Very High Frequency Two-Port Characterization of Transistors

Authors: Jens Christian Hertel, Yasser Nour, Ivan H. H. Jørgensen & Arnold Knott

Abstract: To properly use transistors in VHF converters, they need to be characterized under similar conditions. This research presents a two-port method, using a network analyzer (NWA) with a S-port setup. The method is a one-shot method, providing fast results of the off-state parasitics of the transistors.

Introduction:

- Resonant power converters are becoming more interesting for on-chip power solutions.
- As the switching frequency increases, the parasitic elements of the transistors are used as part of the circuit.
- Proper characterization is needed. The two-port solution is an interesting method, as it is a one-shot relatively easy method.

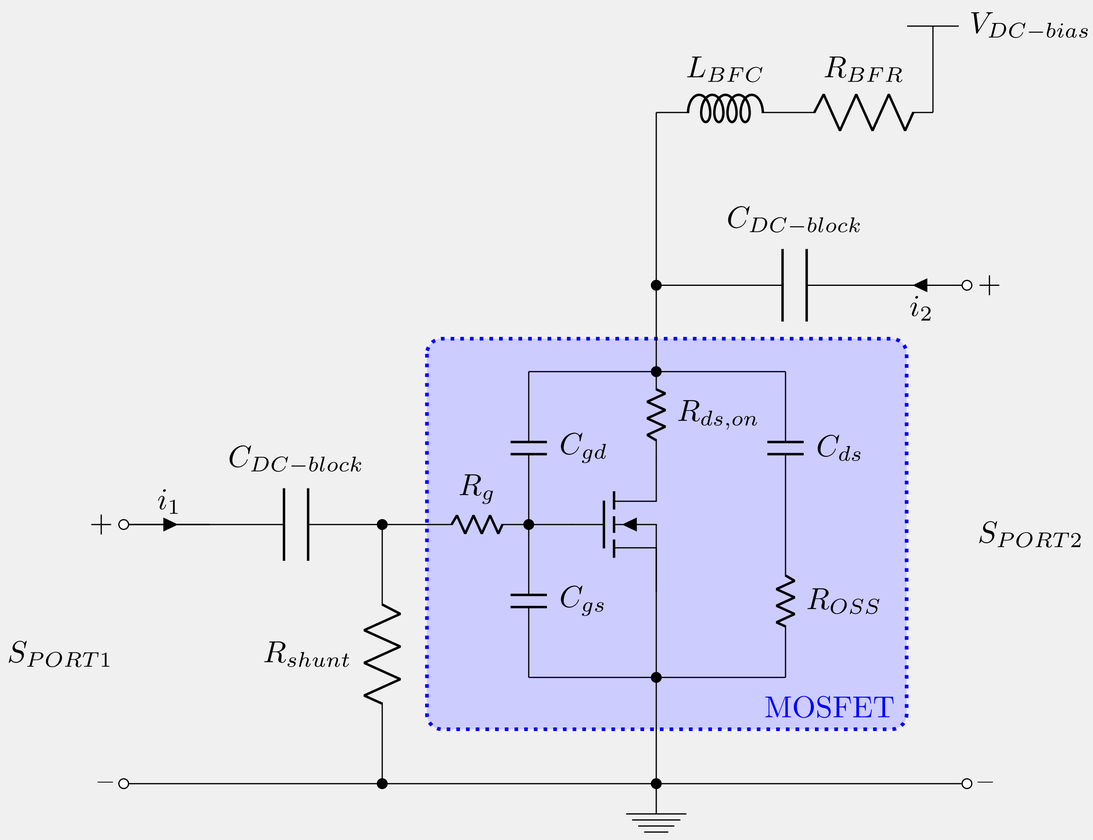

Fig 1. MOSFET in Two-port Characterization

Two-port theory:

- MOSFET modelled as per fig 1. [1]
- Protection circuitry implemented, blocking DC voltage on equipment [2].
- Drain-Source voltage biased through a 10mH choke (L_{BFC}) as well as a large resistance for proper AC blocking capabilities.
- Network derived through ABCD matrices.
- Formulas for capacitances and resistances, from the Z-results of a two-port S-parameter solution.
- Capacitances are found using *imaginary* results of the Z-parameters:

$$Z_{C_{gs}} = -\frac{z_{11}z_{22} - z_{12}z_{21}}{z_{21} - z_{22}}$$

$$Z_{C_{gd}} = \frac{z_{11}z_{22} - z_{12}z_{21}}{z_{21}}$$

$$Z_{C_{ds}} = \frac{z_{11}z_{22} - z_{12}z_{21}}{z_{11} - z_{21}}$$

- Resistances are found, assuming little self-influences:

$$Z_{R_g} = \Re(z_{11})$$

$$Z_{R_{oss}} = \Re\left(\frac{1}{z_{22} \cdot C_{gd}^2 \cdot \omega^2}\right)$$

- To verify method IRF5802 was measured.
- Results on next slide

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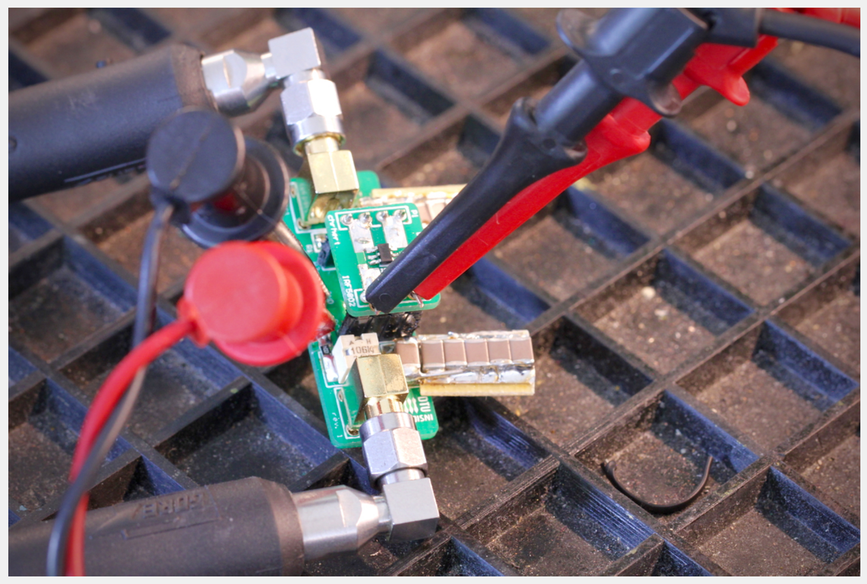
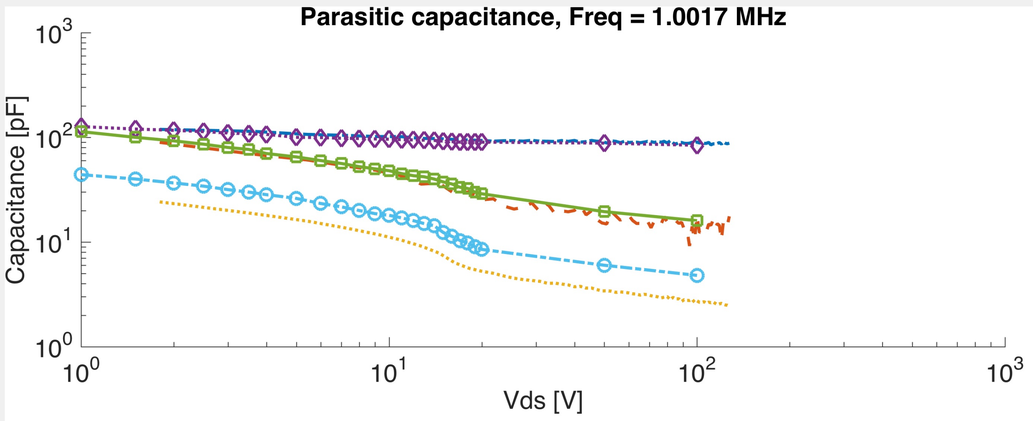
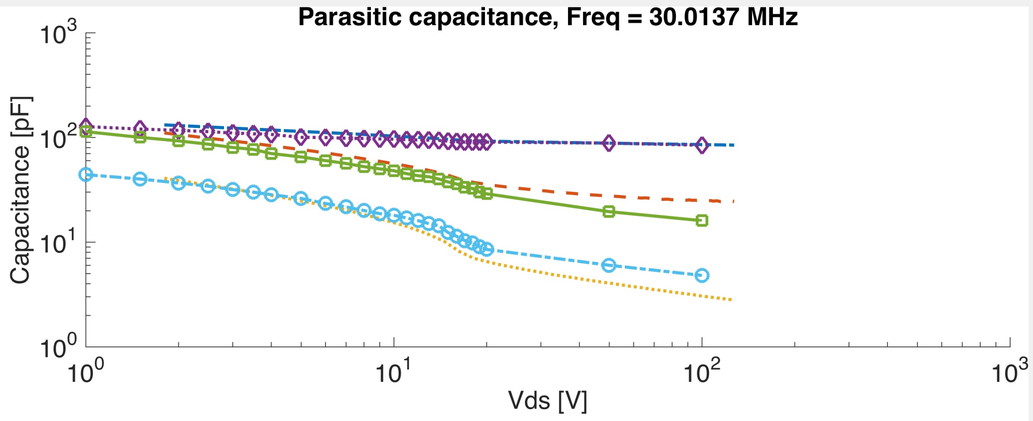
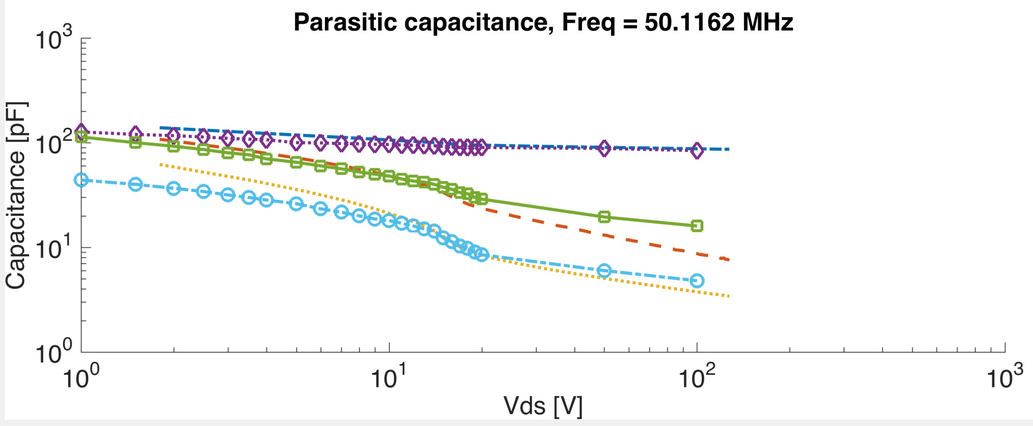
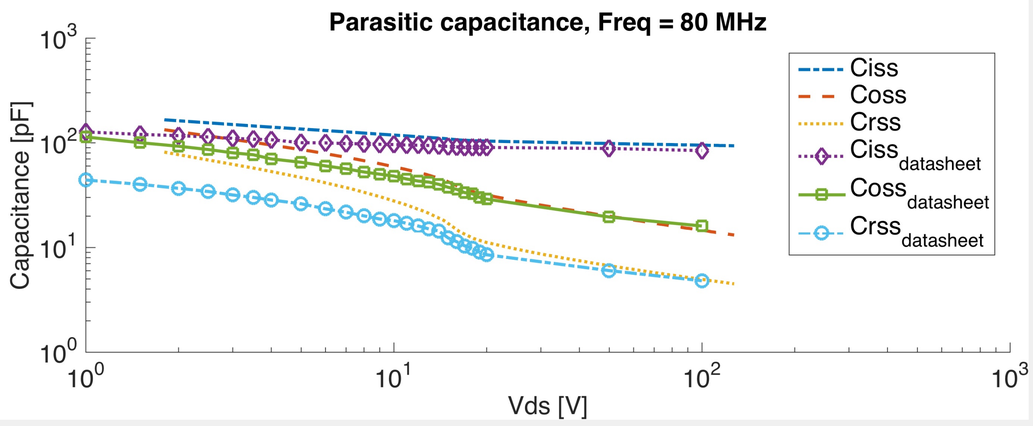
Conclusion: The two-port S-parameter measurements is advantageous to the one-port measurement, as it is a one-shot measurement. The two-port results matches the datasheet values on capacitances. Resistance values are similarly within range of expectation. However, R_{oss} measurements should be confirmed with a one port setup. Future work also consist of including this in a loss model simulation and measurements in a VHF converter.

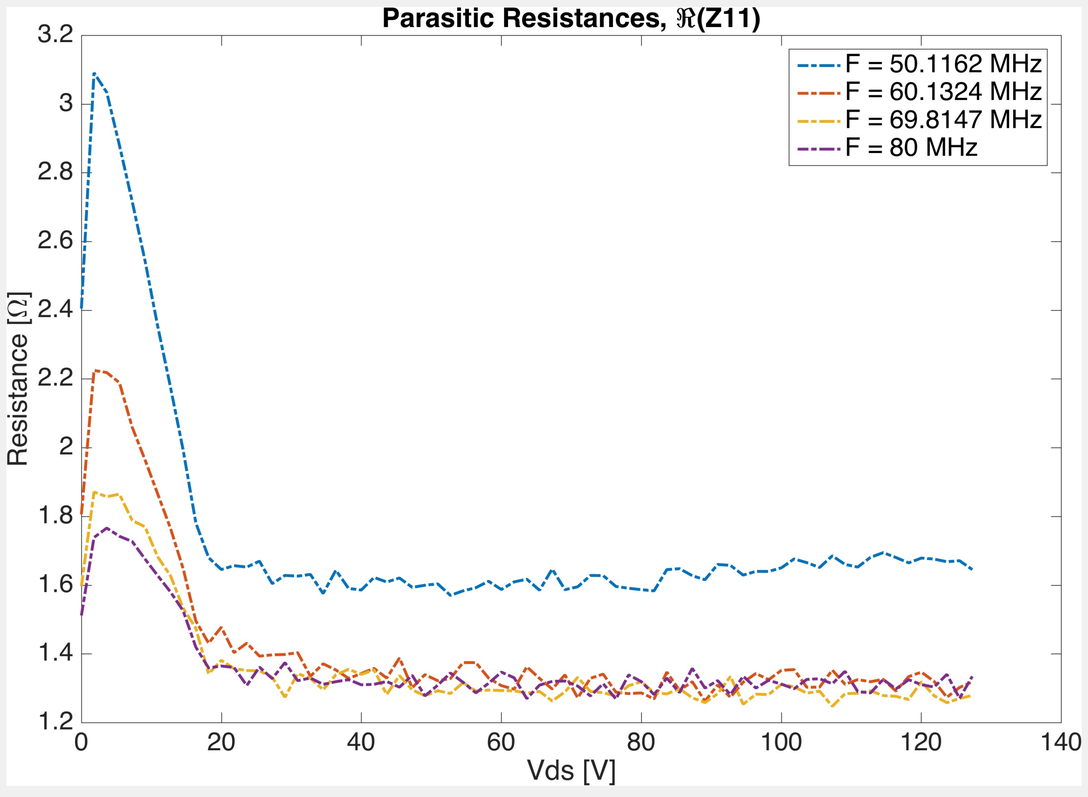


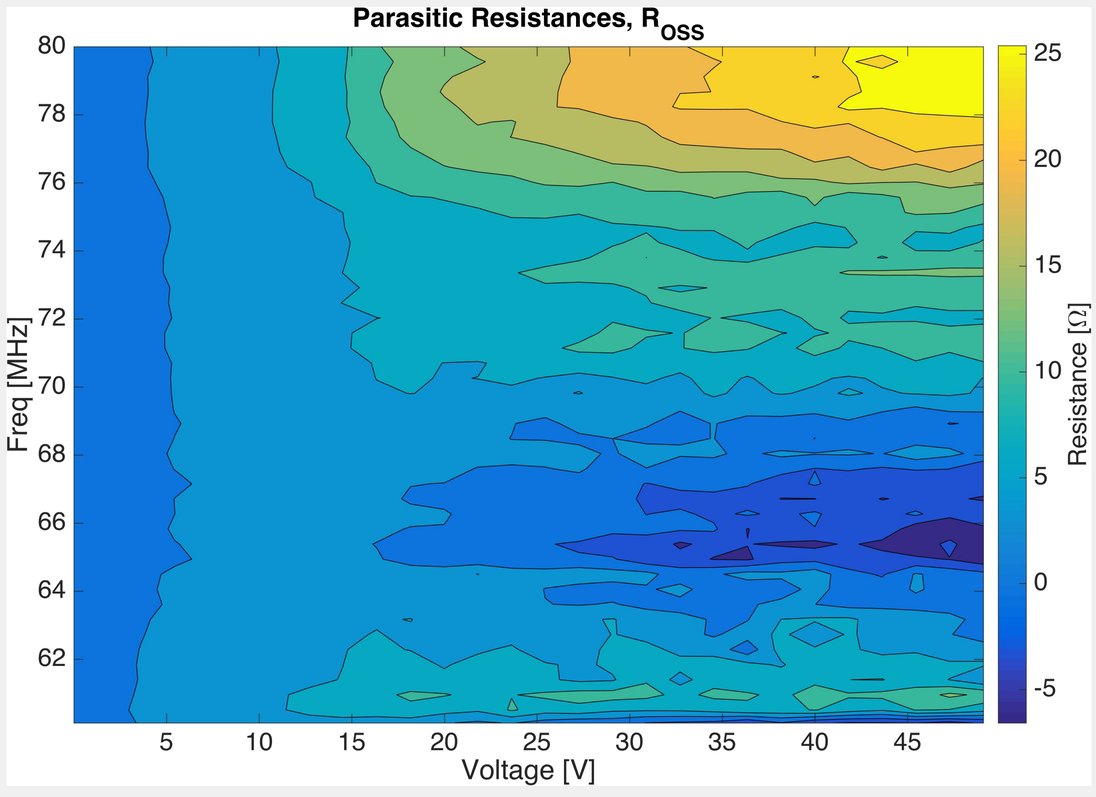












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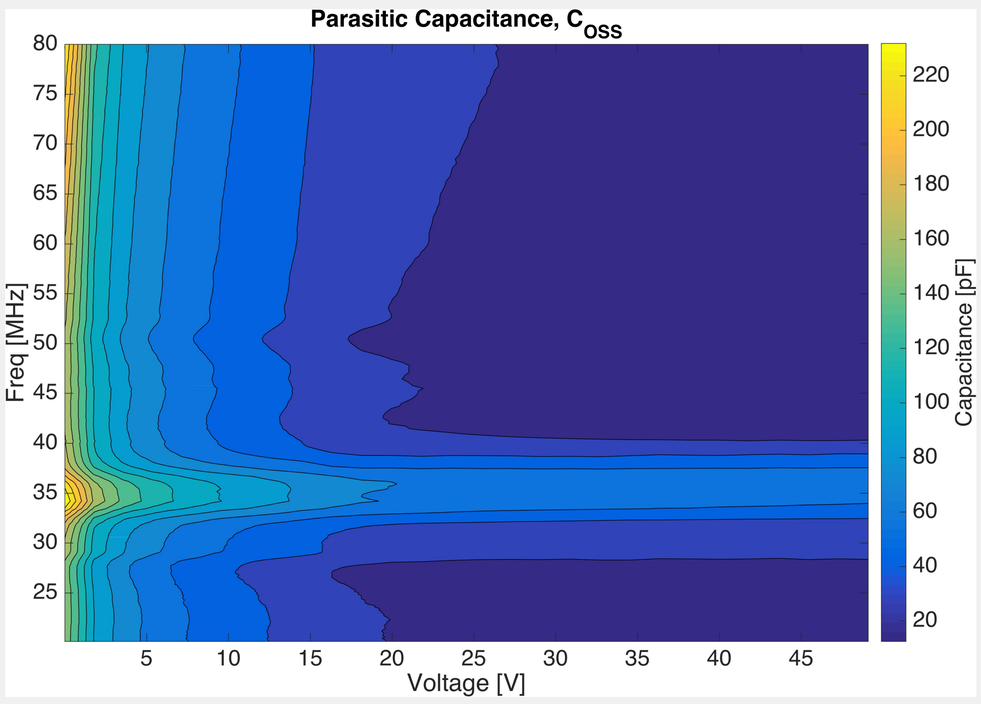
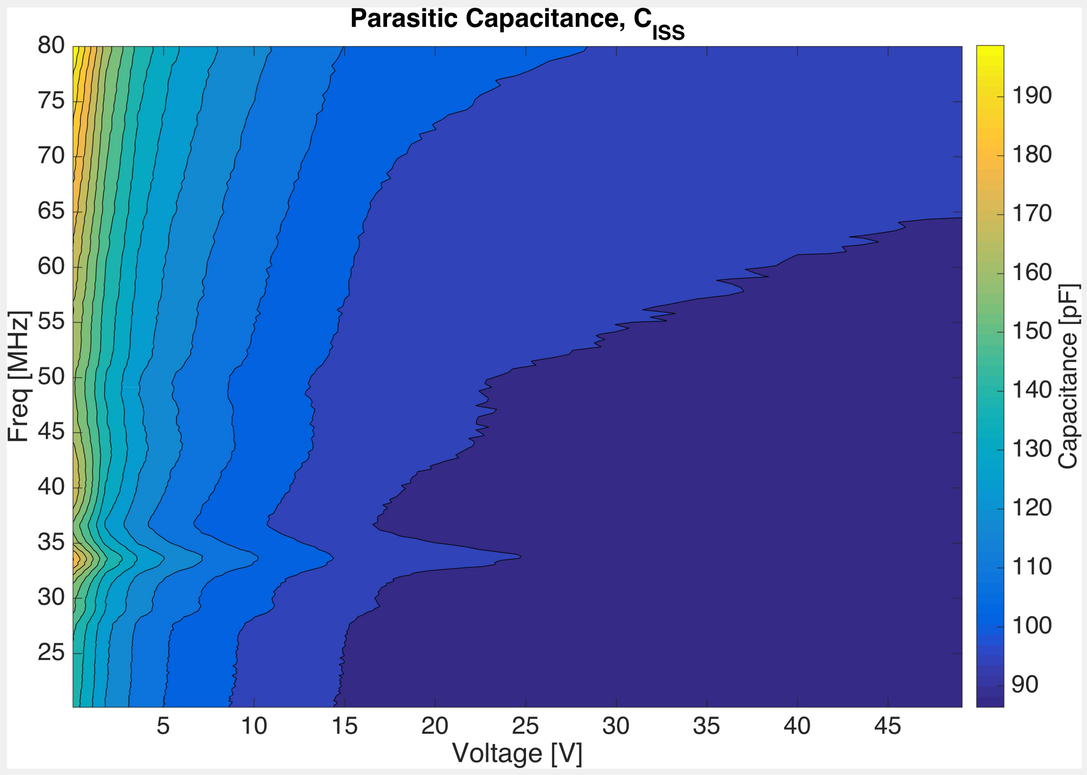
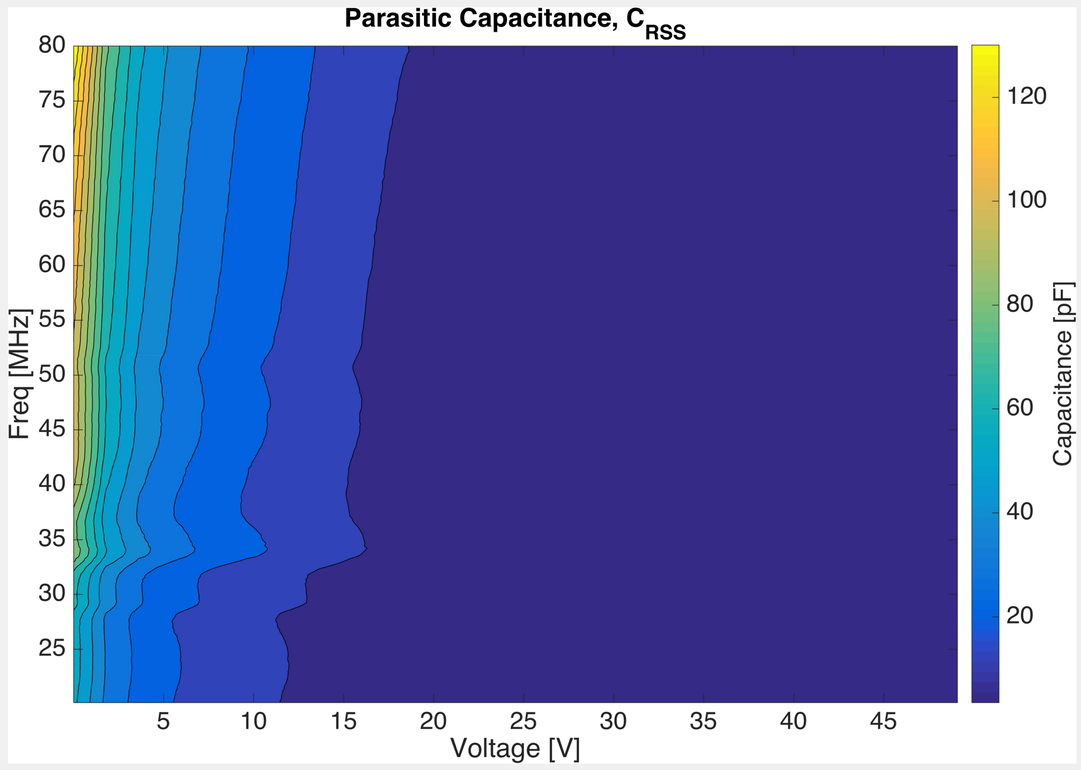
Additional results: Looking at contour plots of the capacitance reveals interesting things:

- C_{RSS} and C_{OSS} are stable over frequency.
- C_{ISS} increase with frequency. However, effect most notably over voltage.
- Measurement setup seems to have an unwanted effect around 30-40 MHz. Corresponds to unknown inductance in the measurement setup.







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[1] A. D. Sagneri, D. I. Anderson, and D. J. Perreault, "Optimization of transistors for very high frequency dc-dc converters," *2009 IEEE Energy Conv. Congr. Expo.*, pp. 1590–1602, 2009.

[2] Z. Chen, "Characterization and Modeling of High-Switching-Speed Behavior of SiC Active Devices," 2009.

[3] S. H.-M. H. M. Jen, C. C. C. Enz, D. R. R. Pehlke, M. Schroter, and B. J. J. Sheu, "Accurate modeling and parameter extraction for MOS transistors valid up to 10 GHz," IEEE Trans. Electron Devices, vol. 46, no. 11, pp. 2217–2227, 1999.