.Paper 326 showed that the square-cube "law" is an identity——here too the gain is a ratio of two voltages, not a performance to be measured.Paper 300 showed that sharing a root is decidable——V_T and V_{ov} are distinct roots in the same place.

Observation 4.3

what is not said.Device limits, frequency response, noise, distortion and design procedure are not treated ——what is shown is that the numerator is the dropped voltage and the denominator a voltage belonging to the device.

5. Census and Closing

1. $V_T = 0.025852$ V (Section 2): **thermal voltage at 300 K.**
2. **three cases, gain 193.408635** (Computation 2.1): **the core.**
3. g_m **moves by** 100 (Observation 2.2): **the gain does not.**
4. 386.817271 **at** 10 V (Computation 2.1): **proportional to the drop.**
5. 100.000000 **at** $V_{ov} = 0.1$ V (Computation 3.1): **a different denominator.**
6. 50.000000 **at** 0.2 V (Computation 3.1): **a chosen quantity.**
7. 20.000000 **at** 0.5 V (Computation 3.1): **lower is higher.**
8. **ratio** 3.868173 (Observation 3.2): **at the same drop.**
9. **they meet at** 0.051704 V (Observation 3.2): $2V_T$**.**
10. **constant or chosen** (Observation 4.1): **the separator; Papers 326, 300.**

Closing: **What sets the gain is neither the device nor the current but the voltage dropped across the load.For a bipolar stage the gain is V_{RL}/V_T, so 0.1 mA with 50 kΩ, 1 mA with 5 kΩ and 10 mA with 500 Ω all give 193.408635 even as g_m moves by a factor of 100——current and resistance enter only as a product.The denominator $V_T = 0.025852$ V is a constant of physics, while in a field-effect stage it becomes the designer's V_{ov}: 100.000000 at 0.1 V, 20.000000 at 0.5 V, the two meeting at $V_{ov} = 0.051704$ V ($= 2V_T$)——two voltages in the same place, one not chosen and one chosen.The separator is whether the denominator is a constant of physics or a voltage the designer picks.Placed among the earlier papers——standing beside Paper 326's "identity, not a law", and keeping Paper 300's discipline between the two denominators.To be honest——this is the small-signal approximation only, with no device limits and no design procedure.**

References

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