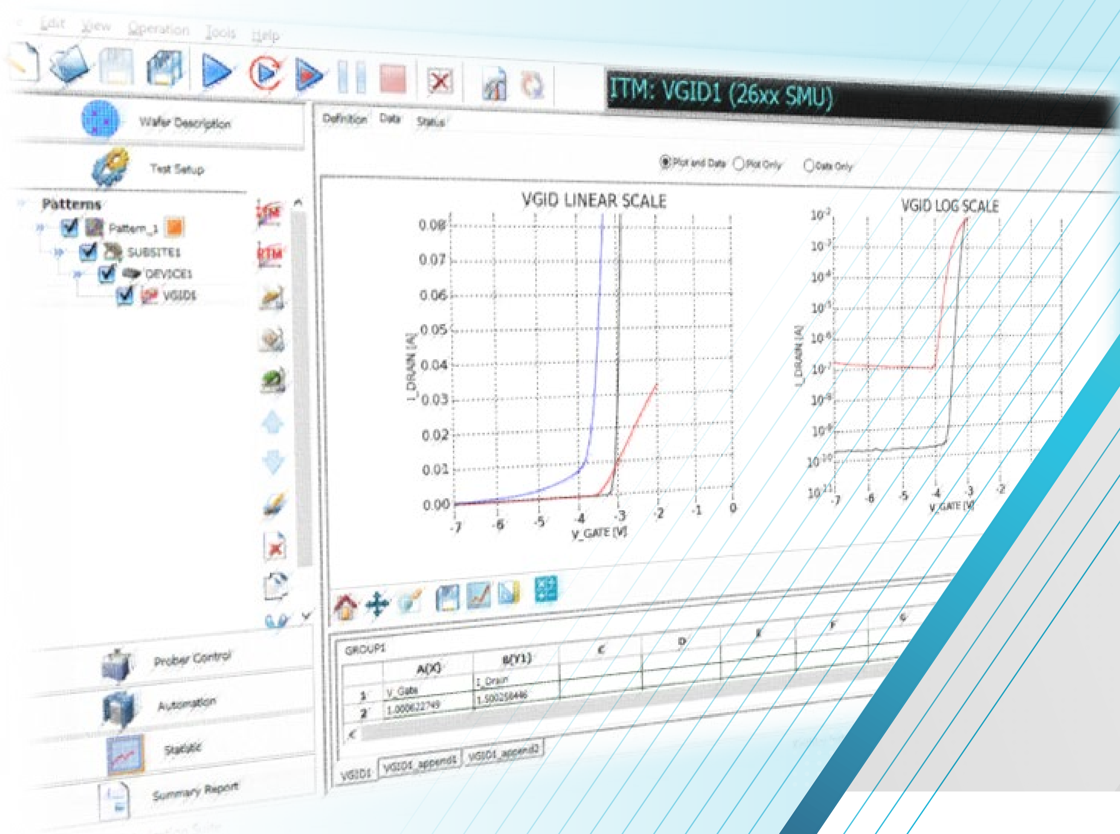
Power Sequence for GaN HEMT Characterization

APPLICATION NOTE



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Abstract

In order to measure the I-V characteristics of gallium nitride (GaN) high electron mobility transistor (HEMT), a special power sequence is required to prevent unexpected damage during IV evaluation. The tools to capture the I-V curve must equip the function for a specific sequence. Keithley's Automated Characterization Software (ACS) gives the ability to perform power sequencing for a GaN HEMT characterization of a device without damaging it and to capture its intrinsic I-V characteristics.

Gallium Nitride Device

Gallium Nitride (GaN) is featured due to its advantage of a wide energy band gap, whose energy is about 3.4eV and three times higher than Silicon's. This feature has been applied to a variety of innovative devices. For instance, in the optical area GaN-based materials emit a shorter wavelength. It led to the introduction of blue and white LEDs to the market. At the same time, it expanded laser diode (LD) wavelength to the range of green, blue, and down to ultra violet (UV). In the power device area, GaN is a material for realizing higher voltage insulation as does silicon carbide (SiC). Much effort is still being made to develop a bulk type vertical GaN power device[4].

Furthermore, GaN has a notable ability to realize a high-speed signal. GaN is a III-V compound semiconductor. Gallium Arsenide (GaAs) and Indium Phosphide (InP) belong to the same group. Their mature application is high frequency devices such as transmission amplifiers and low-noise amplifiers for receivers. Among the III-V group, GaN has an outstanding ability to achieve higher transmission power and higher frequency thanks to its wide band gap and high saturated electron velocity. In addition, it consumes less energy and, as a result, realizes power saving and allows the downsizing of a circuit. These features are applied to communication infrastructures such as wide band telecommunication, broadcasting satellite, and aerospace and defense. For instance, cellular base-station transmitter systems (BTS) is a typical application. A GaN device is widely equipped in BTS from fourth cellular generation (4G), fifth-generation (5G) and further[3].

First HEMT

In 1980, a new type of transistor was introduced[1][2]. The transistor was named high electron mobility transistor (HEMT). The first HEMT consisted of multiple layers of GaAs and doped AlGaAs. The heterojunction and n-doped AlGaAs accumulate electrons within the GaAs layer and forms two-dimensional electron gas (2DEG). 2DEG shows higher mobility than established GaAs devices, therefore contributes to high-speed performance. An HEMT utilizes 2DEG as a channel and controls it through a gate electrode.

GaN HEMT

GaN HEMT is a transistor of the same family as GaAs HEMT. GaN HEMT stacks dissimilar crystals of GaN and AlGaN. This structure induces high density 2DEG, thanks to its piezo-electric and spontaneous polarization (**Figure 1**).

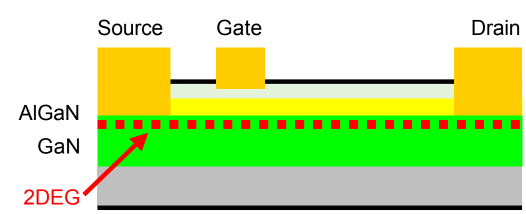

Figure 1. GaN HEMT structure and 2DEG.

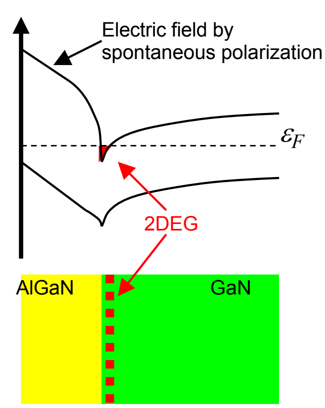

Figure 2. Energy band diagram of GaN HEMT.

In similar fashion to other HEMTs, GaN HEMT controls 2DEG through the gate. GaN HEMT is a "normally-on" transistor, which means drain and source are electrically connected when no gate control is applied. A user needs to apply negative voltage to the gate in order to make a transistor turn-off. Recent efforts change GaN HEMT to a "normally-off" transistor for the purpose of safety needs in power applications[5][6]. However, GaN HEMT is essentially a "normally-on" transistor and is utilized in communication applications such as an amplifier.

Power sequence for GaN HEMT I-V characterization

Because of its "normally-on" characteristic, GaN HEMT requires a specific power sequence in I-V characterization. For GaN HEMT, test engineers need to apply a gate voltage in priority than drain voltage. Forcing negative gate voltage turns off the channel between drain and source, which enables engineers to apply a drain voltage safely. Otherwise, an unexpected inrush current can flow into a transistor and cause unrecoverable damage. At the end of the I-V test, reverse order sequence is necessary.

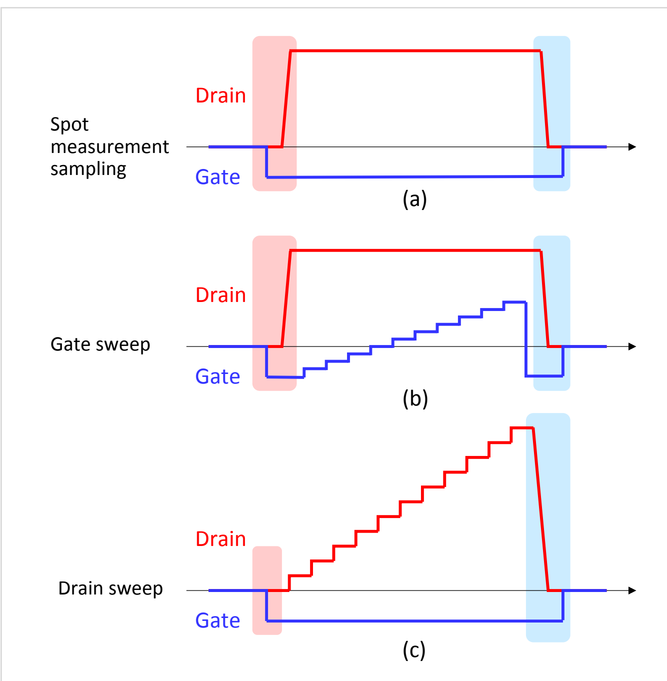

Figure 3. GaN HEMT Soft Bias Sequence. (a) Spot or sampling measurement, (b) IdVg Gate Sweep, (c) IdVd Drain Sweep.

During device development, engineers should prevent samples from damage or degradation by stress in order to take their intrinsic characteristics. During quality improvement or failure analysis, engineers would like to avoid additional damage to devices. For these purposes, software for I-V characterization needs to support the specific power sequence for GaN HEMT.

Software for GaN HEMT I-V characterization

Automation Characterization Suite (ACS) is a Keithley software to configure individual SourceMeter® Source Measure Units (SMUs) as I-V parametric testers for parametric analysis, production testing, or reliability testing according to the hardware configuration. By using high power SMUs, ACS allows it to be a high power parametric analyzer. It is widely applied to high power device testing including LDMOS, IGBT, SiC MOSFET and GaN devices. The popular configurations are commercialized as Parametric Curve Tracer (PCT) Series.

The standard I-V characterization function in ACS, named Interactive Test Module (ITM), has suitable features for GaN HEMT IV measurement. Users can realize testing without any special effort.

(1) Power sequence

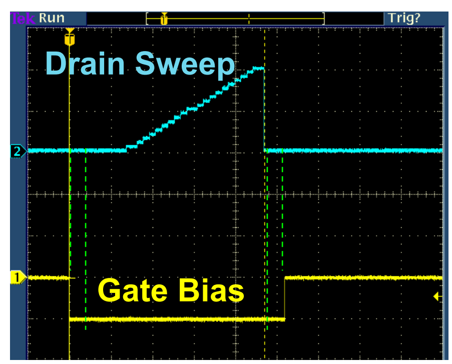

Figure 4. ACS Power Sequence (Drain sweep case).

Figure 4 shows a power sequence example using ACS. Users can configure the SMU output order and adjust the delay time between each SMU. This function enables a user to apply gate voltage in advance of drain voltage, to ensure the transistor is turned off at the time when the drain voltage is applied. At the end of the test, the function keeps the transistor turned off until the drain voltage goes to zero, and releases the gate after that. In the default setup, ACS synchronizes timing of all the SMUs by a hardware triggering system. However, users can optionally set delay times between each SMU action. Users enable this delay by adding one line in the setup file.

```
[engineer_autoInfo]
autoInfo=Lot ID,Remark
defaultValues=,ACSADMIN,,,,,,

[common]
sequence4ITM26=1
```

Figure 5. ACS setting for Power Sequence.

Edit ACS\KATS\ACS_setting.ini. Add one line indicated above.

Then users can see the delay and sequence setup in the “Advanced Setting” dialog in ITM.

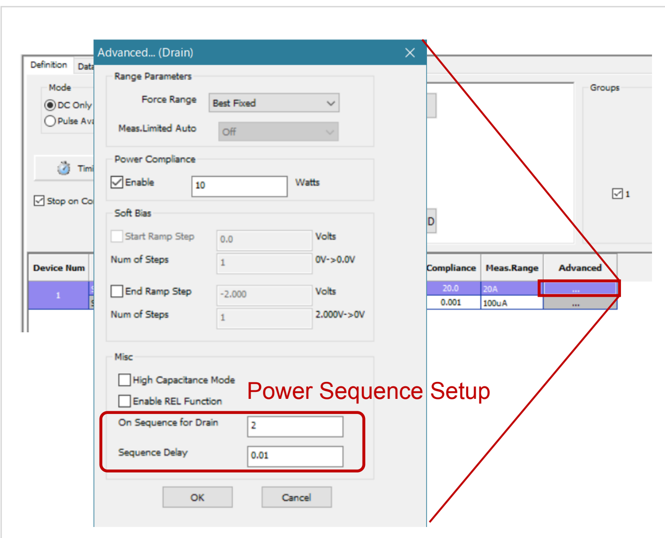

Figure 6. Power Sequence setup.

(2) Soft Bias

In addition to power sequence, “soft bias” helps with reliability testing. Usual bias action is “hard bias”, which means the action that voltage or current bias jumps to the target level in a very short period of time. In contrast, “soft bias” is the action that voltage or current ramps up slowly. In addition, “soft bias” finishes the test with ramp down before the bias reaches zero level.

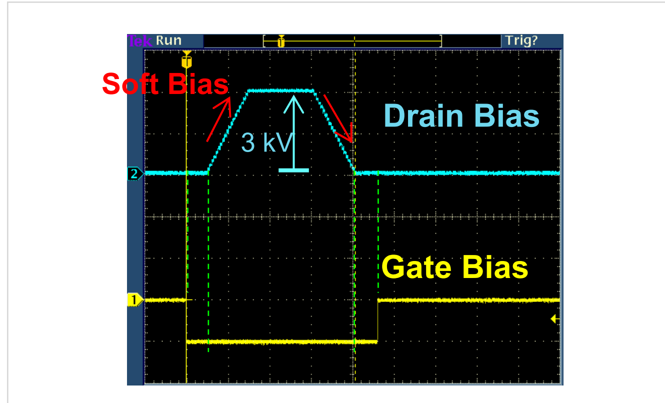

Figure 7. ACS Soft Bias (spot or sampling measurement case).

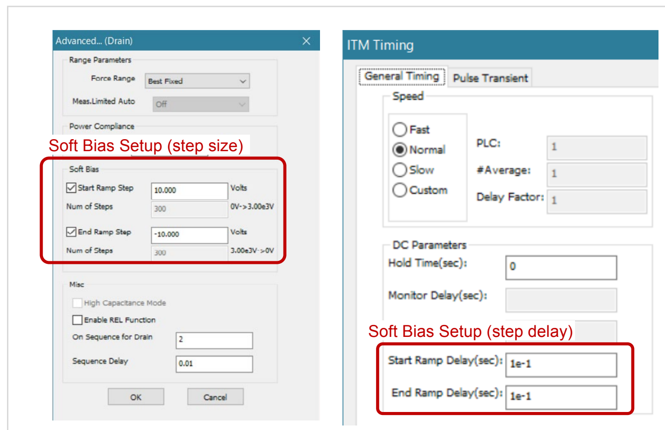

Figure 8. Soft Bias setup.

This feature allows safe testing of a DUT especially in high voltage applications. Test engineers would normally hesitate to apply such a high voltage, 3kV for example, as a hard bias because of the risk of unexpected break down.

This feature also enables users to control charging to the devices, cables, and fixtures. Users benefit from avoiding an inrush current to the device. Moreover, this feature is useful when the device under test (DUT) connection is not ideal. The best connection for I-V parametric testing is a TRIAX cable, which is fully DC guarded from the SMU to the fixture. In practical situations, however, users sometimes cannot prepare a full DC guarding. As a result, some part of the connection is a single wire or co-axial cable, some part of a fixture is not DC guarded, and therefore they can be capacitive or inductive. These connections cause an unexpected overshoot to the DUT, which is not a well-controlled situation for I-V testing. “Soft bias” provides the practical option for such a situation.

Conclusion

GaN HEMT is essentially a “normally-on” transistor. To realize I-V characterization in a safe way, a specific power sequence is required. ACS, which is a Keithley software solution for high power parametric systems, has a sequence output feature as a standard function. Moreover, ACS has a “soft bias” function that makes SMU bias ramp up occur slowly. These features enable users to prevent GaN HEMT devices from damage or stress, and therefore allow the capture of their intrinsic I-V characteristics.

Reference

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