

Qucs

Compact device - circuit macromodel specification

A Curtice level 1 MESFET model

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Introduction

The Metal and Semiconductor FET (MESFET) is a Schottky-barrier gate FET made from gallium arsenide. It is popular for high frequency applications because of its high electron mobility. The device was developed by Walter R. Curtice¹ in 1980 at the RCA Laboratory in Princeton, New Jersey. USA. The MESFET model presented below is based on a Qucs equation defined device (EDD) which functions as a Curtice level 1 MESFET model with interelectrode capacitances. Basic temperature effects are also included.

Qucs EDD model for the Curtice MESFET

Parameters

| Name | Symbol | Description | Unit | Default |
|-------|-----------|--|--------------------|-----------|
| RG | R_G | external gate resistance | Ω | 1m |
| RD | R_D | external drain resistance | Ω | 1m |
| RS | R_S | external source resistance | Ω | 1m |
| VBR | V_{DR} | GS breakdown voltage | V | 10^{10} |
| LG | L_G | external gate lead inductance | H | 0 |
| LD | L_D | external drain lead inductance | H | 0 |
| LS | L_S | external source lead inductance | H | 0 |
| Is | I_S | diode saturation current | A | 10f |
| N | N | diode emission coefficient | | 1 |
| XTI | X_{TI} | diode saturation current temperature coefficient | | 0 |
| EG | E_G | diode energy gap | eV | 1.11 |
| TAU | τ | internal time delay from drain to source | s | 10p |
| RIN | R_{IN} | series resistance to CGS | Ω | 1m |
| CGS | C_{GS} | interelectrode gate-source bias-independent capacitance | F | 300f |
| CGD | C_{GD} | interelectrode gate-drain bias-independent capacitance | F | 300f |
| CDS | C_{DS} | interelectrode drain-source bias-independent capacitance | F | 300f |
| Tnom | T_{NOM} | device parameter measurement temperature | $^{\circ}\text{C}$ | 27 |
| Temp | T | device temperature | $^{\circ}\text{C}$ | 27 |
| Alpha | α | coefficient of Vds in tanh function for quadratic model | 1/V | 0.8 |

¹W.R Curtice, 1980, A MESFET model for use in the design of GaAs integrated circuits, IEEE Transactions on Microwave Theory and Techniques, MTT-28, pp. 448-456.

| Name | Symbol | Description | Unit | Default |
|--------|-----------|---|------------------|---------|
| Beta | β | transconductance parameter | A/V ² | 3m |
| Lambda | λ | channel length modulation parameter for quadratic model | 1/V | 40m |
| VTO | V_{TO} | quadratic model gate threshold voltage | V | -6 |

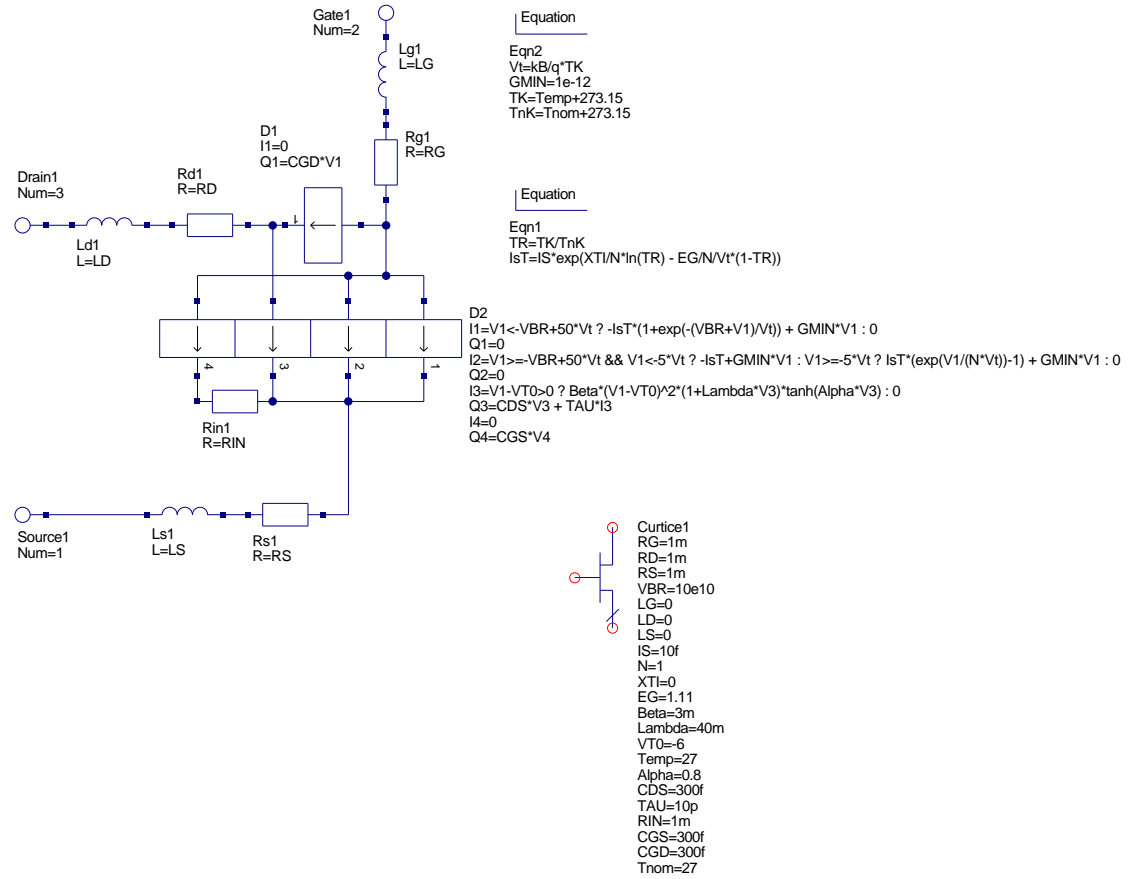


Figure 1: A Qucs EDD model for the Curtice MESFET

The MESFET equations

- DC characteristics

1. for $(V_{GS} < -V_{BR} + 50 \cdot V_T)$

$$I_{GS} = -I_S(T) \cdot \left(1 + \exp\left(-\frac{V_{BR} + V_{GS}}{V_T}\right)\right) + G_{MIN} \cdot V_{GS} \quad (1)$$

2. for $(V_{GS} \geq -V_{BR} + 50 \cdot V_T)$ and $(V_{GS} < -5 \cdot V_T)$

$$I_{GS} = -I_S(T) + G_{MIN} \cdot V_{GS} \quad (2)$$

3. for $(V_{GS} \geq -5 \cdot V_T)$

$$I_{GS} = I_S(T) \cdot \left(\exp\left(\frac{V_{GS}}{N \cdot V_T}\right) - 1\right) + G_{MIN} \cdot V_{GS} \quad (3)$$

4. for $(V_{GS} - V_{TO}) > 0$

$$I_{DS} = \beta \cdot (V_{GS} - V_{TO})^2 \cdot (1 + \lambda \cdot V_{DS}) \cdot \tanh(\alpha \cdot V_{DS}) \quad (4)$$

Where

$$I_S(T) = I_S \cdot \exp\left(\frac{X_{TI}}{N} \cdot \ln(TR) - (E_G/N/V_T) \cdot (1 - TR)\right) \quad (5)$$

$$Tr = \frac{TK}{TnK} \quad \text{and} \quad TK = T + 273.15, \quad TnK = T_{NOM} + 273.15 \quad (6)$$

- MESFET charge equations

- 1.

$$Q_{GS} = C_{GS} \cdot V_{GS} \quad (7)$$

- 2.

$$Q_{GD} = C_{GD} \cdot V_{GD} \quad (8)$$

- 3.

$$Q_{DS} = C_{DS} \cdot V_{DS} + \tau \cdot I_{DS} \quad (9)$$

Test circuits and simulation results

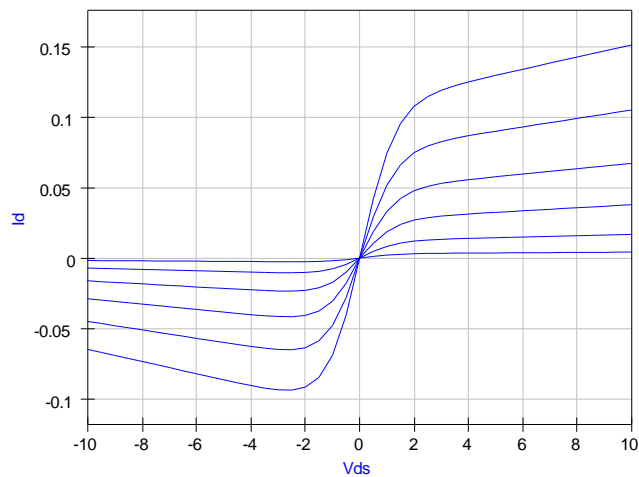
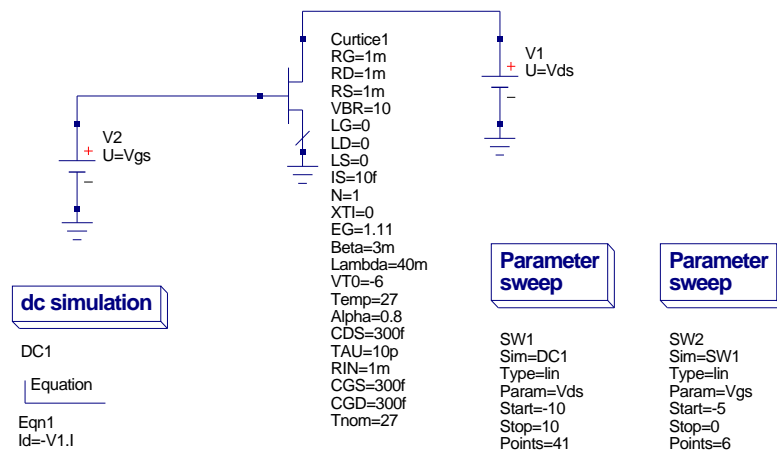


Figure 2: DC test circuit and I_d - V_{ds} characteristics

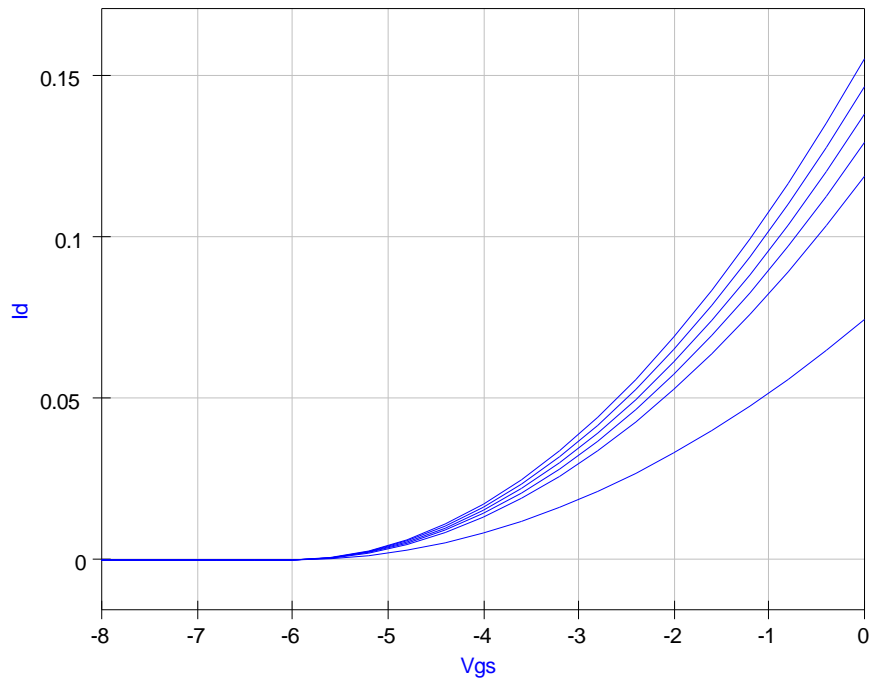
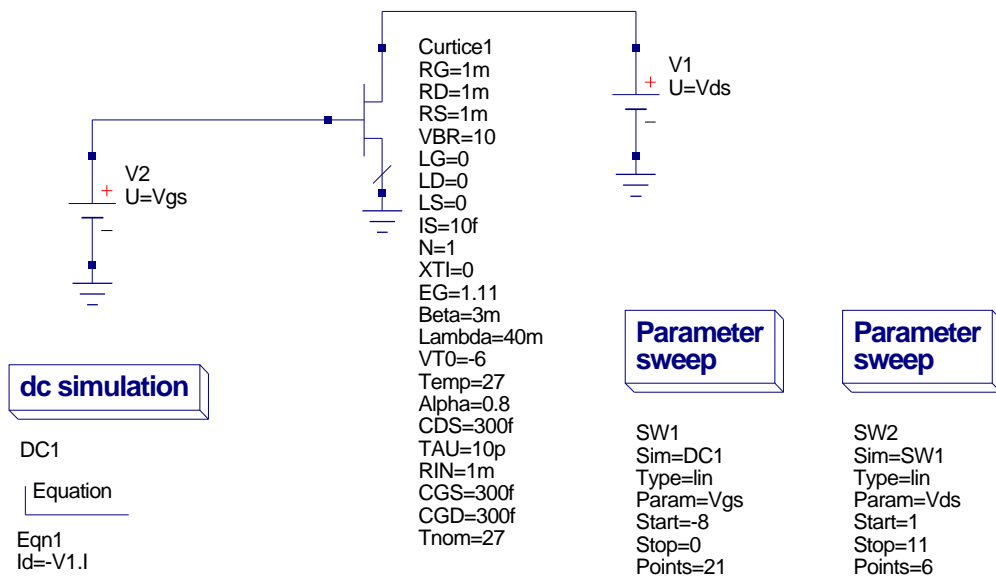


Figure 3: DC test circuit and I_d - V_{gs} characteristics

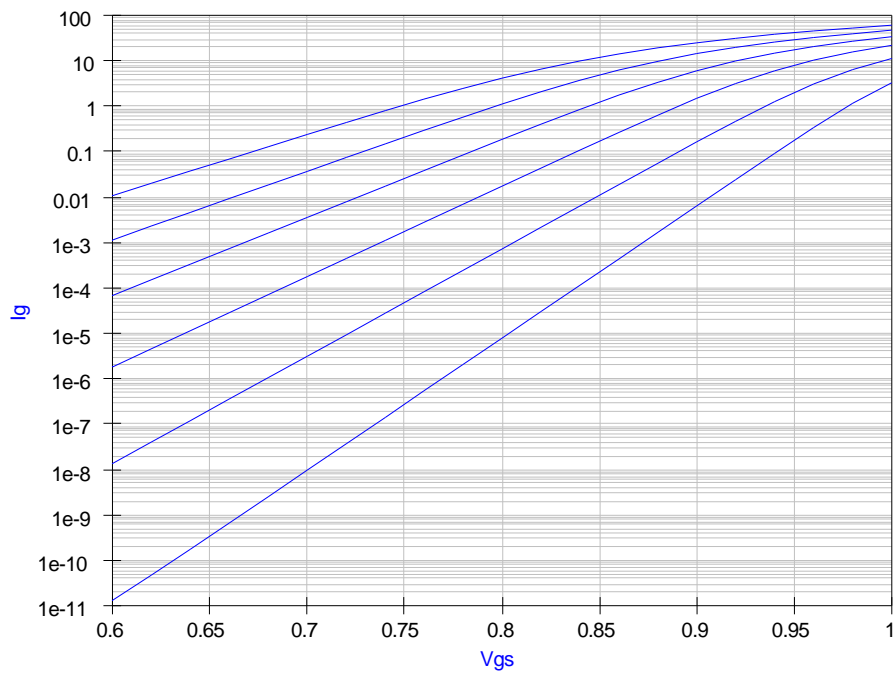
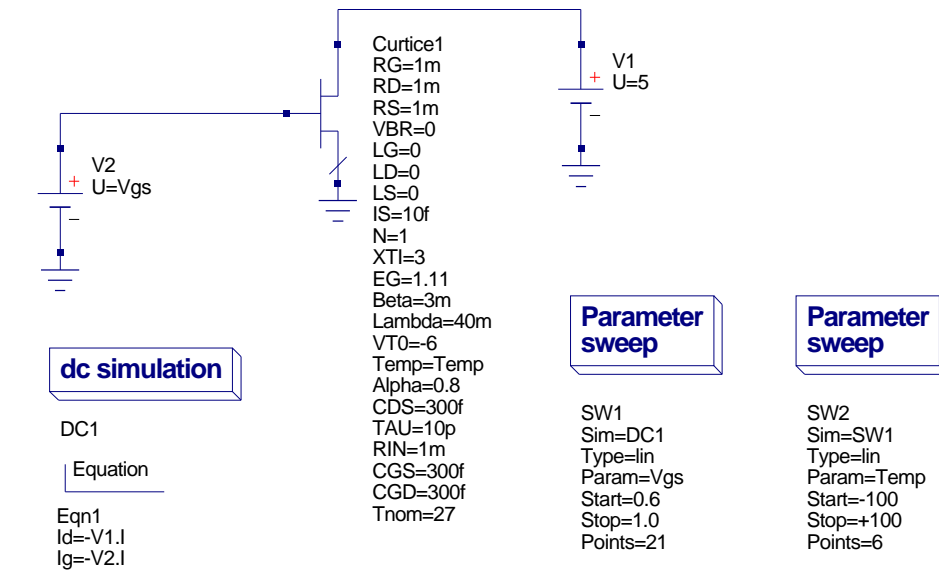


Figure 4: DC test circuit and I_g - V_{gs} characteristics

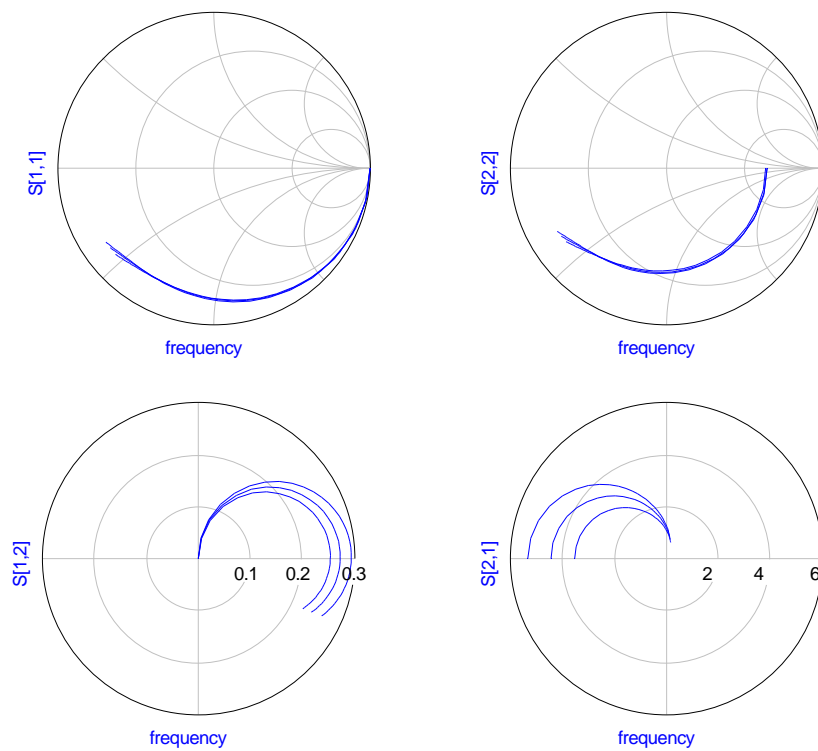
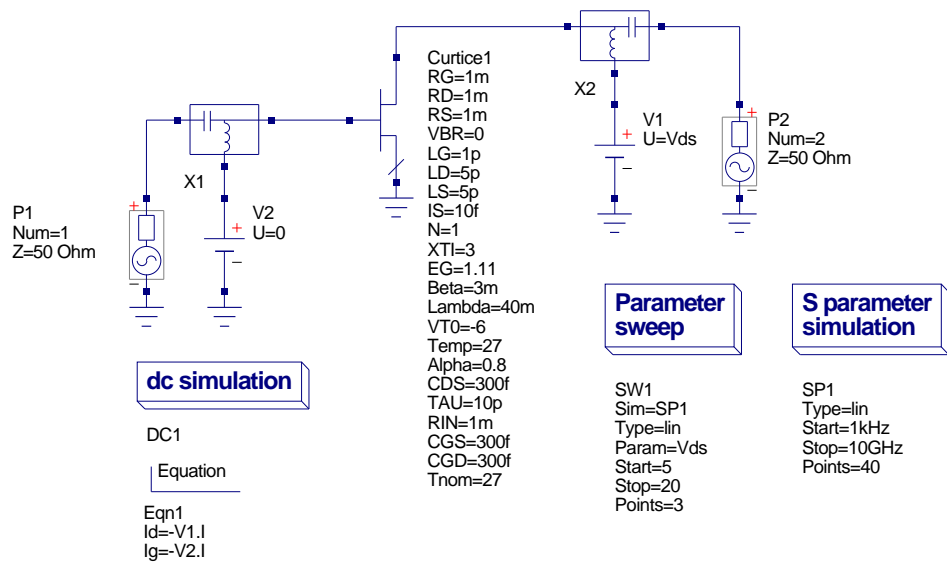


Figure 5: S parameter test circuit and characteristics