User Manual
Small-Signal Probe Station
High Frequency Test Laboratory
315 Bard Hall

Last revised by James Hwang on November 7, 2023

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1. Before Starting

Fig. 1.1 shows that this tool is based on a Cascade Summit 9600 probe station on top of a Kinetic Systems 1201 vibration-isolation table. The probe station is equipped with two Cascade 103-754 x-y-z-θ probe positioners, a Mitutoyo 378-134-4 microscope (with long working distance and a built-in TV camera), and a 6"-diameter microchamber and thermal chuck (−50 to 200 °C). The thermal chuck is controlled by a Temptronic TPO3000 ThermoChuck system. Normally, the probe station is configured for room-temperature measurements with the microchamber cover removed and the thermal chuck turned off. The RF signal path consists of an Agilent E8364B vector network analyzer (VNA), two long and flexible cables, two Agilent 11612V bias tees (capable of pulsed biases), two short and semiflexible cables, and two probes. All of them have 2.4-mm coaxial connectors to support a 50-GHz bandwidth. (Although adaptors can be used to accommodate probes with 2.9-mm or 3.5-mm connectors, they will reduce the bandwidth to 40 GHz and 26 GHz, respectively. In this case, ask the tool owner or an expert user to install the adaptors and/or different cables for you. Never change the adaptors or cables yourself! Although SMA connectors can mechanically mate with 3.5-mm and 2.9-mm connectors, they are not allowed because they would not only degrade the system performance, but also damage the 2.9-mm or 3.5-mm precision connectors.) The DC bias is supplied by an Agilent 4156C precision semiconductor parameter analyzer (PSPA). Both the DC and RF signals are controlled by a personal computer (PC) running Keysight IC-CAP on Windows 10, together with the MPI QAlibria RF calibration software. For users interested in exploring the full capacity of the tool, ask the HFTL manager for manuals provided by manufacturers of individual instruments. If you have any question or doubt about the following instructions, discuss it with the HFTL manager before you unilaterally bend the rules! If you are not sure about something, just ask, he will be happy to help.

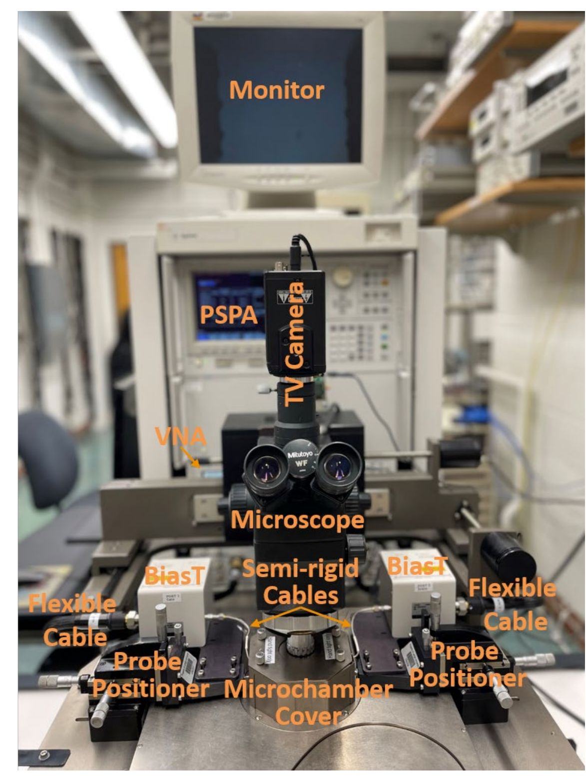


Fig. 1.1. Small-signal probe station.

Although it is possible for you to start with microwave small-signal probing without any experience in DC probing, the normal progression is to be trained on the DC probe station first and to gain some experience there, before advancing to the small-signal probe station. You may also like to make sure a device is working at the DC level before attempting to measure its microwave characteristics.

1.1 Study this manual before arranging for the HFTL manager to give you one-on-one in-person training on the tool! Make sure it is the latest version posted on the CNF website https://www.cnfusers.cornell.edu/node/672, because revisions are frequent. You will need to have your own sample and probes for training, so you may regard it as your first measurement session. You will be charged for the training time, so you will save time and money if you study this manual well before the training.

1.2 Schedule in advance with the HFTL manager for your first training/measurement session only after you have your own sample, probes and know what kind of measurement you like to do with them. After you successfully complete the training and become a qualified user of this tool, for additional measurement sessions, you still need to make sure the HFTL manager, the tool owner, or an expert user is available. Currently, HFTL does not allow unsupervised use!

1.3 Bring your own probes! This is because RF probes are delicate, can be easily abused, and have strong personalities that can change with wear and tear. If you don't have them, you can purchase them from probe suppliers such as MPI, FormFactor or GGB. Confirm with the tool owner that your probes are compatible with the tool. For example, each probe should have three tips for ground, signal, and ground (GSG) contacts, respectively. The center-to-center pitch (spacing) between the tips is typically 100, 125, 150 or 250 µm, matching the pitch of the contact pads on your sample. Study supplier's website to decide what kind of probes works better for your sample. For example, for contacting gold pads, probes with beryllium-copper tips such as FormFactor ACP probes may be preferred, because springy beryllium copper can skate on soft gold to increase the contact area. For contacting aluminum pads, probes with tungsten tips such as FormFactor INFINITY probes may be preferred, because hard tungsten can break through the aluminum oxide on the surface of aluminum when it is exposed to air. Probes with vertical or angled (usually around 45°) connectors may be preferred for your measurements.

1.4 You will be given access to the Coral workstation dedicated to HFTL, as well as the PC dedicated to this tool. Each time you use the tool, make sure to log on and off both the workstation and the PC, so you can be charged accordingly. Since the same Coral workstation controls the access to several HFTL probe stations, after you enable your use of the small-signal probe station, log off the workstation so that others can use it to enable their use of other probe stations. Even after you log off the workstation, the charging clock will continue ticking until, after you finish your measurement, you log onto the workstation to disable your use of the small-signal probe station.

1.5 Other than carefully adjusting the microscope, the wafer chuck, the vacuum switches, the probe positioners, and the z-lever, never touch or lean on the probe station! Otherwise, it may damage the sample or probes. Keep in mind that any rough motion will set off vibrations to allow the probes to scratch the sample if they come in contact.

1.6 Everything on the probe station is delicate. Do not force them beyond their normal movement range and permanently damage them!

1.7 Never touch the gold-plated surface of the wafer chuck with bare hands or metal tweezers! Use plastic tweezers or plastic-tipped metal tweezers. When working with Si MOSFETs or other oxide devices, ground yourself with the wristband to avoid damaging them. If you can feel a static shock by touching a metal, you should definitely ground yourself regardless what you are working with.

1.8 If you accidentally drop or lose the sample, a screw, or anything else in the microchamber, ask the tool owner to fish it out. Don't attempt to disassemble the microchamber yourself!

1.9 Never change the hardware configuration other than mounting your own probes! Please understand that it is impossible to manage a shared facility with a variable configuration customized for each user, smart or dumb.

1.10 If you encounter anything unexpected during the measurement, don’t hide it! Report it to the tool owner and record it on the workstation. Users violating these rules will be removed from the list of qualified users.

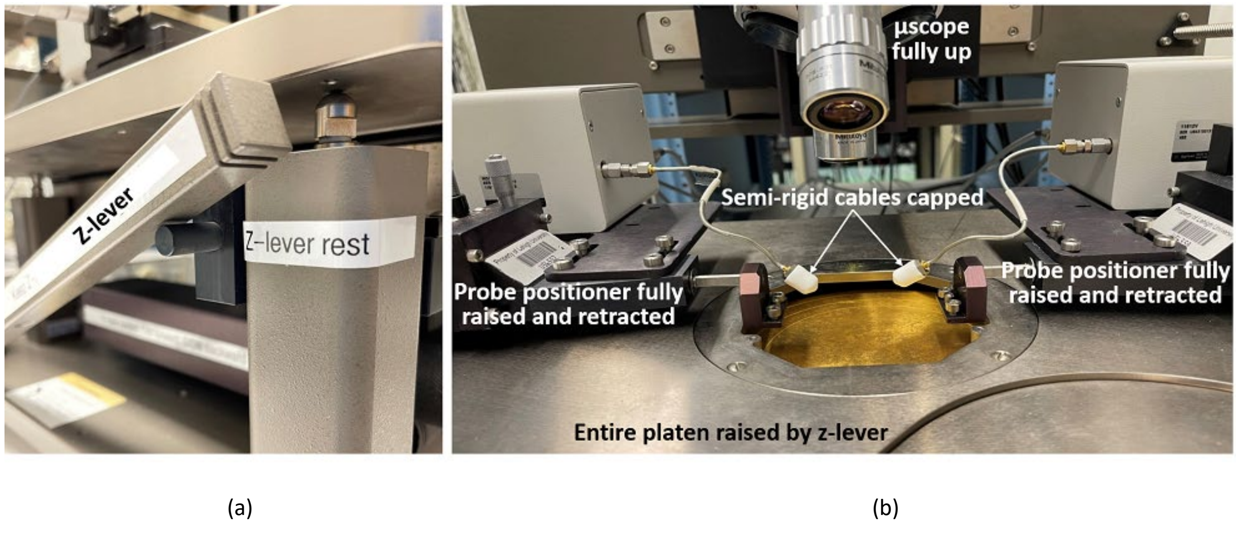
2. Prepare for Measurement

2.1 Log on both the workstation and the PC.

2.2 Remove the dust cover and store it in the top right drawer of the workbench to the left of the DC probe station.

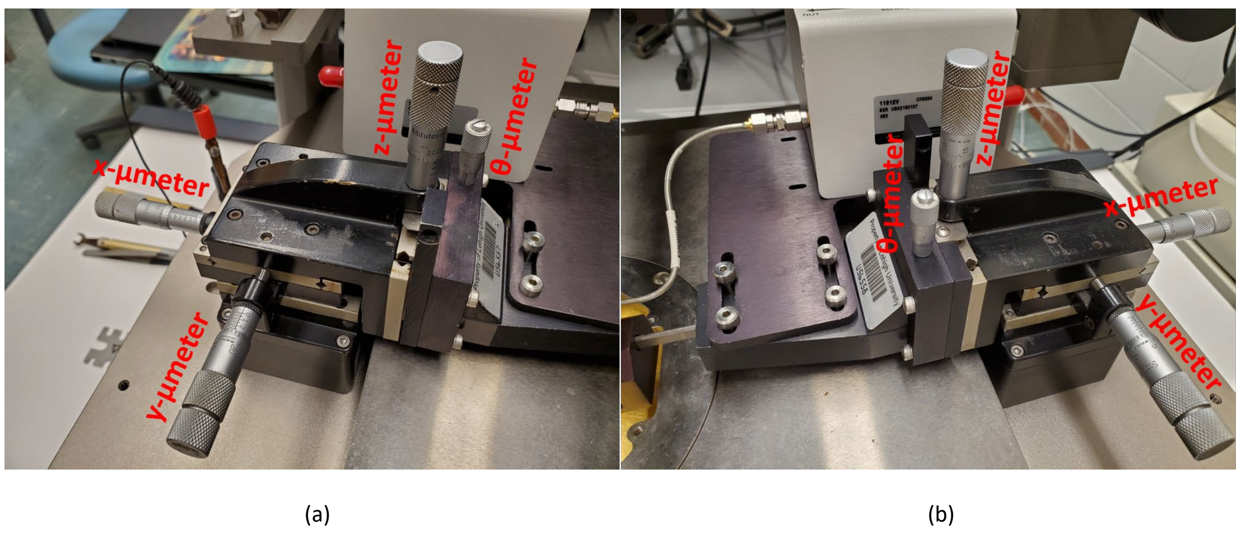
2.3 Make sure the tool is set up with the z-lever propped up on the rest, the microscope fully raised, the semiflexible cables protected by end caps, and the probe positioners fully raised and retracted (Fig. 2.1) by gently turning the z- and x- micrometers to their middle settings around 4 (Fig. 2.2). The probe positioners are mounted on a platen resembling a table top. The z-lever raises the entire platen up along the z-axis and separates the platen from the wafer chuck. The probes point at each other along the x-axis. The probes can be laterally moved along the y-axis to ensure that they point at each other.

2.4 Make sure the VNA and PSPA have been turned on for at least a half hour and there is no error message on the screen. Normally, the VNA and PSPA are left on 24/7.



(a) (b)

Fig. 2.1. Default setup with (a) z-lever propped up and (b) microscope and probe positioners raised and retracted.



(a) (b)

Fig. 2.2. (a) Left and (b) right probe positioners with x-, y-, z- and θ-micrometers.

3. Install Probes

3.1 Remove the mounting screws from the probe positioners [Fig. 3.1(a)]. If necessary, use the Allen wrench from the accessary box on the table to loosen them before turning them by hand.

3.2 Place both the Allen wrench and the screws back in the accessory box, even though they may be needed in a few minutes. This is to ensure that they will not accidentally be lost.

3.3 Install the probes one by one. If the connector on a probe is protected by an end cap, remove it and put it in the probe box.

3.4 Remove a probe from its box by loosening the thumb screw. Be careful not to touch the probe tips or bump them into anything else! It will be a kiss of death.

3.5 Place the thumb screw back in the probe box.

3.6 Visually inspect the probe connector and probe tips to make sure they are in good condition. If necessary, use the air can to blow off dusts. However, don't blow too hard. Too forceful an air jet can bend the tips. Too much evaporation can freeze the tips and crack them. Ask the tool owner for the probe manual before you try to fix the probe yourself. If you are not sure about the condition of the probe, ask the tool owner or an expert user to take a look.

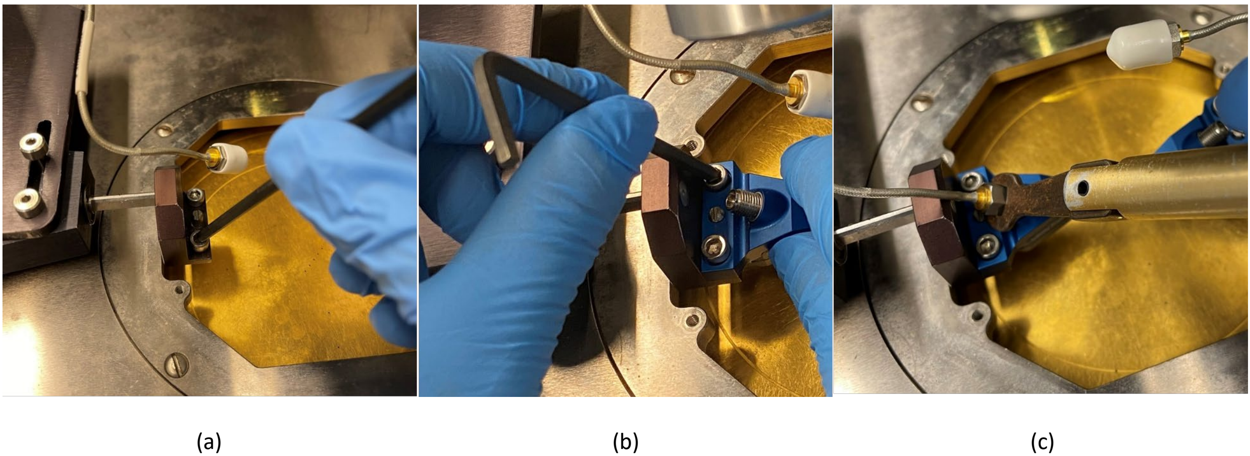
3.7 Hold a probe in one hand. It is suggested to cradle the prob tips in the palm to prevent them from bumping into something.

3.8 With one hand holding the probe, use the other hand to fetch the mounting screws from the accessory box and place them on the probe. Place it on the probe positioner and align it with the mounting holes. Tighten them by hand for at least a few turns to make sure the probes will not fall off the probe positioners when letting go your other hand.

3.9 Further tighten the screws by turning the short arm of the Allen wrench [Fig. 3.1(b)]. Don't use the long arm of the Allen wrench for more leverage. Never overtighten the mounting screws! Otherwise, the screw thread can be tripped and the probe positioner damaged.

3.10 Remove the end caps from the semiflexible cables and save them in the accessory box.

3.11 Use one hand to carefully align the semiflexible cable to the connector on the probe. Do not overbend the cable because it is only semiflexible with a minimum bending radius! Fig. 3.2 illustrate an abused cable that has to be replaced. The cable is bent so sharply next to the connector that the steel woven sheath is broken. Make sure the faces of the cable and probe connector are parallel, so they can easily be screwed together by the other hand all the way until the last turn. Otherwise, unscrew them and try again. The nut on the connector should push the center pin of the connector straight in to and out of its receptacle on the probe. If the center pin



(a) (b) (c)

Fig. 3.1. (a) Removing screws, (b) mounting a probe, and (c) connecting the probe to the semiflexible cable.

rotates, it will cut circular grooves in the receptacle and permanents damage the probe. Keep in mind that the most expensive part of a probe is usually its connector.

3.12 While holding the cable with one hand to prevent it from turning, use the other hand to grab the torque wrench from the accessory box for the final tightening of the connector [Fig. 3.1(c)]. Stop as soon as the spring-loaded torque wrench clicks at the preset torque of 8 inch-pound. Never turn a clicked torque wrench for extra torque!

Fig. 3.2. An abused cable.

3.13 Make sure the wafer chuck is centered with respect to the microchamber. At the center of the chuck, locate the center vacuum hole, which is the middle one in a closely spaced row of five holes. Use it as the reference to center the probes and the microscope.

3.14 Roughly position the probes under bare eyes. Move the probes toward each other until their tips are near the center hole of the wafer chuck but a few millimeters apart. Never move the probes without monitoring their movements with bare eyes, through the microscope, or on the TV monitor! Be careful not to bump the probes together!

3.15 Lower the z-lever first, then the probes until they are within a few millimeters of the wafer chuck.

3.16 Switch on the microscope light. The switch is on the right side of the bridge the microscope is mounted on.

3.17 Make sure the zoom knob on the front right of the microscope is rotated all the way counterclockwise, which gives the lowest zoom ratio with the maximum field of view. (Rotating the knob all the way clockwise increases the zoom from 1X to 2X.)

3.18 Center the microscope on the center hole of the wafer chuck then focus on the surface around the hole. Observe the microscope light spot converging to a small circle a few millimeters in diameter while centering on the hole.

3.19 If you cannot see the shadow of any probe (Fig. 3.3), adjust the probe positioners to bring the probes a little closer to the chuck and each other under bare eyes. If you only see one probe in the microscope, carefully position the other probe under bare eyes to bring it into the view. The microscope has a wider field of view than the TV has, so always check through the microscope before checking on the TV screen. Normally a 10X lens works well with devices that are several hundred microns long, so that the probes need to be several hundred microns apart. For larger devices that require the probes to be farther apart and to be seen under a wider field of view, you may try the 2X lens first. However, never switch the lens without first fully raising the microscope!

3.20 Raise the probes as high as possible but without losing their shadows as shown in Fig. 3.3(b). This way, when you move to the contact substrate in the next section, the probes will not crash into them when the z-lever is lowered.

3.21 Lift the z-lever!

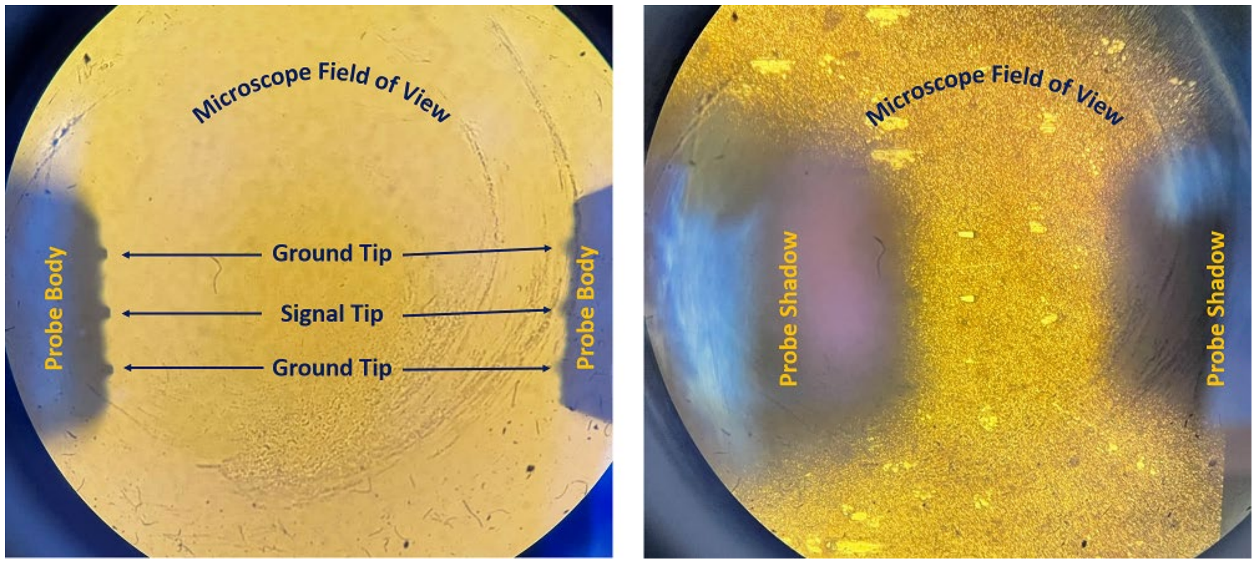


Fig. 3.3. Both probes within the field of view of the microscope but (a) almost touching the wafer chuck with the probe tips clearly visible and (b) lifted up from the wafer chuck with faint shadows.

4. Planarize Probes

It is critical that the three (GSG) probe tips are on the same horizontal plane parallel to the surface of the device under test (DUT). This way, when the probe contacts the DUT, all three tips will make good contacts with their respective contact pads to ensure a smooth transition of the microwave signal from the probe to the DUT and vice versa. To this end, in addition to the x-, y-, and z- micrometers, each probe positioner is equipped with a θ-micrometer which rotates the probe around the x-axis (Fig. 2.2).

4.1 Make sure the z-lever is up! Never move the probes or the wafer chuck when they are in contact with each other!

4.2 Use the x- and y-controls of the wafer chuck to move it left and out to reveal the contact substrate on the right auxiliary chuck [Fig. 4.1(a)]. Make sure the edges of the contact substrate are pushed squarely against top and side ledges of the auxiliary chuck, which aligns it with the x- and y-axes of the wafer chuck. The contact substrate may be uniformly covered by gold instead of lattice-patterned as shown in Fig. 4.1(a).

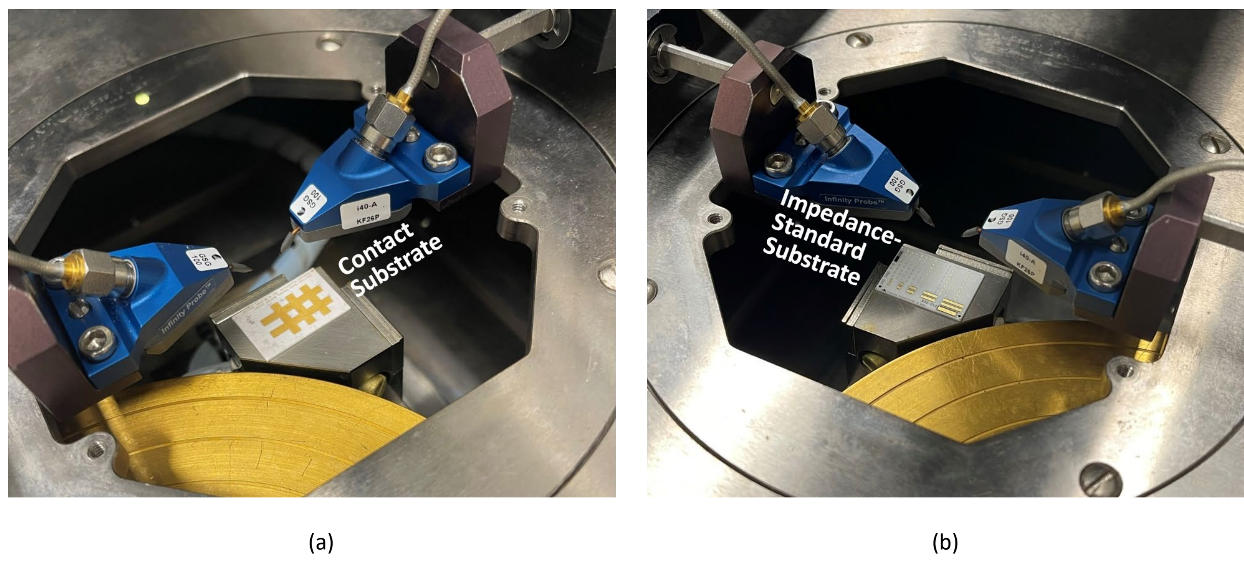
4.3 Turn on the vacuum pump under the vibration-isolation table. The switch is on the power cord for the pump [Fig. 4.2(a)].

4.4 Turn on the vacuum to the right auxiliary chuck [Fig. 4.2(b)]. The switch is the second from the top among the bank of vacuum-control switches on the right of the probe station. Do not confuse the vacuum pump switch with the vacuum control switches.

4.5 Focus the microscope on the metal surface of the contact substrate. If it is uniformly covered by shining gold without obvious features, you may focus on the edge of the contact substrate before moving towards its center.

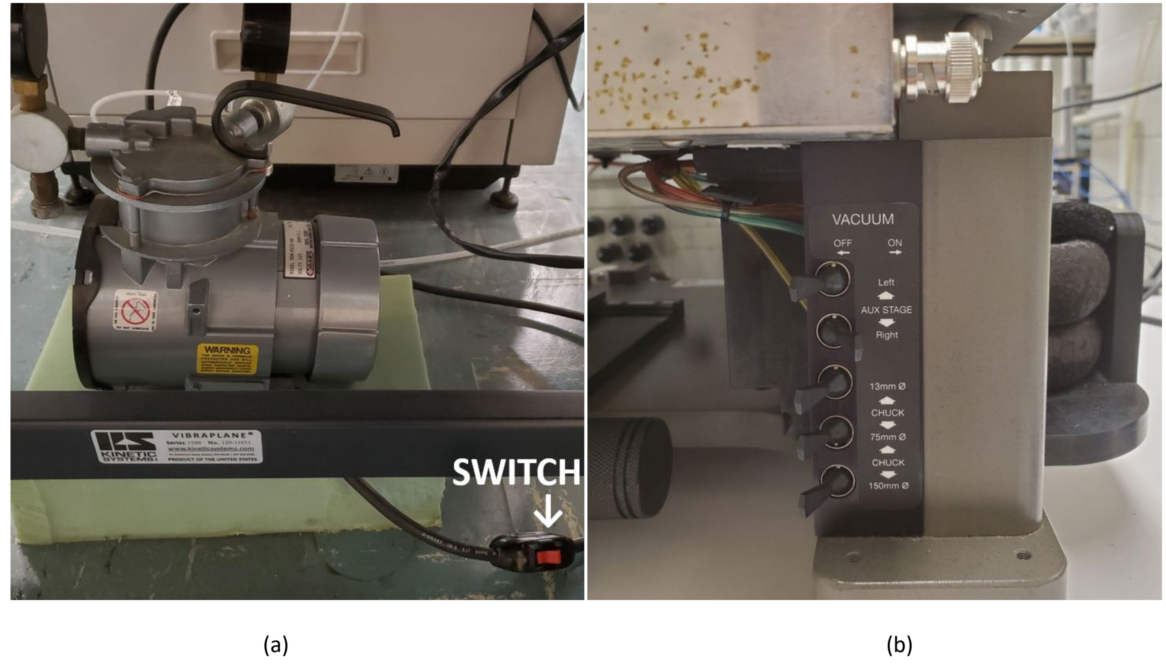
4.6 Gently lower the z-lever and make sure the probe shadows can be seen through the microscope [Fig. 3.3(b)], but the probes are not touching the contact substrate yet.

4.7 While monitoring through the microscope, turn the z-micrometer to bring one probe down further to contact the contact substrate. Be gentle to avoid crash landing! Allow the tips to skate on the contact substrate for about 50 µm as revealed by their tracks after the probes are lifted up and the contract substrate relocated [Fig. 4.3(a)]. Estimate the length of skate by comparing it to the probe pitch. For example, for a probe pitch of 100 µm, the skate should be about one quarter of the pitch, although orthogonal. Don't damage the tips by making them skate too far!



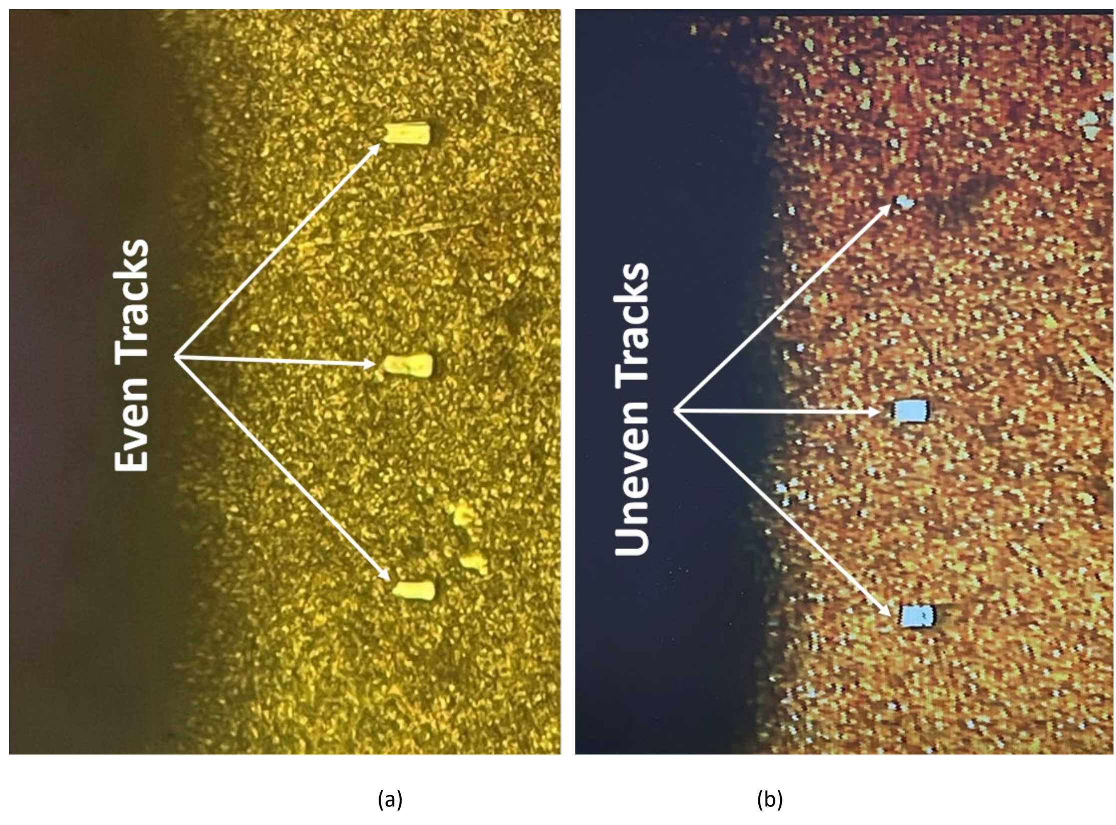
(a) (b)

Fig. 4.1. (a) Contact substrate and (b) impedance-standard substrate (ISS) on right and left auxiliary chucks, respectively.



(a) (b)

Fig. 4.2. (a) Vacuum pump and (b) switch bank.



(a) (b)

Fig. 4.3. (a) Even and (b) uneven tracks left by planarized and tilted probes, respectively.

4.8 If the three tracks are uneven [Fig. 4.3(b)], finetune the θ-micrometer of the probe positioner, move to a new contact area, and repeat Step 4.7 until all three tracks are even [Fig. 4.3(a)]. However, before adjusting the θ-micrometer, make sure the probe is lifted from contacting the substrate by lifting the z-micrometer! Otherwise, you will grind the probe to death.

4.9 Repeat Steps 4.7–4.8 on the other probe.

4.10 Without adjusting the z-micrometers of both probes, lift the z-lever, move to a new area of the contact substrate, then gently lower the z-lever to make sure each probe consistently make three even tracks on the contact substrate. The z-lever can become your best friend in probing.

4.11 After both probes are planarized, use the z-micrometers to lift them up as much as possible until you are about to lose their shadows in the microscope [Fig. 3.3(b)].

4.12 Lift the z-lever! Always lift the z-lever when moving from one substrate to another such as from the contact substrate in this step to the impedance standard substrate (ISS) in the next step! It is rare that two substrates are of exactly the same height.

4.13 Switch off the vacuum to the right auxiliary chuck.

5. Orient Wafer Chuck

This section aligns the x-axis of the wafer chuck with that of the probes, making it easier to probe different devices on the same sample using the z-lever and chuck movement without frequent adjustment of the probe positioners.

5.1 Lift the z-lever if it is not already up and propped up on the rest!

5.2 Move the chuck right and out until you can see the impedance standard substrate (ISS) on the left auxiliary chuck [Fig. 4.1(b)].

5.3 Make sure the edges of the ISS are aligned with the ledges of the auxiliary chuck.

5.4 Switch on the vacuum to the left auxiliary chuck. The switch is the top one among the bank of vacuum-control switches on the right of the probe station.

5.5 Focus the microscope on the ISS.

5.6 Lower the z-lever. You should see the probe shadows through the microscope [Fig. 3.3(b)]. Otherwise, gently adjust the probe positioners while monitoring the probe movement with bare eyes until you can see their shadows through the microscope. Continue adjusting the z-micrometer until the probe tips are visible under the microscope (Fig. 5.1) but not yet touching the ISS.

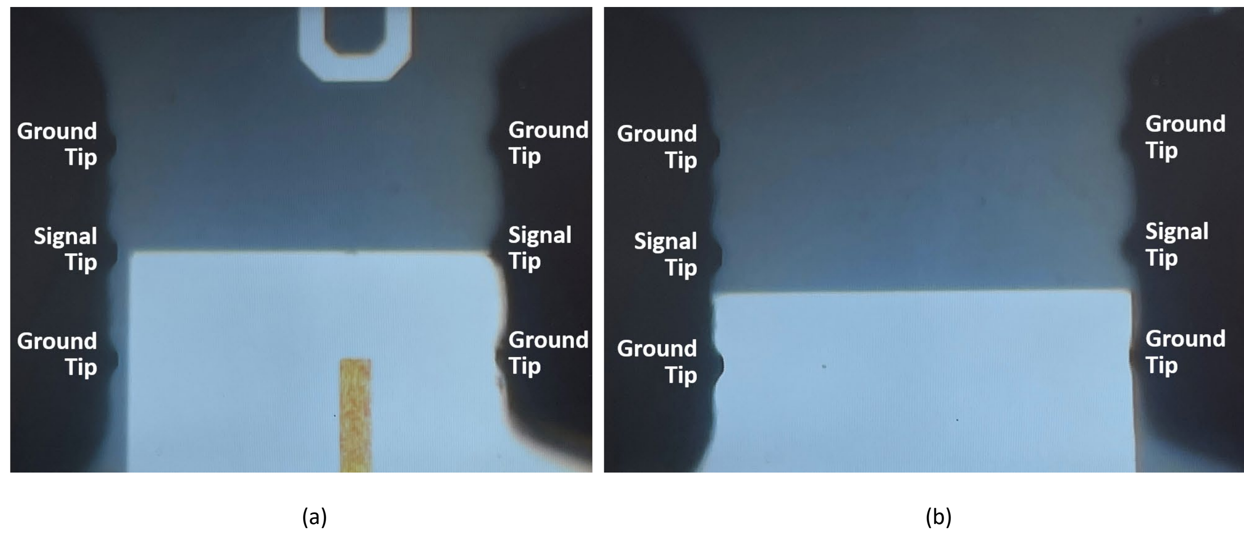
5.7 Move the chuck so that you can see through the microscope the "alignment edge" on the lower right of the ISS (Fig. 5.2). Never allow the probes to touch and scratch the ISS in this step! Otherwise, you may damage both the probe and the ISS.

5.8 Move the chuck so that the alignment edge is centered under the probes with respect to the y-axis [Fig. 5.1(a)].

5.9 Make sure the probes are not touching the ISS! Otherwise, you will leave a long trailmarker for your negligence when you move the chuck. Without the probes touching the ISS, move the chuck in the x-direction while monitoring the movement of the alignment edge in the y-direction.

5.10 If the probes are no longer centered on the alignment edge [Fig. 5.1(b)], rotate the chuck slightly by turning its ϕ-micrometer (not the θ-micrometer on the probe positioner!), then repeat Steps 5.8 and 5.9. Keep in mind that the chuck can only be rotated by ±7° maximum.

5.11 Stop adjusting the ϕ-micrometer of the chuck when the alignment edge remain centered under the probes despite the x-movement of the chuck. This means the x-axis of the probe positioners are aligned with the x-axis of the chuck.



(a) (b)

Fig. 5.1. Probes (a) centered on and (b) offset from the alignment edge w.r.t. the y-axis.

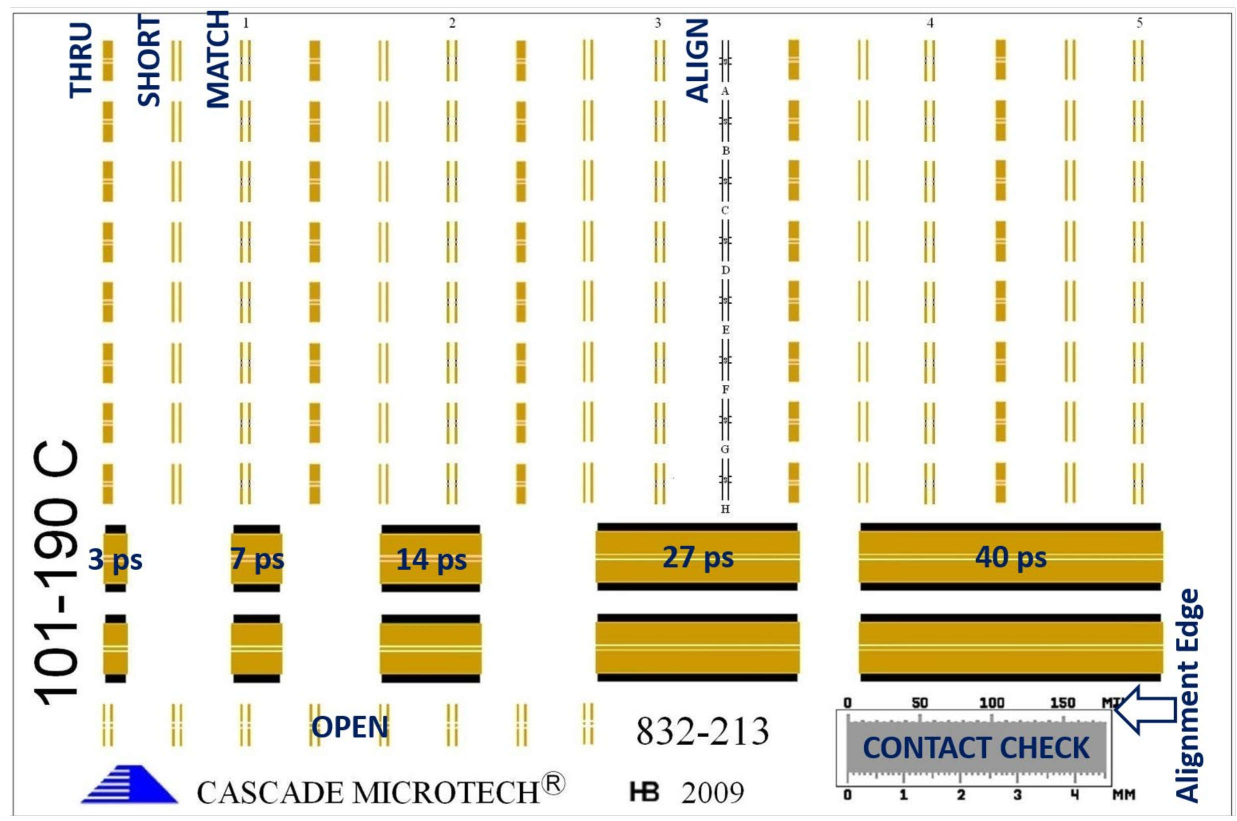


Fig. 5.2. CASCADE 101-190 impedance-standard substrate (ISS).

5.12 Lift the z-lever!

6. Set Probe Overtravel

This section ensures reliable probe contacts to different devices on the same sample using the z-lever and chuck movement without frequent adjustment of the probe positioners.

6.1 Lift the z-lever if it is not already up and propped up on the rest [Fig. 2.1(a)]!

6.2 Read the ISS layout sheet posted on the equipment rack above the PC screen to find the specified row and column of the impedance standards you are required to use.

6.3 Locate the specified set of impedance standards on the ISS (Fig. 5.2). Do not touch other sets of impedance standards! Each set of impedance standards can only be probed for about 20 times.

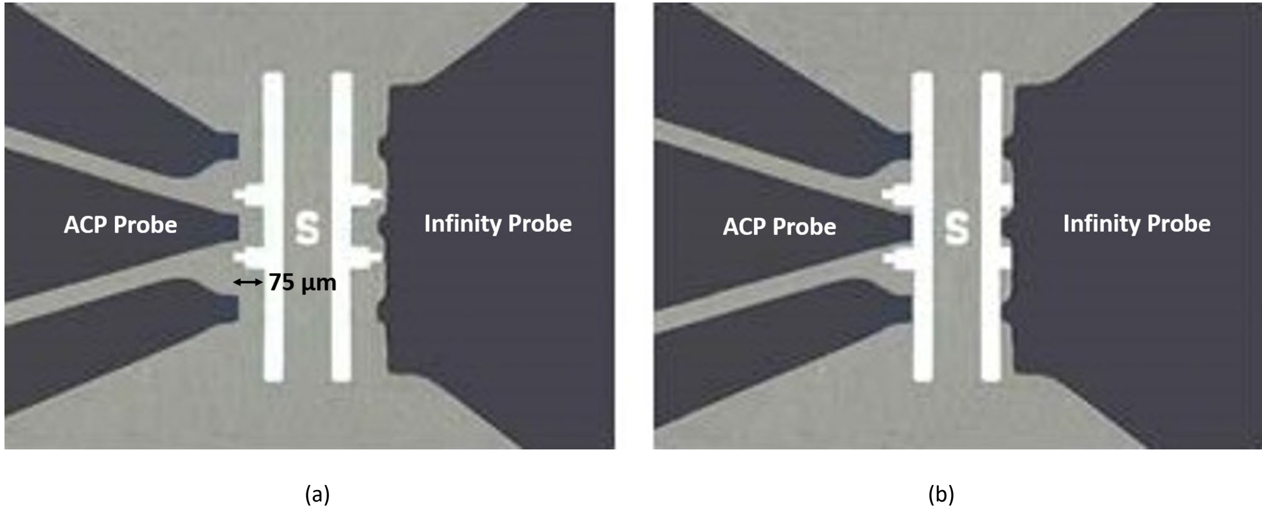
6.4 Lower the z-lever.

6.5 Adjust the probe positioners to align the probe tips on the alignment marker [Fig. 6.1(a)].

6.6 Gently lower the probes to contact the alignment marker, then add sufficient overtravel (downward adjustment of the z-micrometer after initial touchdown) to allow the tips to skate horizontally 75–125 µm for ACP probes, 50–75 µm for Infinity probes, or another amount specified by the probe manufacturer [Fig. 6.1(b)]. The same amount of overtravel and skate will be used in most measurements.

6.7 Lift the probes by lifting the z-lever without adjusting the z-micrometers of the probe positioners. Lower the z-lever to confirm that the overtravel is repeatable.

6.8 Lift the z-lever! Always lift the z-lever before moving to another device or substrate, because the substrate may not be flat and no two substrates (e.g., contact substrate and ISS) are of exactly the same height.



(a) (b)

Fig. 6.1. (a) Initial and (b) final contact positions of the probe tips on the alignment marker of the ISS.

7. Calibrate and Validate Setup

A valid calibration allows you to de-embed the scattering (S) parameters of the DUT between the probe tips from the S parameters measured on the VNA. Because each probe is different, it needs to be individually calibrated. A proper calibration and validation procedure may also determine whether your probes are good enough to generate meaningful data.

7.1 From the PC desktop, open “IC-CAP” if it is not already open. It may take a few minutes for the "IC-CAP/Main" home screen to pop up as in Fig. 7.1. If IC-CAP cannot be opened, make sure the PC is connected to the internet. Each time IC-CAP is opened, the PC must fetch the IC-CAP license from the server via the internet.

7.2 On the top menu of "IC-CAP/Main," click on "File," "Open," "Desktop," then copy “Test.mdl” to your own folder "D:\Users\NetID." Because “Test.mdl” is frequently updated by the tool owner, it is recommended that you make a fresh copy to your folder each time you use the tool. Do not mess with the folders of other users!

7.3 Go to "D:\Users\NetID," open your own copy of "Test.mdl," which provides the basic test setup as shown in Fig. 7.1.

7.4 On the "Test" top menu, click on to open the window for "IC-CAP/Hardware Setup" as shown in Fig. 7.2.

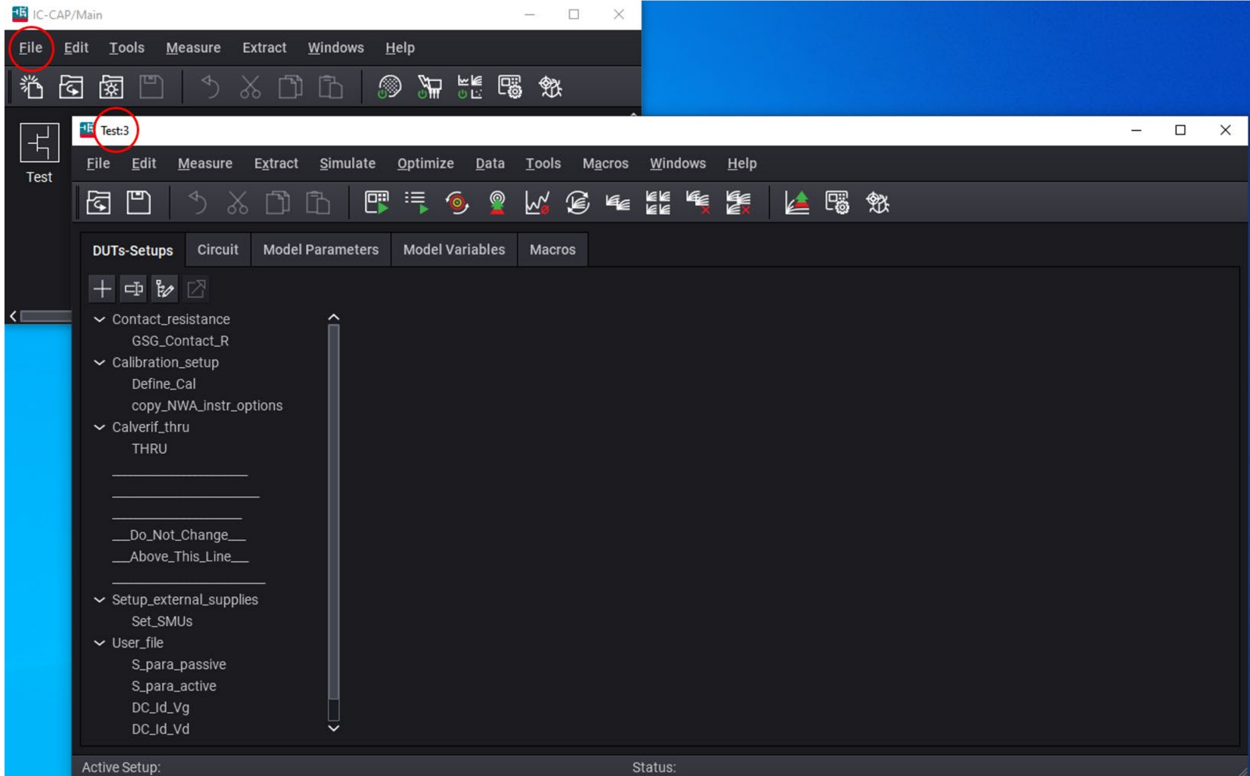


Fig. 7.1. "Test" home screen in IC-CAP.

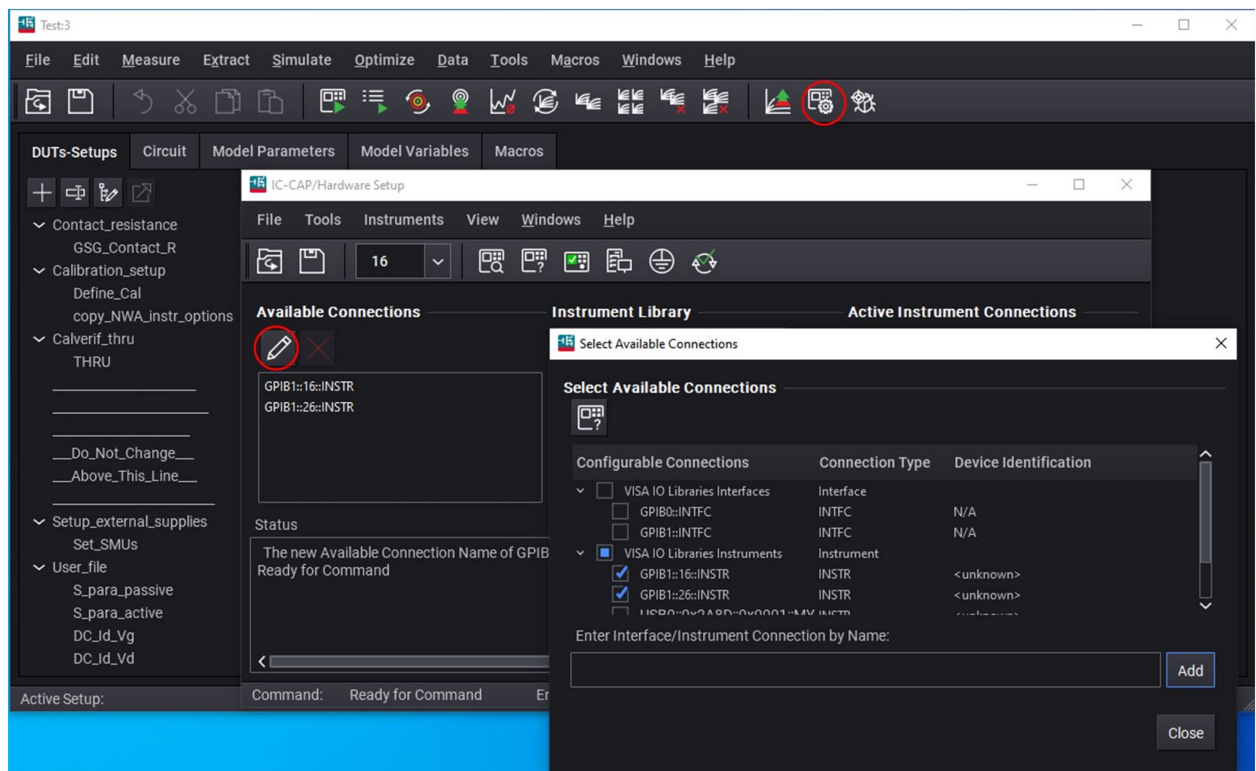


Fig. 7.2. "Test" hardware setup.

7.5 Under "Available Connections," click on to "Select Available Connections." Check "VISA IO Libraries Instruments." Confirm that "GPIB1::16::INSTR" and "GPIB1::26::INSTR" are checked. If on the third row "USB0:..." is also checked, an error message will appear to tell you that it cannot be found. Don't worry. Just click on "OK" on the error message and it will be automatically unchecked. Click on "Close" on the lower right to return to the "Hardware Setup" window. Don't click on "Add." If you do, an error message will appear to remind you that IC-CAP doesn't know what "Interface/Instrument Connection" to add. Just click on "OK" to return to Fig. 7.2 before closing it.

7.6 On the "IC-CAP/Hardware Setup" window and under "Active Instrument Connections," click on to "Rebuild Active Instrument" for about a minute. Once it is finished, confirm that both "KeysightPNA" and "HP4156" are listed as shown in Fig. 7.3. Close the "IC-CAP/Hardware Setup" window and return to the "Test" home screen as shown in Fig. 7.1.

7.7 Lift the z-lever if it is not already up and propped up on the rest [Fig. 2.1(a)]!

7.8 To check the probe contact resistance, locate the "CONTACT CHECK" pattern on the lower right of the ISS (Fig. 5.2). Gently lower the z-lever to land both probes on "CONTACT CHECK," observing that the probe tips skate by the amount set in Sec. 6.

7.9 On the "Test" home screen (Fig. 7.1), click on "DUTs-Setups" if it is not highlighted. Under "Contact_resistance" on the left menu, if "GSG_Contact_R" is not highlighted as shown in Fig. 7.4, click on it. Click on "Extract/Optimize" on the top menu, then double click on "Contact_check" on the left menu. When the "Prompt Dialog" window pops up, don't enter any dialog. Just click on "OK" to measure the contact resistance.

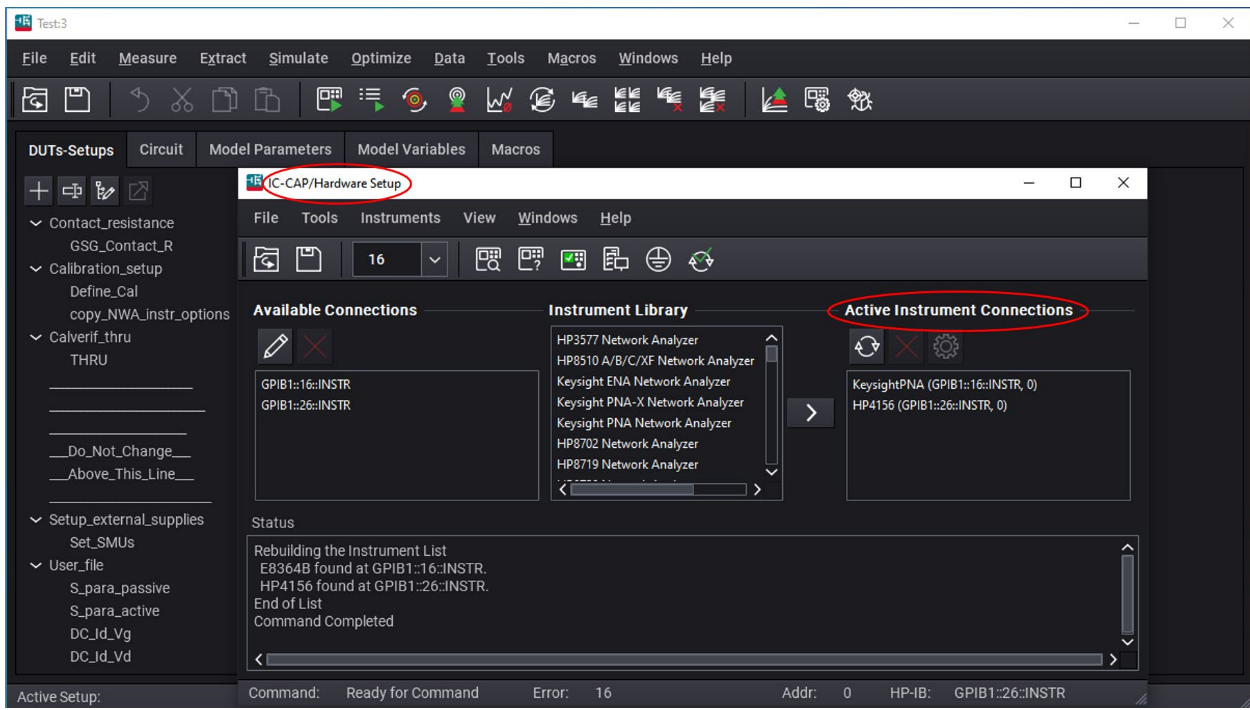


Fig. 7.3. Set available instrument connections.

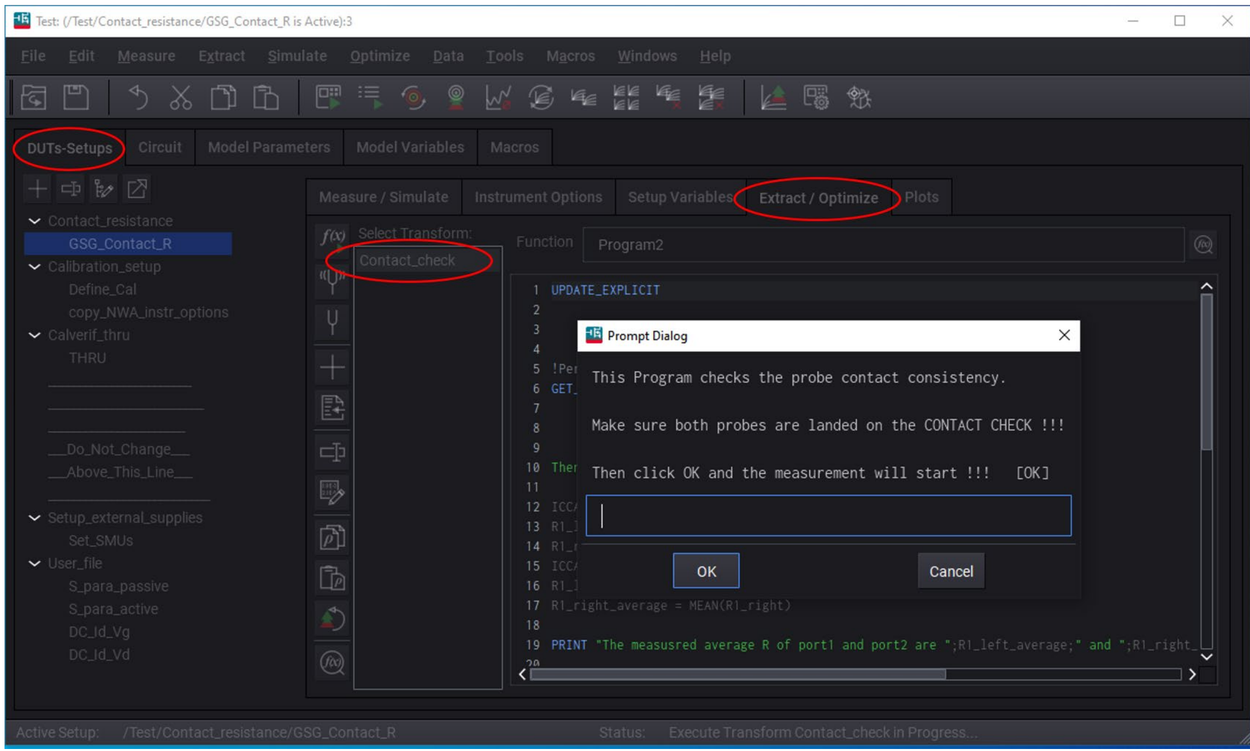


Fig. 7.4. Check probe contacts.

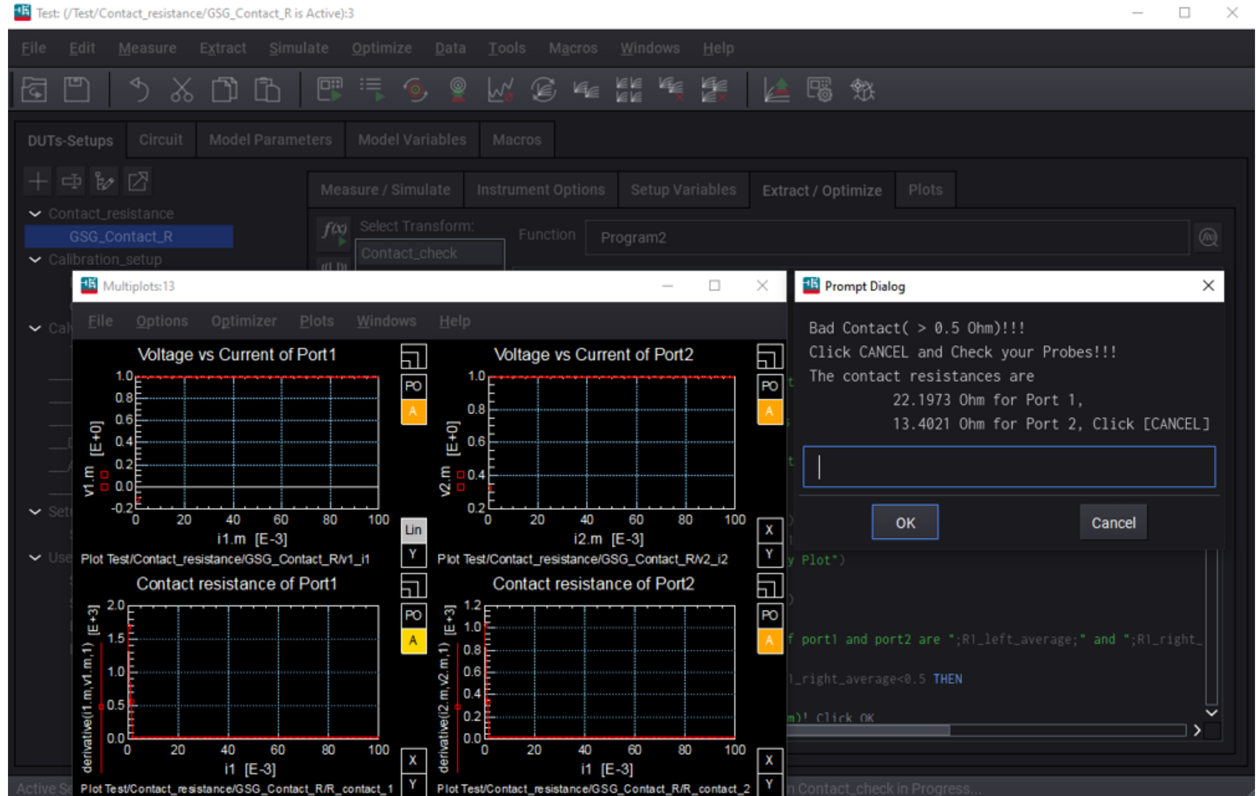


Fig. 7.5. Measured contact resistances.

7.10 After the measurement is completed in a few seconds, the "Multiplots" window pops up and the "Prompt Dialog" shows up again with new messages as shown in Fig. 7.5. "Multiplots" plots the V-I characteristics and ∂V/∂I slopes (resistances) of Port 1 and Port 2, while "Prompt Dialog" reports contact-resistance values of each port. (In microwave terminology, a "port" is generally formed by two terminals such as the signal and ground terminals of a coaxial cable or a microstrip/coplanar transmission line. Usually, Port 1 is the input on the left, while Port 2 is the output on the right. For example, a 3-terminal transistor in a common-source configuration can be a 2-port microwave device, so that Port 1 is formed between the gate and source while Port 2 is formed between the drain and source.) If the contact resistances are less than 0.5 Ω, you should see “Congrats, Contact Consistency Check Passed!!!,” so you can move on to the next step by clicking on "OK." Otherwise, check your probes, the alignment, and the overtravel, and clicking on "OK" and double click on "Contact_check" again to repeat it. If the problem persists, discuss it with the tool owner or an expert user.

7.11 Lift the z-lever!

7.12 On the "Test" home screen as shown in Fig. 7.1, click on “Model Variables,” set the frequency range and step size of the measurement as shown in Fig. 7.6. Set "FMIN" for the minimum frequency (default is 1 GHz; minimum is 400 MHz for the current bias-Ts), "FMAX" for the maximum frequency (default is 40 GHz; maximum is 50 GHz if the probes and cables are capable), "FSTEP" for the step increment of a linear sweep (default is 100 MHz). You can change these parameters if you like, but do not change anything else. If you prefer a logarithmic sweep instead of a linear sweep, discuss it with the tool owner or an expert user.

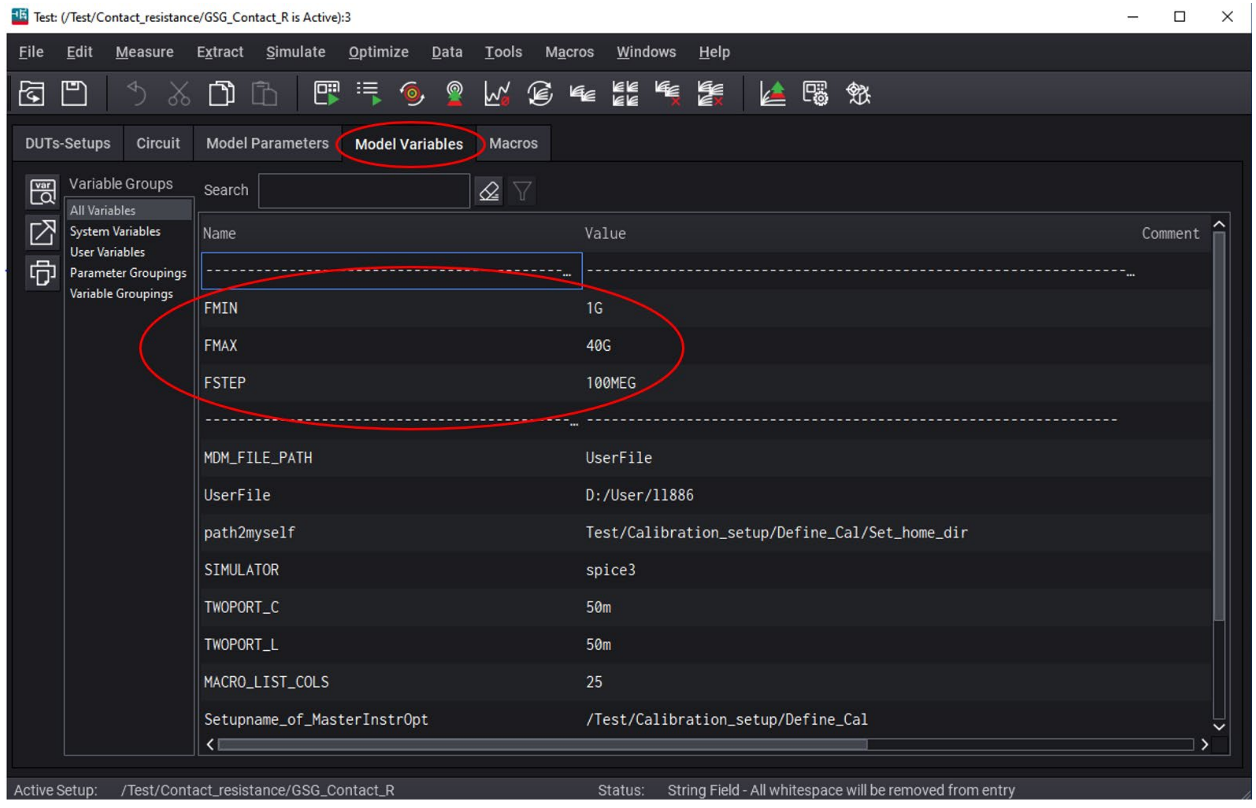


Fig. 7.6. Set frequency range and step size.

7.13 On the "Test" home screen (Fig. 7.1), go back to “DUTs-Setups” on the top menu. Under “Calibration_setup” on the left, highlight “Define_Cal” as shown in Fig. 7.7. Click on “Instrument Options” on the top menu. Confirm that both Port 1 source power and Port 2 source power are preset at a low and safe level of −25 dBm. If you desire other power levels, discuss with the tool owner or an expert user. Scroll down to “Cal/State File Name [.csa|.cst only],” double click on the file name and change it according to the format “your NetID_Date_Fmin_Fmax_Fstep.cst.” Change all parts of it, including "NetID," "Date," "Fmin," "Fmax" and "Fstep." Because all parts are critical, don't just change some parts while ignoring others! Keep in mind that, each time you use this tool, you need to recalibrate and give a new name to the "cal file" to avoid accidental reuse of the same file name on another day. If necessary, use “p1” for 0.1 GHz and "40p1" for 40.1 GHz because the only period allowed is immediately before "cst." Record the exact file name on paper or phone, because you will need it later for QAlibria! Any typo in the file name will be rejected by the VNA.

7.14 Click on “Extract/Optimize” on the top menu of “Define_Cal,” double click on “Send_to_VNA” as shown Fig. 7.8. Click on “OK” three times when three new windows pop up to return to Fig. 7.8 and leave it open. Don’t change anything here.

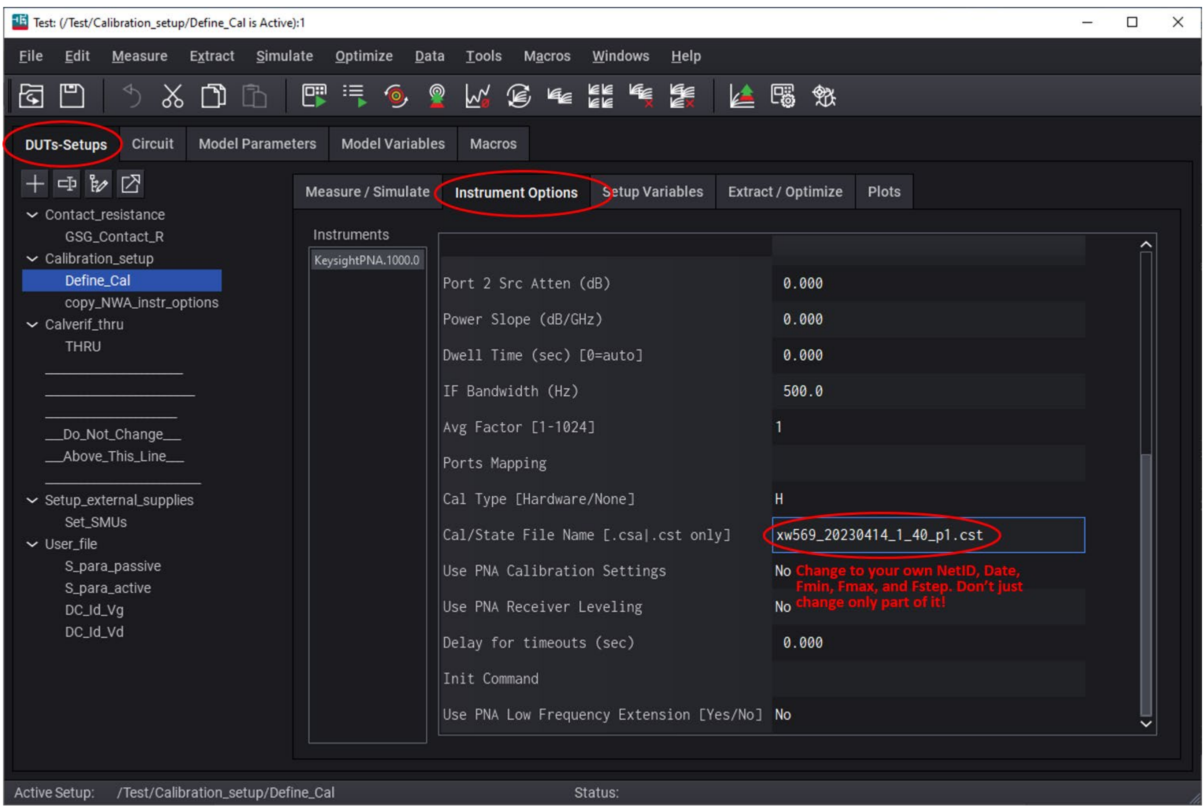


Fig. 7.7. Enter your unique calibration file name.

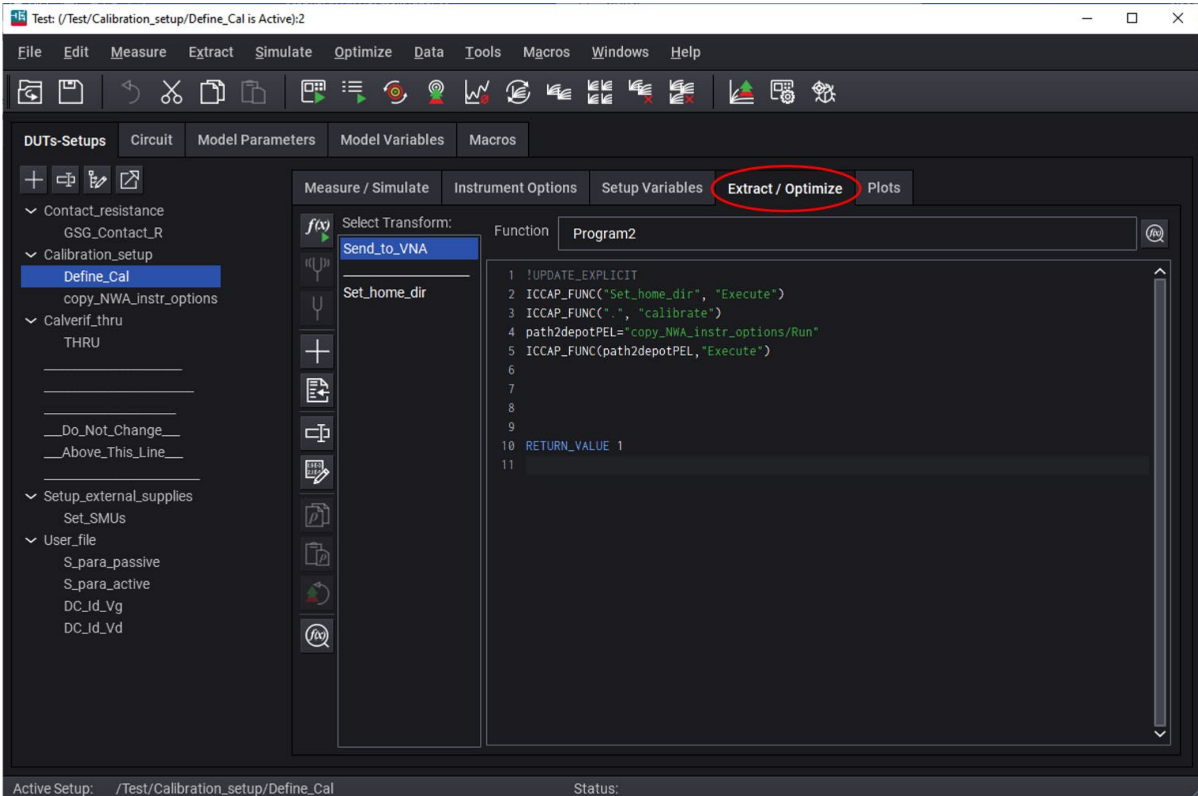


Fig. 7.8. Define calibration file and send it to VNA.

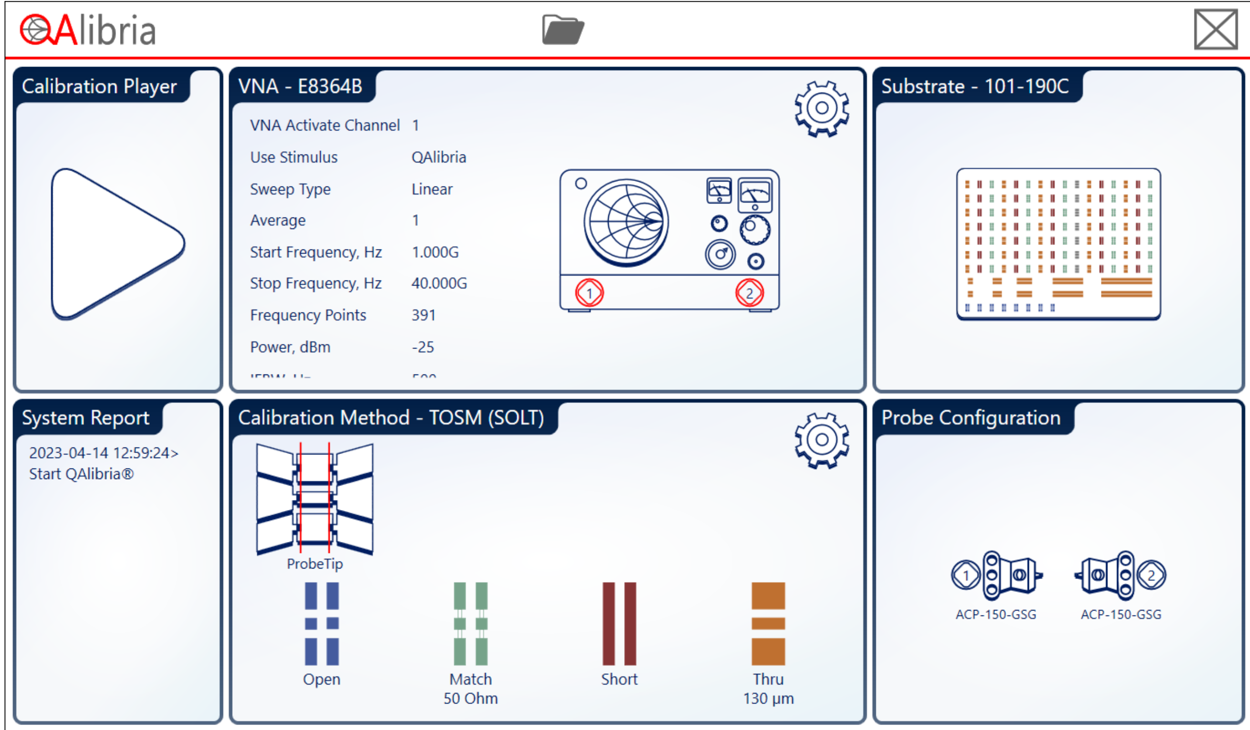


Fig. 7.9. QAlibria home screen.

7.15 On the PC desktop, open "QAlibria-RF Calibration Suite," check "Connect to VNA," then click on "Dashboard." You should see the home screen of QAlibria with six modules as shown in Fig. 7.9. The default VNA is "E8364B" from Keysight, the default impedance-standard substrate is "101-190C" from FormFactor, and the default calibration method is "TOSM (SOLT)." Confirm the settings in the "VNA" module are consistent with that set at Step 7.13. If you click on "Dashboard" without first checking "Connect to VNA," Fig. 7.9 appears with only four modules. Under a generic "VNA Instrument" and "History," "DemoCommunicator" is highlighted under "History." In this case, click on "GPIB1::16::INSTR" and it appears under "Please copy NI Resource." Click on "Set" and confirm that under "VNA Information" "E8364B" appears. Click on at the top to go to the QAlibria home screen (Fig. 7.9) with six modules. Confirm that the "VNA – E8364B" module appears.

7.16 In the "Probe Configuration" module, click on and Fig. 7.10 shows up. To choose the probe model, click on and Fig. 7.11 pops up. In the right module "Configuration," Check "Use Different Probe" only if the Port 2 probe is different from the Port 1 probe. On the right of "Family," click on > to choose the probe family, then "< Configuration" to return on Fig. 7.11. Under , only "Single" is allowed because the present VNA has only one channel between Port 1 and Port 2. Under , change "GSG" to "GS/SG" if you have those types of probes. Under "GSG" or "GS/SG," select the probe pitch. The selected probe pitch will be highlighted in red. Click on < Recent Probes near the top of the "Configuration" module to go back to Fig. 7.10. Then click on to go back to the QAlibria home screen (Fig. 7.9.) QAlibria will automatically update the calibration coefficients based on the probe model you selected. If your probes are not listed, QAlibria will not know what calibration coefficients to use. In this case, you can click on in the "Calibration Method" panel of the home screen to choose another calibration method such as TMRR as shown in Fig. 7.12.

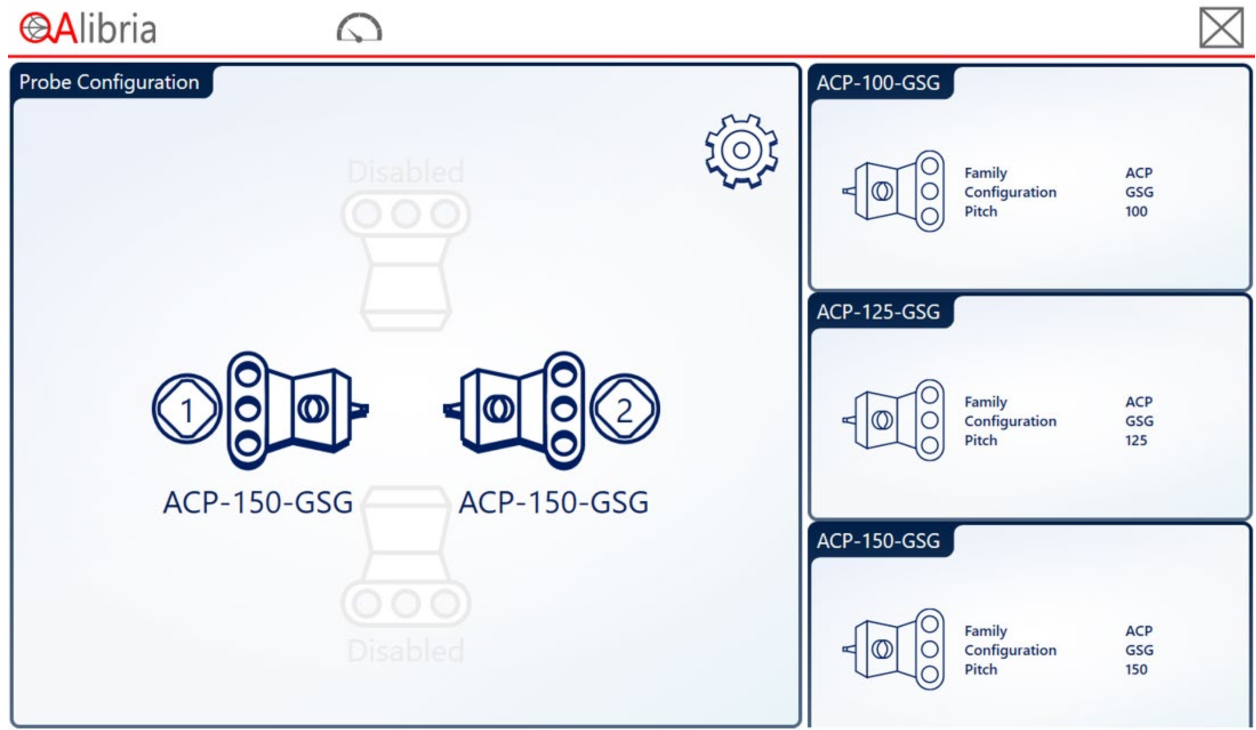


Fig. 7.10. Probe configuration.

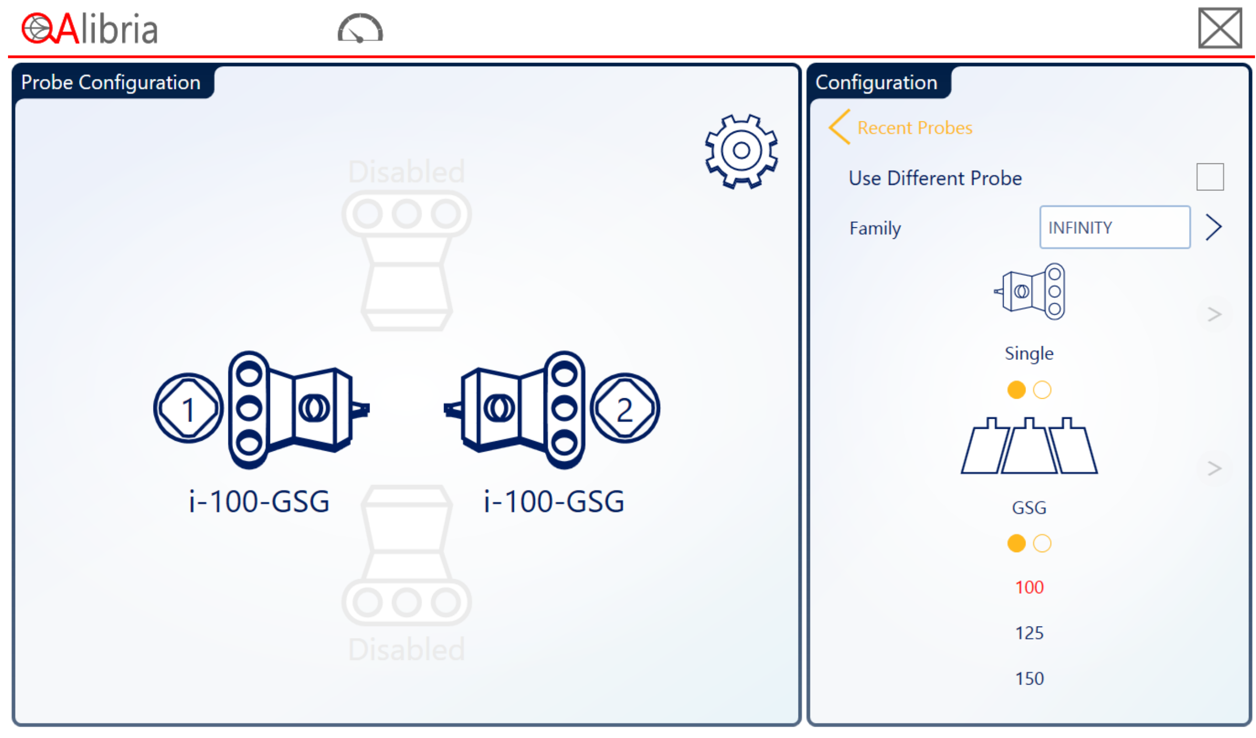


Fig. 7.11. Probe configuration details.

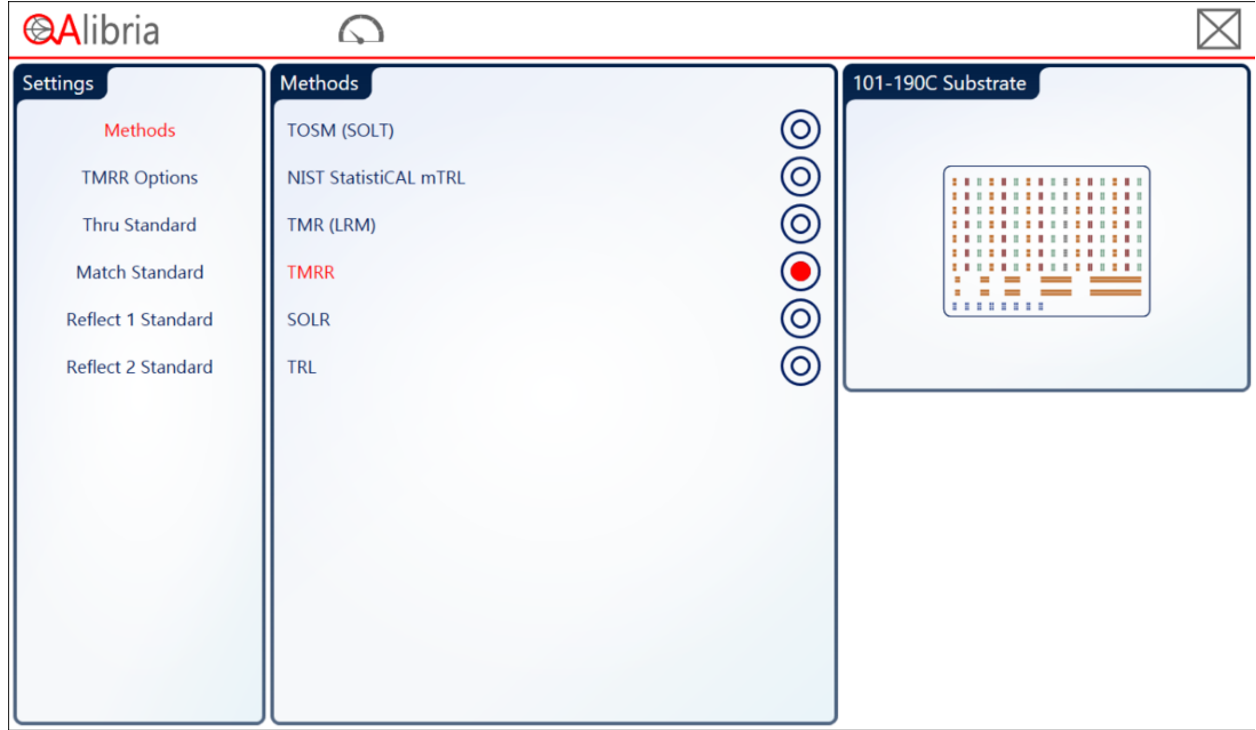


Fig. 7.12. Different calibration methods.

7.17 In the "Calibration Player" module of the QAlibria home screen (Fig. 7.9), click on ▷, Fig. 7.13 appears. Under the "TOSM (SOLT) Calibration" module or another name corresponding to a different calibration method, enter the "Cal_Set" name exactly the same as you recorded in Step 7.14 without the ".cst" extension. Other than the file name, it is not necessary to click on any icons in this module. If you cannot recall the file name, go back to Fig. 7.8, click on the top menu "Instrument Options" to go back to Fig. 7.7 and scroll down to locate the cal file name.

7.18 Under the "Standards" module of Fig. 7.13, click on ⚙ to make sure "Auto" ▷ instead of "Manual" is selected as shown in Fig. 7.14. Confirm that the "OPEN" standard is highlighted. Click on ↩ then ▷, Fig. 7.15 shows up to confirm that the "OPEN" calibration standard will be the first to be measured.

7.19 Make sure the z-lever is up!

7.20 Move the chuck to locate the "OPEN" standard in the specified row and column. Gently lower the z-lever with the left hand to approach "OPEN" while finetuning the chuck with the right hand, so that the probe tips, after skating under the overtravel set in Sec. 6, end up in the middle of the contact pads for "OPEN" [Fig. 7.16(a)]. If the tips land too near or too far, lift the z-lever, adjust the x-micrometer of the probe positioner, and try it again. Don't change the preset overtravel by adjusting the z-micrometer of the probe positioner!

7.21 On Fig. 7.15, click on "Measure" to let the VNA acquire the definition of "OPEN."

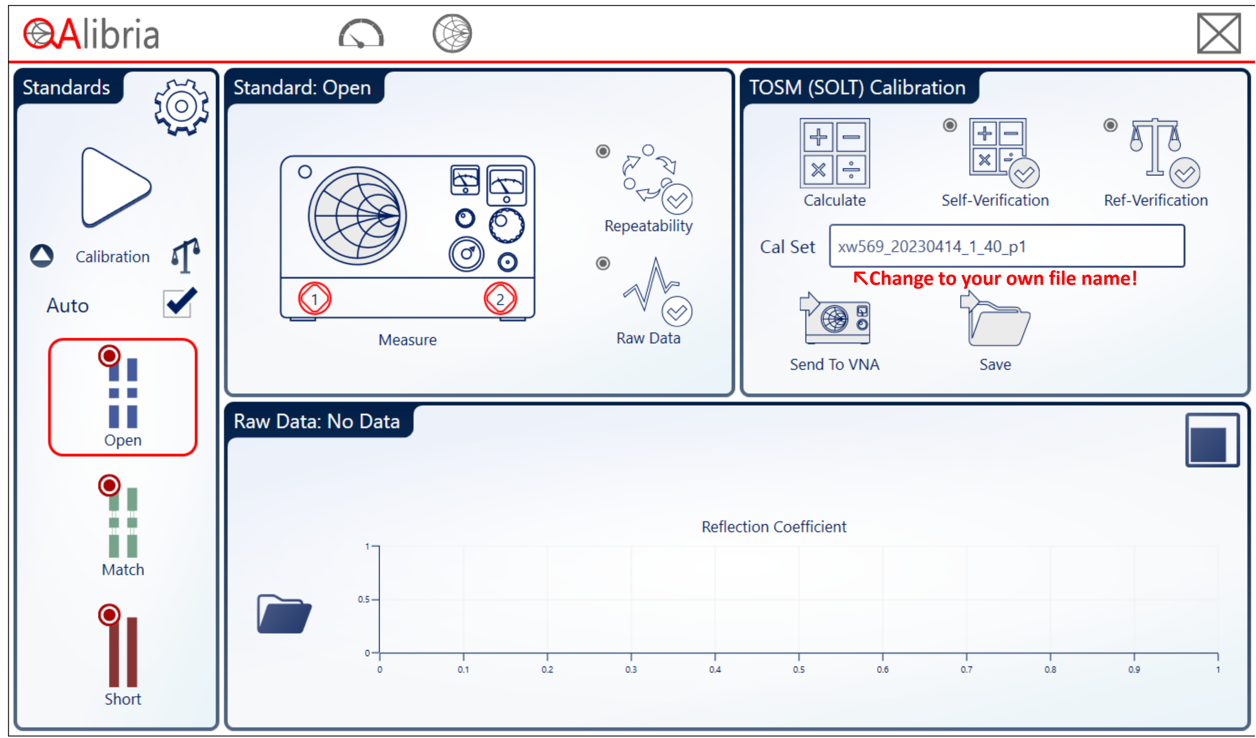


Fig. 7.13. Enter your unique file name for the "Cal Set."

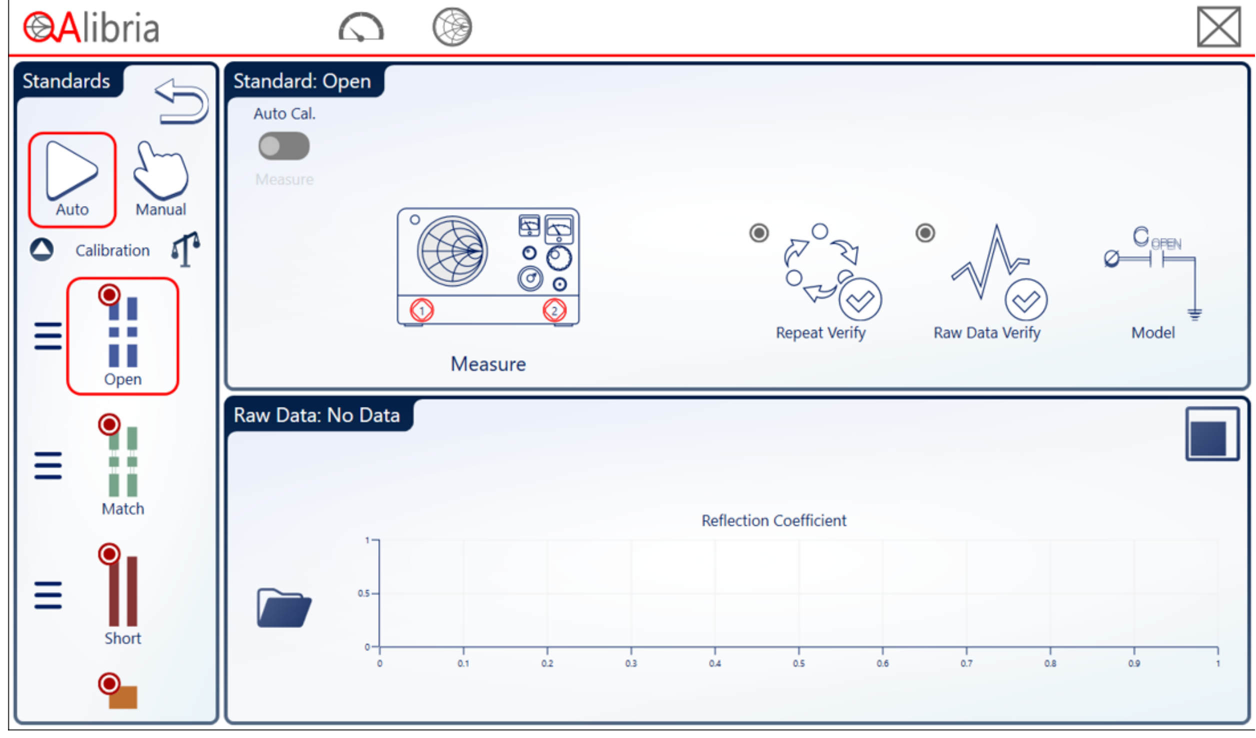


Fig. 7.14. Select "Auto" for the sequence of calibration standards.

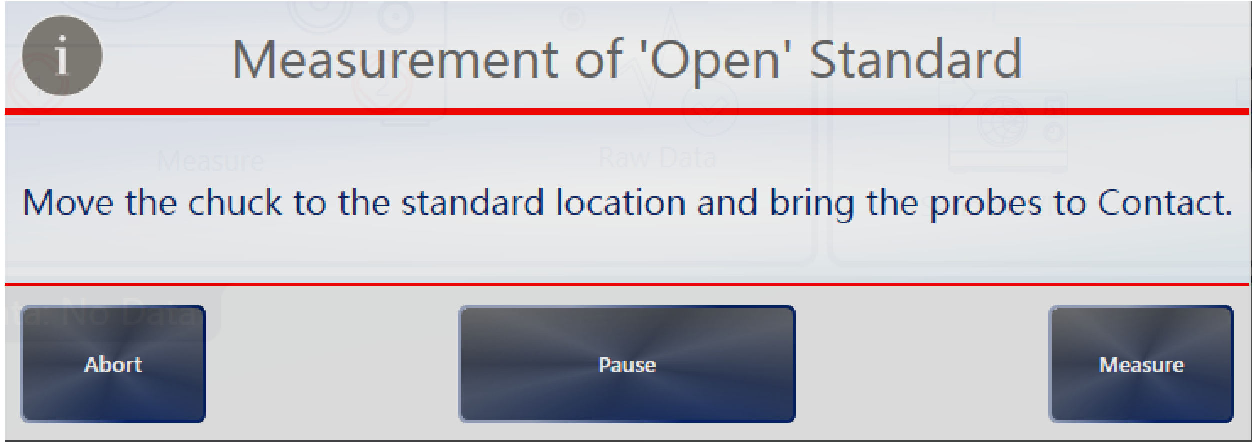
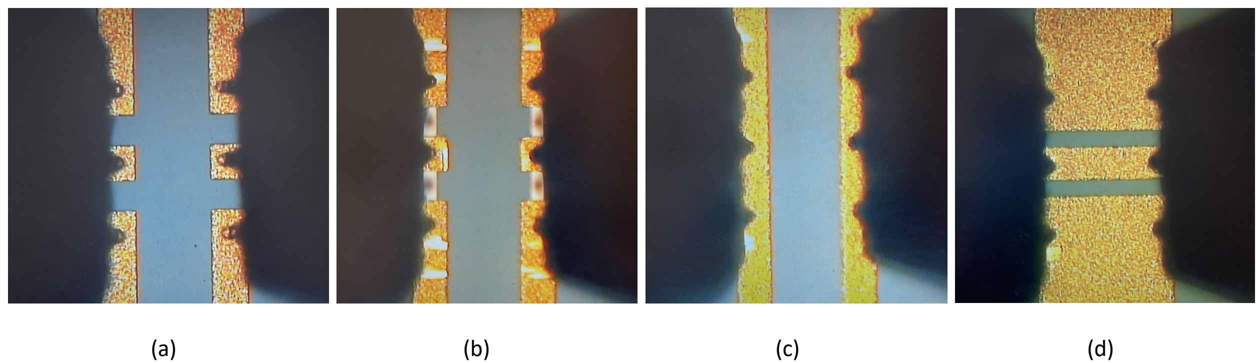


Fig. 7.15. Measuring the "OPEN" impedance standard.



(a) (b) (c) (d)

Fig. 7.16. Correct probe landing on (a) "OPEN," (b) "MATCH," (c) "SHORT," and (d) "THRU" standards.

7.22 After "OPEN" is measured, Fig. 7.15 should pop up again but with “Measurement of ‘MATCH’ Standard” on the top. Lift the z-lever, move to the "MATCH" in the specified row and column, and repeat Step 7.22 for "MATCH." ("MATCH" is often called "LOAD.") Similarly, follow the message in Fig. 7.15 to repeat Step 7.22 for "SHORT" and "THRU" in sequence. ("THRU" is often used as a "LINE" standard, too.) Always make sure to lift the z-lever when moving the chuck! Make sure the probe tips end up in the middle of a standard (Fig. 7.16). Make sure the probe tips skate from the edge of the standard by the same amount. After "OPEN," "MATCH," "SHORT," and "THRU" are all measured, QAlibria will automatically calculate the error terms and send them to the VNA.

7.23 To validate the calibration, land the probes on "THRU" if they are not already there. Go back to the IC-CAP "Test" home screen (Fig. 7.1 or Fig. 7.8). Under “Calverif_thru” click on “THRU,” Fig. 7.17 pops up. Click on [icon] on the left menu to measure "THRU." If you have entered a wrong cal file name or made other mistakes, an error message will pop up, so that you need to debug what you have done so far in Sec. 7.

7.24 If there is no error and "Measure Complete" shows up on the bottom, go to “Extract/Optimize,” and double click on “SHOW_PLOT” as shown in Fig. 7.18. For a good calibration, the insertion loss should be on the order of 0.1 dB across the defined frequency range (Fig. 7.19), even though it increases monotonically with frequency. The "THRU" standard is 1-ps long. However, the calibrated delay time may be shortened by the probe skate.

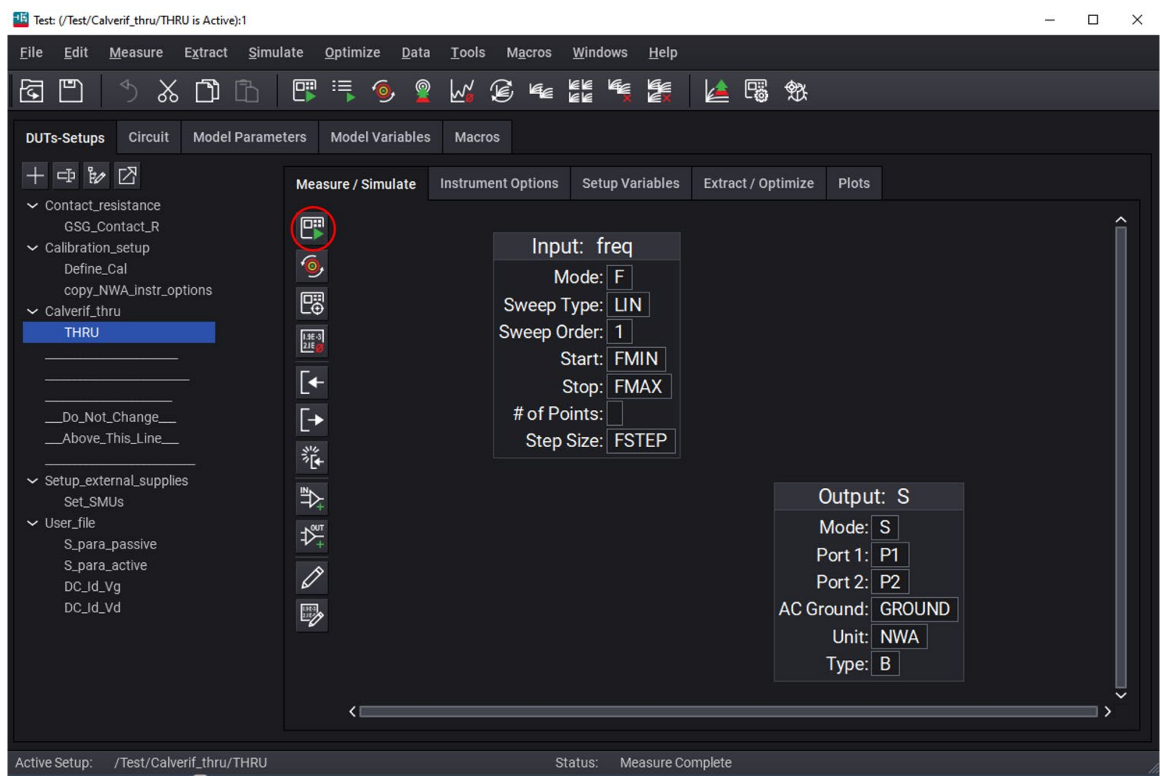


Fig. 7.17. Validate calibration on the "THRU" standard.

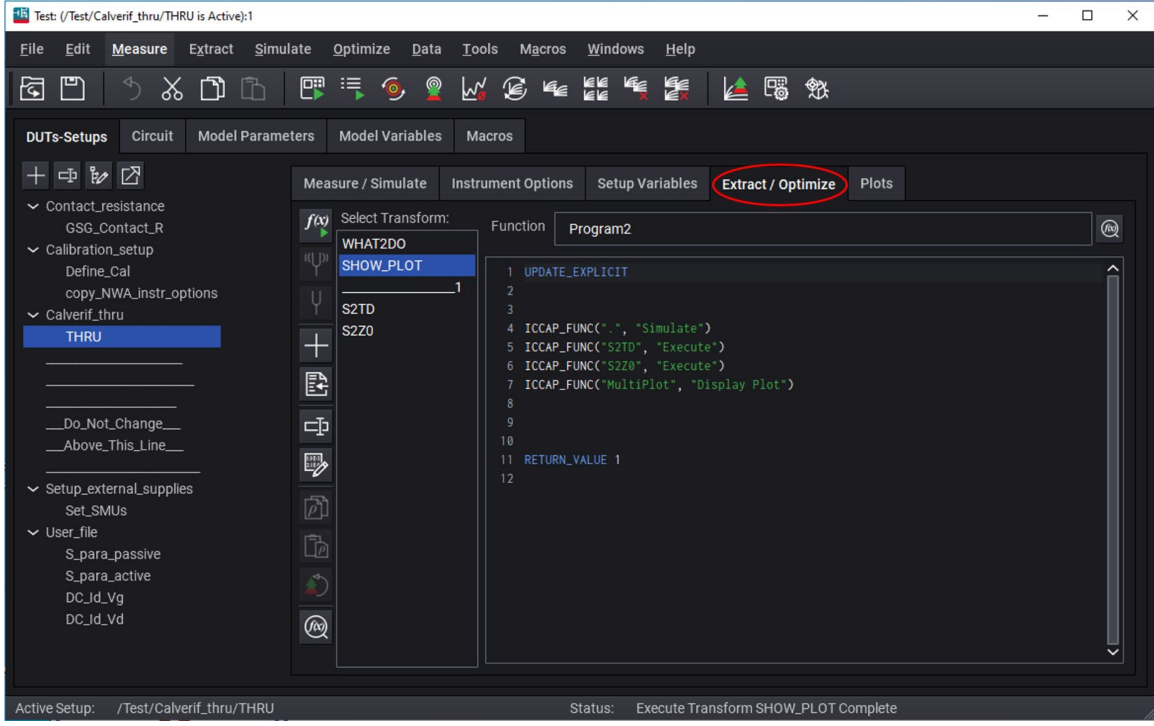


Fig. 7.18. Extract measured characteristics of the "THRU" standard.

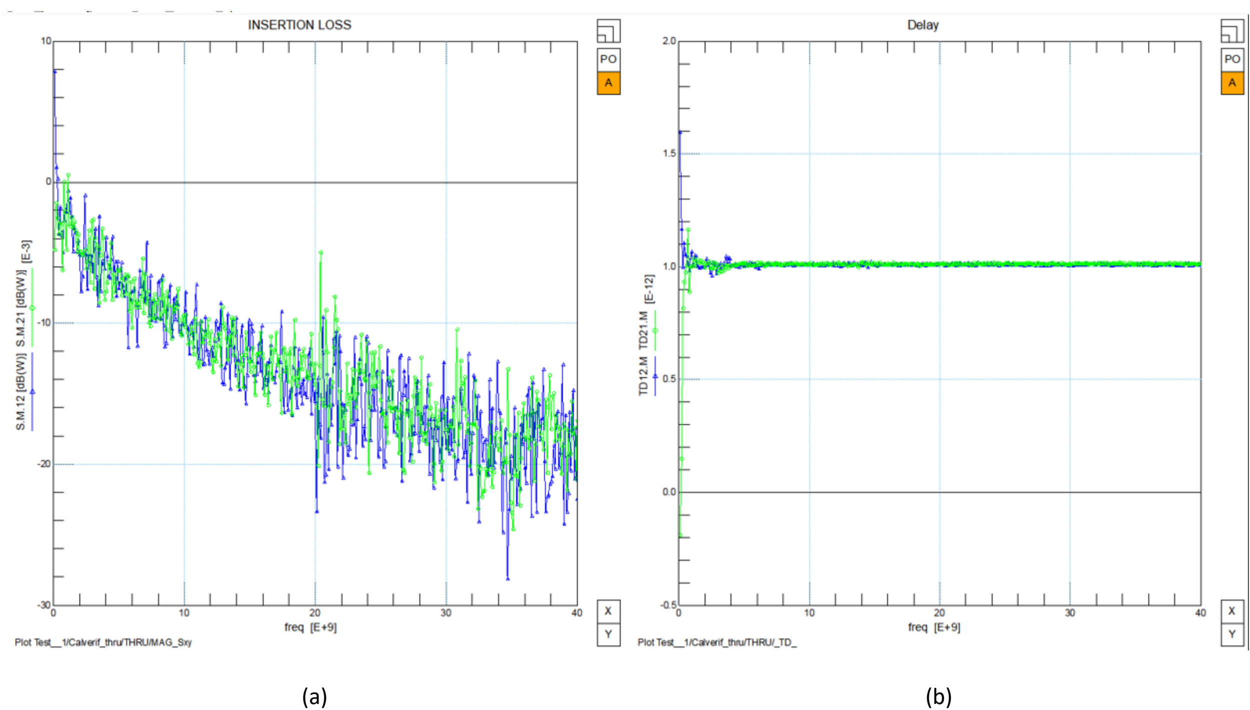


Fig. 7.19. (a) Insertion loss and (b) delay time measured on a 1-ps-long "THRU." Note the vertical scale of (a) is in 0.001 dB, so, in this case, the maximum insertion loss at 40 GHz is approximately 0.1 dB.

7.25 If the insertion loss is much greater than 0.1 dB or the delay time is not in the 0.5–1 ps range, the calibration is invalid. Repeat Steps 7.13–7.24 and give a new name to the cal file in IC-CAP and QAlibria by adding an ascending version number such as "xw569_20230321_p1_40p1_p1_v2.cst" in IC-Cap and "xw569_20230321_p1_40p1_p1_v2" in QAlibria until the insertion loss is on the order of 0.1 dB and the delay time is 0.5–1 ps. If the problem persists, discuss it with the tool owner or an expert user. Make sure the cal file name is consistent between IC-CAP and QAlibria except for the ".cst" extension and it is unique each time you start over from Step 7.13!

7.26 Close QAlibria by clicking on ☒ at the upper right corner of the QAlibria home screen (Fig. 7.9). Then click on "Exit" as shown in Fig. 7.20. Never click on "Save and Exit!" Otherwise, it will overwrite the default program and you will need to ask the tool owner to restore it so as not to surprise the next user.

7.27 Lift the probes by the probe positioners to prepare for moving from the ISS to the sample.

7.28 Lift the z-lever!

7.29 Turn off the vacuum to the left auxiliary chuck.

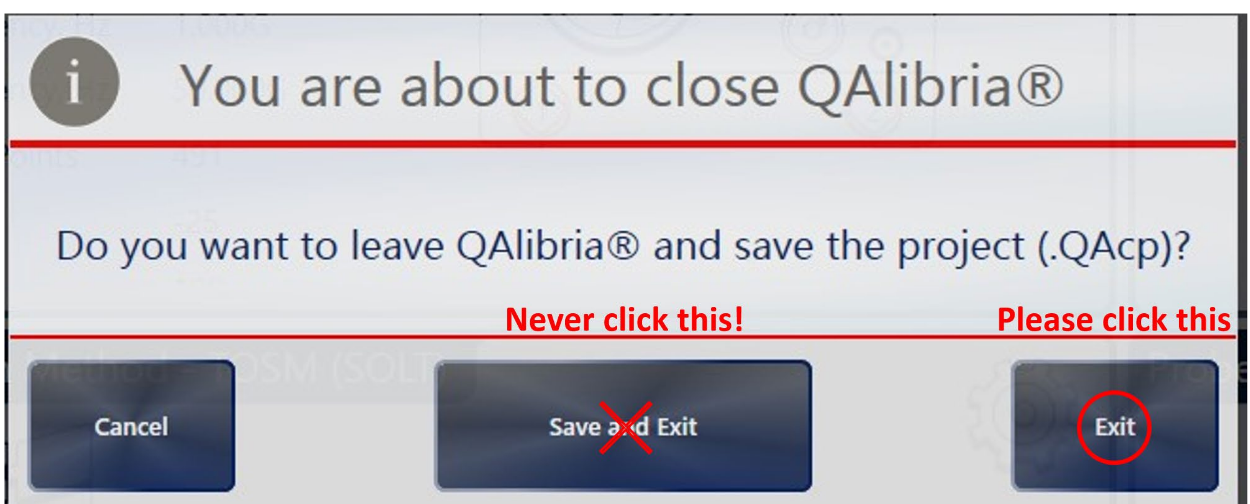


Fig. 7.20. Closing QAlibria.

8. Measure Devices

With all the careful preparation, you finally get to measure your sample.

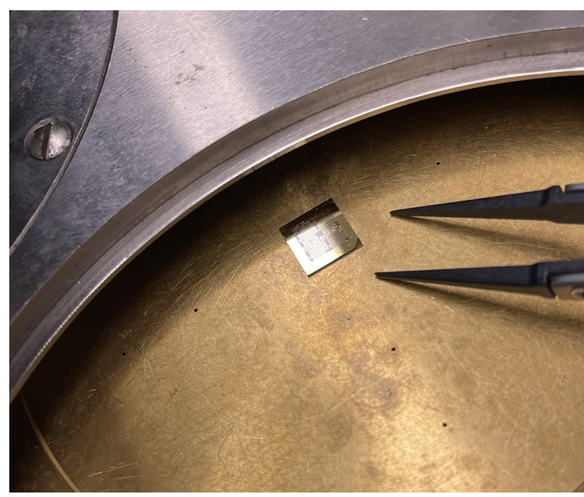


Fig. 8.1. Load the sample onto the center of the wafer chuck.

8.1 Lift the z-lever if it is not already up and propped up on the rest [Fig. 2.1(a)]!

8.2 Turn the doorknob counterclockwise to open the microchamber access door.

8.3 Gently move the wafer chuck out using the x- and y-controls of the wafer chuck. As shown in Fig. 8.1, the chuck can only be a little more than half way out. Never attempt to force it totally out!

8.4 Using plastic or plastic-tipped tweezers from the accessory box or your own supply, load the sample onto the center of the chuck (Fig. 8.1), with its x-axis aligned with the x-axis of the chuck. Avoid scratching the soft surface of the gold-plated chuck. Never touch the chuck with bare hands or metal tweezers!

8.5 Turn on the vacuum switch for the chuck among the bank of toggle switches at the lower right of the probe station. Turn on the 3rd switch from the top for < 2” samples. Turn on both the 3rd and 4th switches for 2" < sample < 4”. Turn on the 3rd, 4th, and 5th switches for > 4” samples.

8.6 Using plastic or plastic-tipped tweezers, gently nudge the sample to make sure the sample is held by vacuum. If not, check the backside of the sample to make sure it is flat and clean, then try it again. If the problem persists, discuss it with the tool owner or an expert user.

8.7 Gently move the wafer chuck back to the center of microchamber using the x- and y-controls of the wafer chuck.

8.8 Turn the doorknob clockwise to lock the microchamber.

8.9 Move the chuck to locate the DUT under the microscope. Focus the microscope on the DUT. Make sure the microscope is zoomed all the way out.

8.10 Slowly lower the z-lever and make sure the probes are not touching the sample yet.

8.11 Adjust the probe positioners until you can see their shadows under the microscope [Fig. 3.3(b)].

8.12 Orient the chuck to align the DUT's x-axis with that the probe positioners. For probing multiple devices on the same sample, it will be more convenient to precisely align the sample's x-axis with that of the chuck and the probe positioners according to Sec. 5. To do this, follow the same procedure as in Sec. 5 except by using a long feature on the sample instead of the alignment edge on the contact substrate. Keep in mind that the wafer chuck can only be rotated for ±7°. If the sample is grossly misaligned, you will have to turn off the vacuum, rotate the sample, turn on the vacuum, and check the alignment again.

8.13 Finetune the probe positioners to contact the DUT with the amount of skate set in Sec. 6 (Fig. 6.1).

8.14 In the "Test" project you loaded in Step 7.1 (Fig. 7.1), select the proper IC-CAP setup for your devices. There are five basic setups as illustrated in Figs. 8.2–8.6: “S_para_passive” for S-parameter measurements without any DC bias, “S_para_active” for S-parameter measurements with DC biases supplied through the bias-Ts, “DC_Id_Vg” for DC measurements of transfer characteristics of a transistor, “DC_Id_Vd” for DC measurements of output characteristics of a transistor; and "S-para_ext_bias" for S-parameter measurements with external DC biases supplied through DC probes (Sec. 11). You can customize them and save them under new file names. "FMIN," "FMAX," and "FSTEP" were set in Step 7.13. Conventionally, the left (input) port is "P1" and the right (output) port is "P2." "NWA" means "VNA." The left bias-T is connected to HRSMU3 (±100 V, 0.1 A) of the PSPA, while the right bias-T is connected to HPSMU5 (±200 V, 0.5 A) of the PSPA. Their DC input is set in voltage such as Vg and Vd. "Compliance" is set to a small limit such as 10 mA to avoid burning out the DUT, or, worse, the test setup in case the DUT is shorted out!

8.15 On the "Test" home screen of Figs. 8.2–8.6, click on [icon] on the left menu and you should see at the bottom of the screen “Measurement in progress.”

8.16 After the message “Measurement done,” check the data by clicking on “Plots” on the top menu and choose or customize the plot settings. Fig. 8.7 shows that "S11_S22_Smith" plots S_{11} and S_{22} on a Smith chart, "S12 _S21_Polar" plots S_{12} and S_{21} on a polar chart, and "MAG_S12_S21" plots the frequency dependence of magnitudes of S_{12} and S_{21} on a log-log chart. Fig. 8.8 shows that "Id_Vg" plots the transfer characteristics of a transistor. Fig. 8.9 shows that "Id_Vd" is for plotting the output characteristics of a transistor.

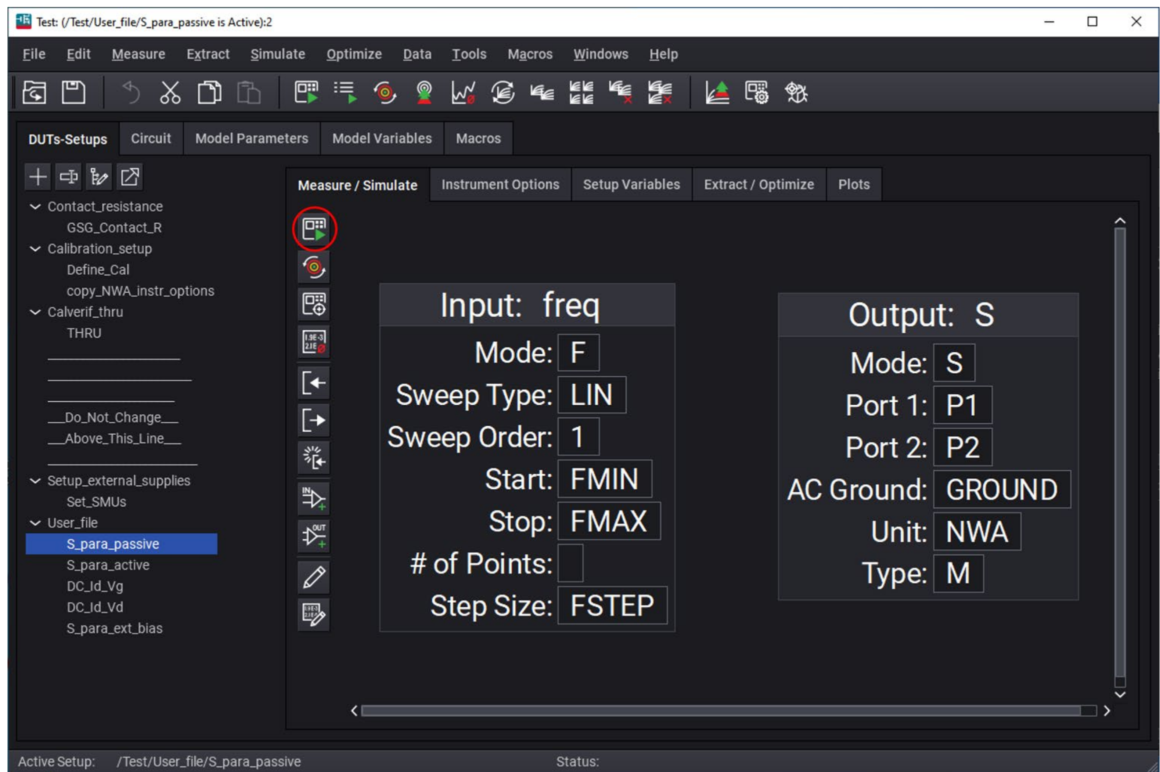


Fig. 8.2. Template for measuring S parameters of a passive device without any bias.

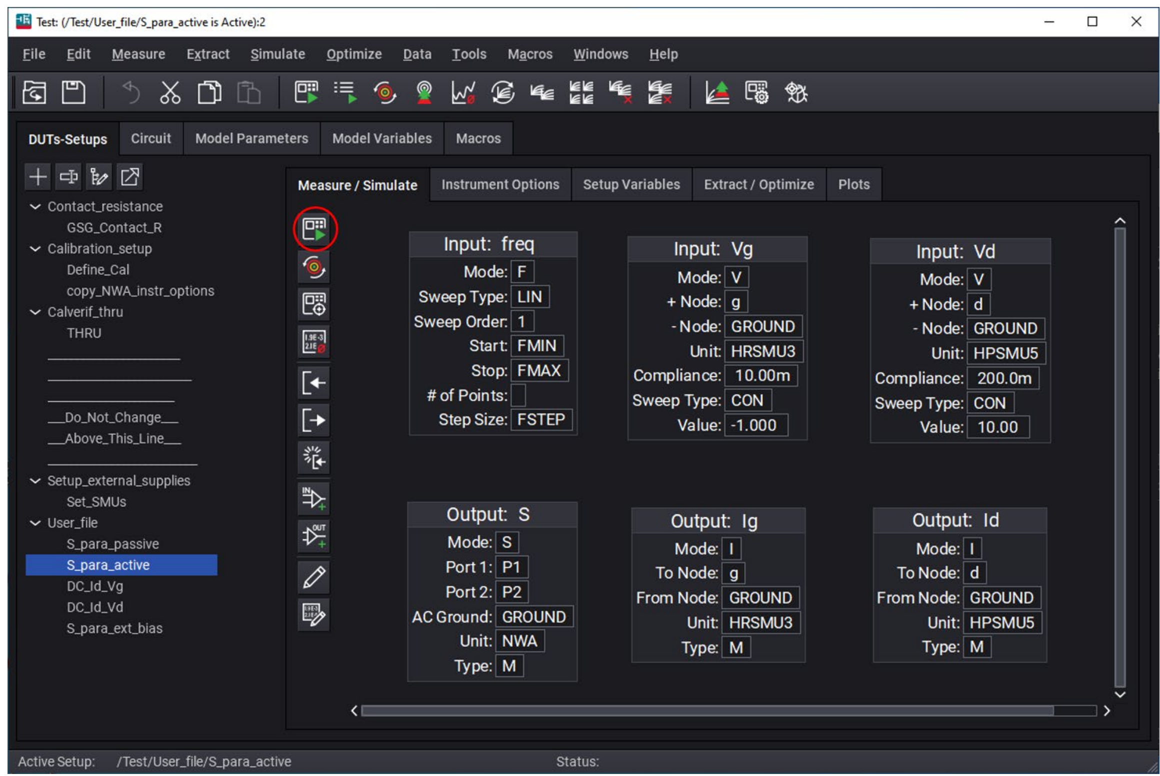


Fig. 8.3. Template for measuring S parameters of an active device biased through bias-Ts.

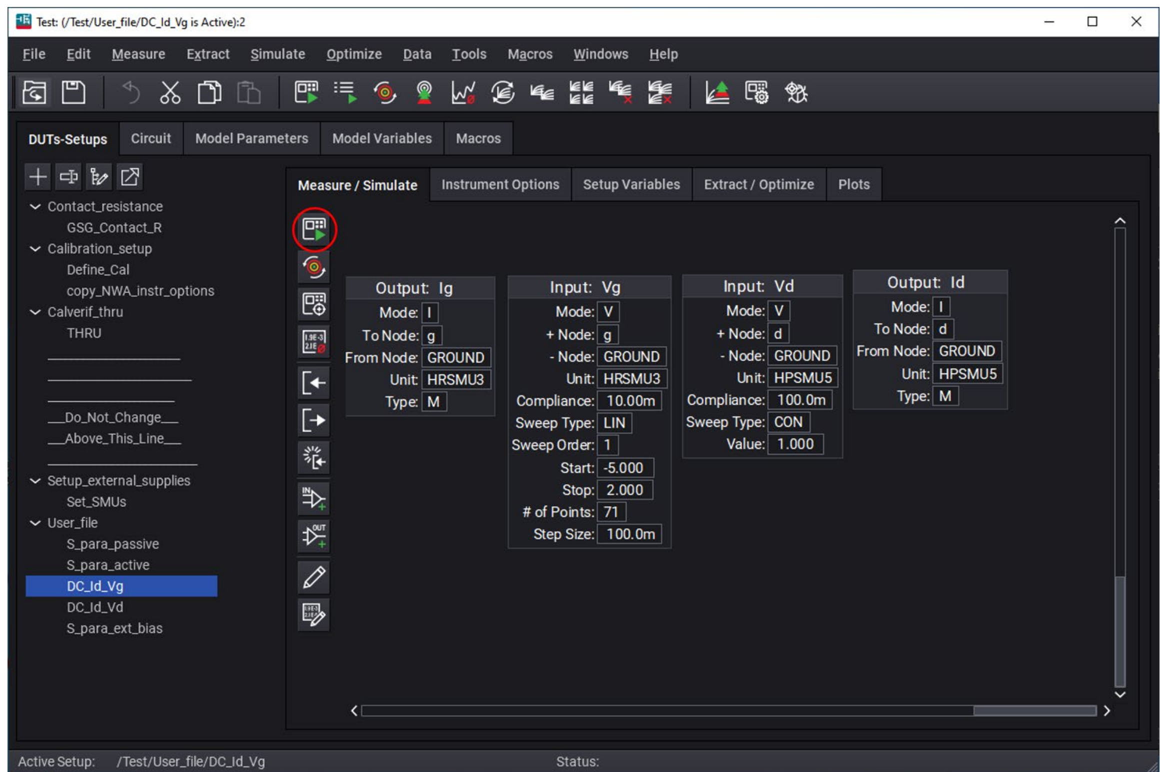


Fig. 8.4. Template for measuring transfer characteristics of a transistor.

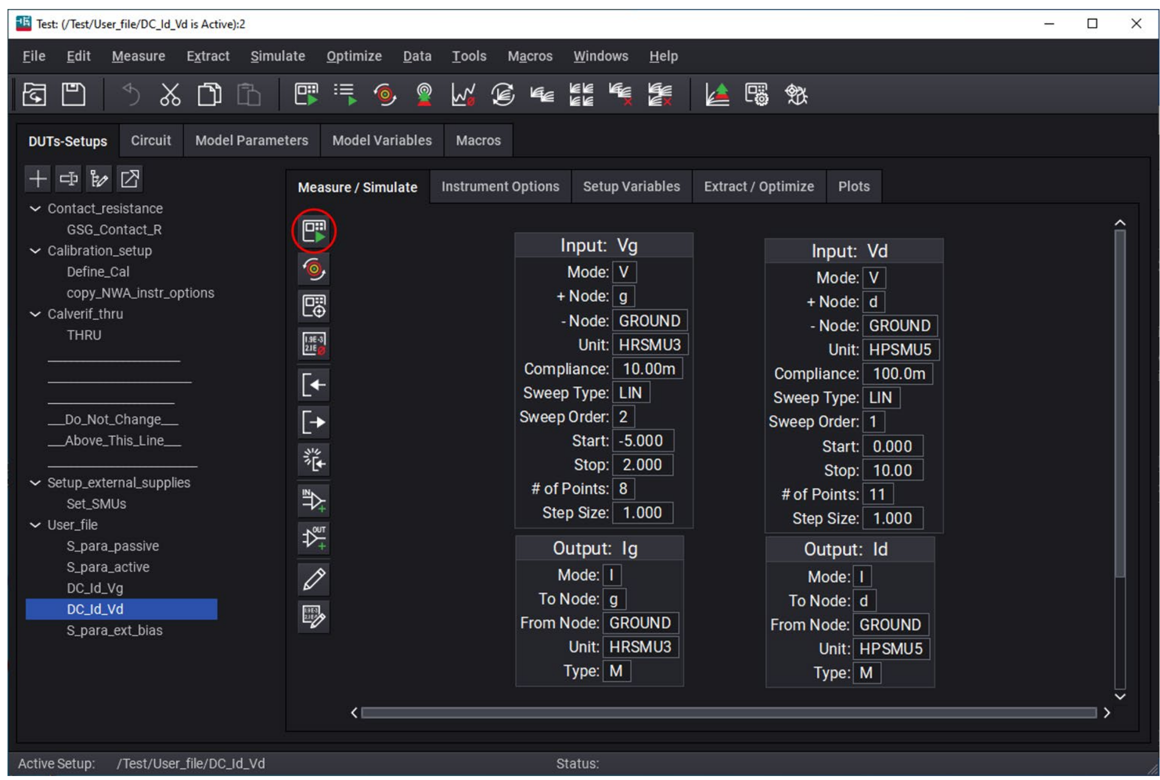


Fig. 8.5. Template for measuring output characteristics of a transistor.

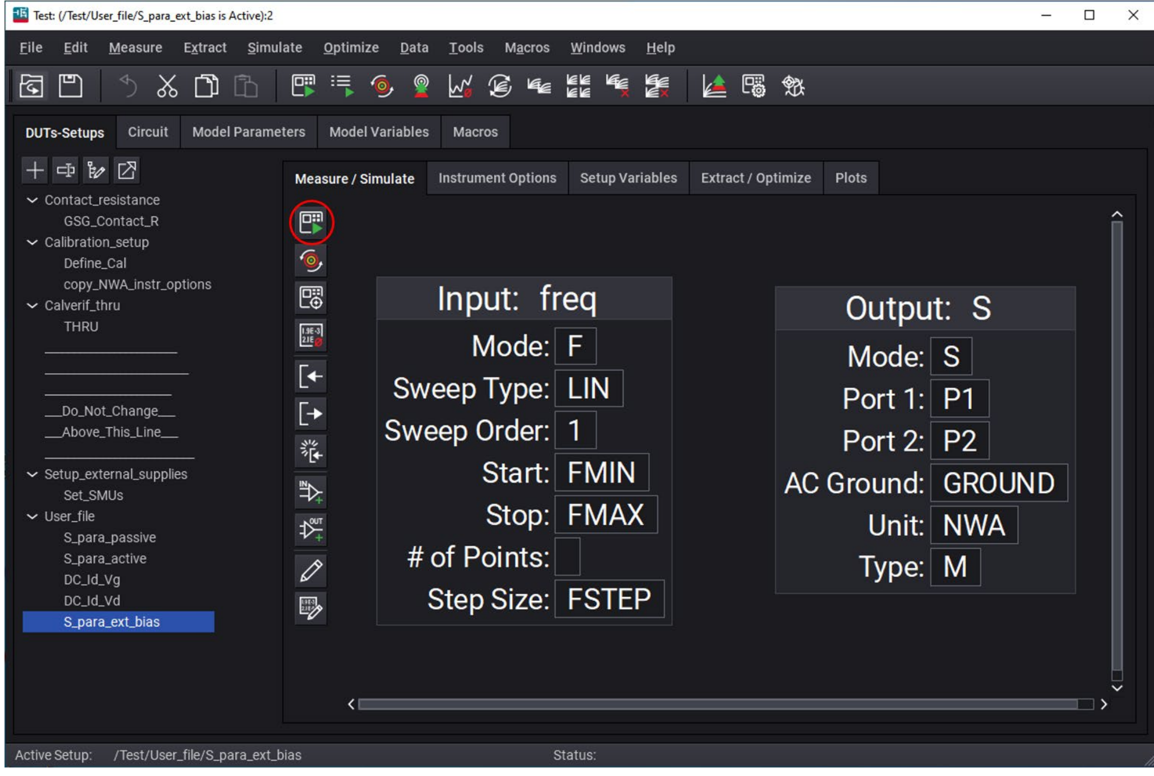


Fig. 8.6. Template for measuring a device with external biases.

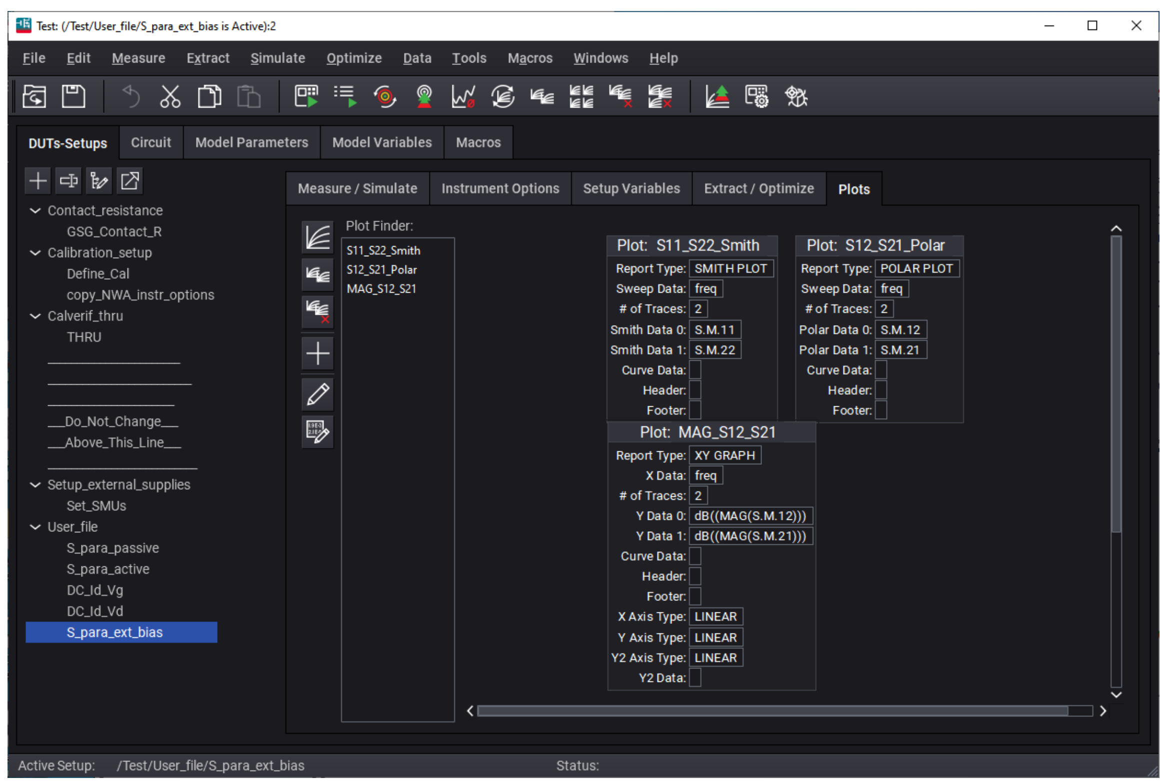


Fig. 8.7. Plotting measured S parameters.

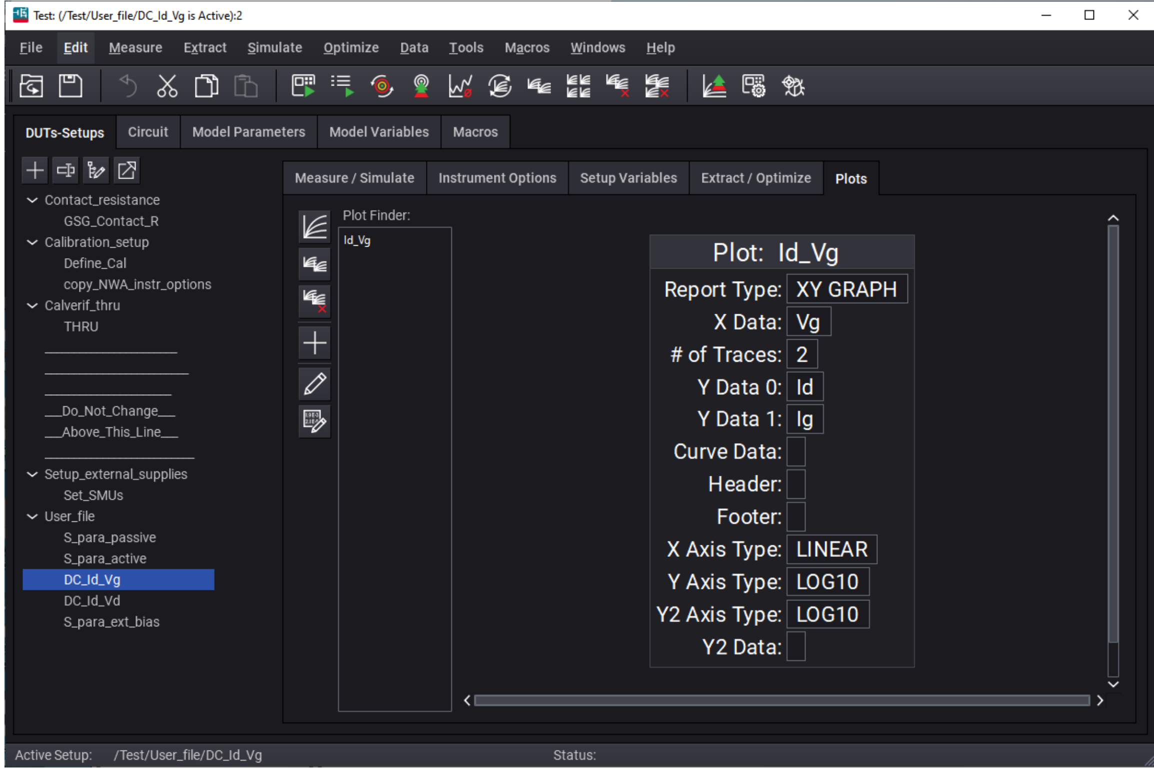


Fig. 8.8. Plotting measured transfer characteristics of a transistor.

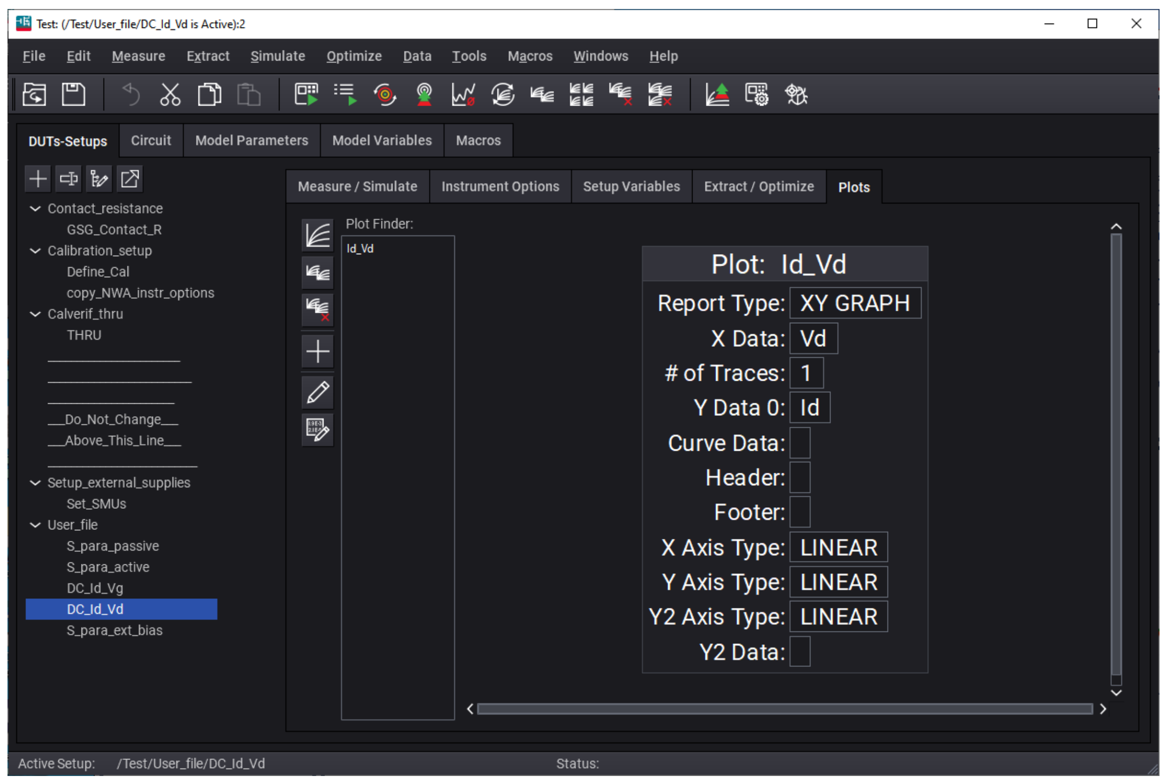


Fig. 8.9. Plotting measured output characteristics of a transistor.

8.17 Double click on ""S11_S22_Smith," "S12 _S21_Polar," or "MAG_S12_S21" to display the plot. If the plot is not satisfactory, repeat Steps 8.14–8.16. Save the desired image by clicking on "File" and "Save Image" on the window displaying the plot.

8.18 Export the data in the .mdm format to your own folder by clicking on “Extract/Optimize” On the top menu. To export the data in the s2p format, double click on “Export_s2p” (Fig. 8.10).

8.19 Lift the z-lever!

8.20 For measuring another device on the same sample, move the chuck to locate the next device.

8.21 Gently lower the z-lever to land the probes on the new DUT and observe the tips skate.

8.22 If necessary, finetune the probe positioners as in Step 6.6.

8.23 If the device needs to be tested under different bias conditions, copy and paste setups from Step 8.14 and rename. If "FMIN," "FMAX", or "FSTEP" needs to changed, you need to recalibrate the system by repeating Sec. 7 and give a the new cal file a unique name.

8.24 Repeat Steps 8.14–8.23 until all devices are measured.

8.25 Save your project to your folder on the PC. IC-CAP will not auto-save your project. To save your project, click on "File" on the top menu of the "Test" home screen (Fig. 7.1). Click on "Save As," Fig. 8.11 pops up. It is recommended the "Select File Type" remains ".mdl" but "File Name" points to your own folder. Click on "OK" to save the project. if no more measurement will be done, exit IC-CAP by closing all windows. Sign out "User." Leave the PC on.

Measure / Simulate | Instrument Options | Setup Variables | Extract / Optimize | Plots

Select Transform: Export_s2p

Function: Program

```
dummy = USERC_get_object_name(path2myself)
PRINT "exec.Xfm ";VAL$(path2myself);" ..."

act_setup = SUBSTR$(VAL$(path2myself),1, STRRPOS(VAL$(path2myself), "/")-1)
act_dut = SUBSTR$(VAL$(act_setup),1, STRRPOS(VAL$(act_setup), "/")-1)

setup_name = SUBSTR$(VAL$(act_setup),STRRPOS(VAL$(act_setup), "/")+1)
dut_name = SUBSTR$(VAL$(act_dut),STRRPOS(VAL$(act_dut), "/")+1)

PRINT "exec.Xfm ";VAL$(act_setup);" ..."
PRINT "exec.Xfm ";VAL$(act_dut);" ..."
PRINT "exec.Xfm ";VAL$(setup_name);" ..."
PRINT "exec.Xfm ";VAL$(dut_name);" ..."

s2p_file_name = VAL$(UserFile)&"/"&VAL$(dut_name)&"_"&VAL$(setup_name)&".s2p"
PRINT "exec.Xfm ";VAL$(s2p_file_name);" ..."

iccap_func(".","Export S2P Data Measured")

```

Fig. 8.10. Export the data in the .s2p format.

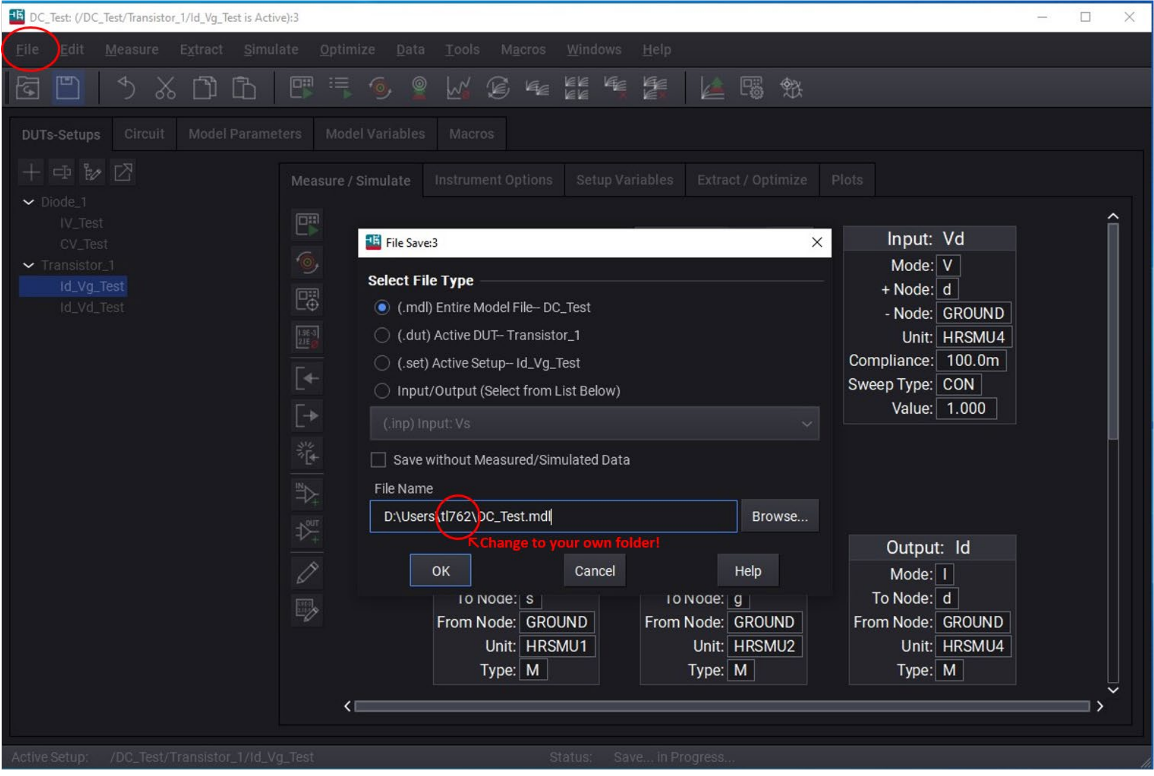


Fig. 8.11. Saving a "Test" project.

8.26 Make sure the z-lever is up!

8.27 Lift the probes fully by using the z-micrometers on the probe positioners. Retract the probes fully by using the x-micrometers on the probe positioners. The micrometers should be set around 4 as in Step 2.3.

8.28 Lift the microscope fully, retract it towards the back, and turn off the microscope light.

8.29 Make sure that the tool is returned to the same condition as when you started! This means the z-lever is propped up on the rest, the microscope is fully raised and retracted, and the probe positioners are fully raised and retracted as in Step 2.3 (Fig. 2.1 and Fig. 2.2).

8.30 Open the microchamber door.

8.31 Move the chuck halfway out.

8.32 Turn off the vacuum switch and the pump.

8.33 Use plastic or plastic-tipped tweezers to unload the sample. If you plan to remeasure the same sample in the near future, it can be stored in the nitrogen-flushed dry box to the right of the probe station. Make sure you clearly mark your name, date, and the device type such as "GaN HEMT." The dry box will be periodically cleaned by the tool owner and anything not clearly marked will be removed without notice.

8.34 Return the chuck to the center of the microchamber.

8.35 Close and lock the microchamber.

9. Uninstall Probes and Finish Up

In general, reverse Sec. 3 and Sec. 2.

9.1 Make sure the z-lever is up, the microscope fully raised and retracted, the probe positioners fully raised and retracted, the chuck is centered in the microchamber, and the chuck is not rotated at an angle!

9.2 Uninstall a probe by holding a semiflexible cable with one hand to prevent it from turning. Use the other hand to grab the torque wrench from the accessory box and loosen the connector that attaches the semiflexible cable to a probe. While holding the cable in one hand, use the other hand to unscrew the connector completely. Separate the semiflexible cable from the probe. Be careful not to permanently bend the cable! Protect the connectors on the probe and semiflexible cable with rubber caps from the probe and accessory boxes, respectively.

9.3 Use the Allen wrench from the accessory box to loosen the probe mounting screws. Hold the probe with one hand and use the other hand to completely unscrew the screws. Without losing grip of the probe, use the same hand to lift the probe, flip it to drop the screws in the accessory box, and place the probe back in the probe box. Secure the probe to the box with the thumb screw. Put the mounting screws back to the probe positioners and hand-tighten them.

9.4 Repeat Steps 9.2 and 9.3 to uninstall the other probe.

9.5 Make sure all accessories are back in the box and there is nothing else left on the probe station!

9.6 Put the dusk cover back on the probe station.

9.7 Make sure your project is saved on the PC by following Step. 8.25! IC-CAP will not auto-save your project.

8.36 Log off IC-CAP and the PC.

8.37 Log onto the Coral workstation again and disable the small-signal probe station. Otherwise, the charge will continue to accumulate until you return to disable the small-signal probe station.

8.38 Record any issues/problems before logging off the workstation.

10. Measure Devices at Temperature

The Temptronic TPO3000 ThermoChuck system can control the chuck temperature between −50 °C and +200 °C (Fig. 10.1). It is at the right of the probe station. It is normally off because most measurements are performed at room temperature. The probe station is equipped with an electrically shielded and light-tight microchamber for controlled sample environment. Although it is by no means a vacuum enclosure, it is sufficiently airtight for flushing with dry nitrogen to prevent frost formation at temperatures as low as −50 °C. Follow these steps to control the chuck temperature either by heating or cooling:

Fig. 10.1. Temptronic TPO3000 ThermoChuck System.

10.1 Never heat or cool without the microchamber simply because you or your sample is tough! Before any heated or cooled measurement, you need to ask the tool owner or an exert user to install the top-hat-shaped cover of the microchamber, which encloses the sample and wafer chuck in dry nitrogen to prevent oxidation during heating or condensation during cooling. To accommodate the microchamber cover, the probe positioners may have to be moved. You will be charged by the time spent in installing/removing the microchamber. Never attempt to install or uninstall the microchamber yourself!

10.2 After the microchamber is installed, follow Secs. 2–8 to perform a room-temperature measurement and make sure the setup and the sample are performing as expected.

10.3 If you need to do both heated and cooled measurements, it is better to do heated measurements first to help remove the moisture from inside the microchamber which prevents condensation during cooling later.

10.4 Make sure the probes are lifted up from the sample by adjusting the probe positioners instead of the z-lever! This is because lifting the z-lever creates a gap between the probe platen and the bottom of the microchamber that houses the wafer chuck.

10.5 Make sure the microchamber is closed by 1) closing the access door, 2) lowering the z-lever, and 3) lowering the microscope! The objective lens of the microscope should have a skirt attached to seal the top of the microchamber while the microscope is laterally moved.

10.6 Turn on (counterclockwise) the N_2 flow meter on the right-front leg of the vibration-isolation table to purge the microchamber under 7 standard cubic feet per minute (SCFM).

10.7 Purge the microchamber until the humidity drops below 10%. Humidity and temperature in the microchamber are read from the little display to the right of the microscope. Do not confuse the microchamber temperature with the chuck temperature, the latter is displayed on the Temptronic controller only.

10.8 After purging to less than 10% humidity, reduce the flow to 3 SCFM if the desired chuck temperature is below 41 °C, and 2 SCFM if it is above 41 °C.

10.9 Never heat or cool the chuck with the probes contacting the sample! Otherwise, the difference in thermal expansion can cause the probe and sample to move against each other damaging both.

Fig. 10.2. Temptronic temperature controller.

10.10 Turn on the Temptronic controller on top of the Temptronic refrigerator (Fig. 10.2).

10.11 For several minutes, the Temptronic controller displays "Wait." The refrigerator is more than 20 years old and cannot be rushed. Be gentle and patient!

10.12 After the "Wait" message disappears, "TA" should illuminate and the chuck temperature gradually approaches the default setting of 41, while "T1" and "T2" display "100" and "−50," respectively.

10.13 After "TA" reaches 41 and "AT TEMP" illuminates, press "T1" and use "↑" and "↓" on the keypad to set it to the desired chuck temperature if it is above 41 °C; press "T2" and use "↑" and "↓" to set it to the desired chuck temperature if it is below 41 °C. Do not touch other keys of the keypad by removing its cardboard cover!

10.14 For temperatures below 41 °C, make sure the sample is not frosted by checking it through the microscope! If you see any frost, press "TA" to return to the default temperature of 41 °C and alert the tool owner or an expert user, before causing further damage.

10.15 Wait until the Temptronic controller verifies that the desired chuck temperature is reached by illuminating "AT TEMP," before contacting the sample with probes to begin the measurement. Be patient. It takes time for the temperatures of the chuck and sample to equilibrate in any case. Even after the chuck is "AT TEMP" and before starting the measurement, it is best to wait a few minutes for the sample temperature to approach that of the chuck. Keep in mind that the temperature controller senses the temperature of the chuck, not the temperature of the sample.

10.16 Follow Sec. 8 to measure the device.

10.17 Always lift the probes by the probe positioners before changing to the next device or temperature!

10.18 After finishing the at-temperature measurement, press "TA" to return the chuck temperature to the default setting of 41 °C.

10.19 Wait for as many minutes as needed for the chuck temperature to return to 41 °C and "AT TEMP" illuminates again, before shutting down the Temptronic controller, stopping the N_2 flow, and opening the microchamber. This is critical for preventing frost, which may ruin not only the test setup, but also your sample. Temptronic uses both heating and cooling to accurately control the temperature. The < −50 ° refrigerant continues to circulate below the chuck until its temperature is above 40 °C. If you open the microchamber before the chuck temperature reaches 41 °C, frost will form on the body of the chuck even if its top is above freezing.

10.20 It is usually a good idea to repeat the measurement at the room temperature to confirm the sample is not degraded by the temperature cycle.

10.21 Follow Sec. 9 to uninstall the probes and to finish up.

10.22 Ask the tool owner or an expert user to uninstall the microchamber. Pay close attention to details so you can become an expert user one day.

11. Measure Devices with External Supplies

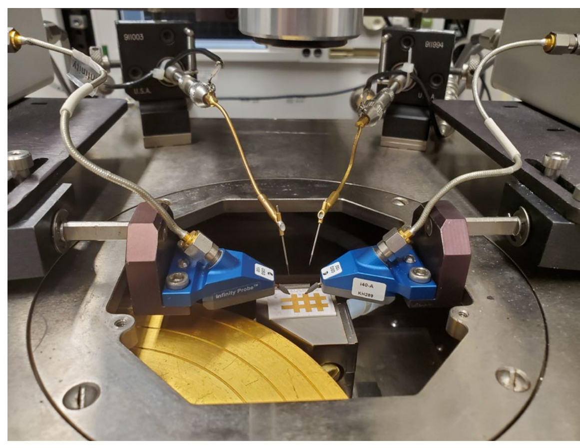
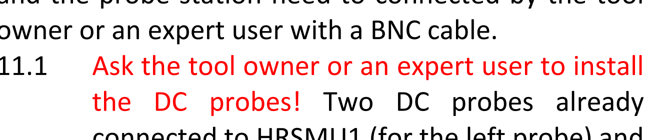


Fig. 11.1. Two DC probes added to the small-signal probe station.

For measuring a device biased externally through DC probes instead of through the bias-Ts, the Agilent 4156C PSPA can also supply voltages to the probes. For example, HRSMU1 and HRSMU2 of the PSPA can be used to supply V_{GG} and V_{DD} through two additional DC probes (Fig. 11.1). Each HRSMU has a capacity of ±100 V and 0.1 A. If higher power is needed, an HPSMU can be used to supply ±200 V and 0.5 A. For either the HRSMU or the HPSMU, if the voltage exceeds 40 V, the interlock terminals of the 41501B and the probe station need to connected by the tool owner or an expert user with a BNC cable.



11.1 Ask the tool owner or an expert user to install the DC probes! Two DC probes already connected to HRSMU1 (for the left probe) and HRSMU2 (for the right probe) of the PSPA are stored at the back of the probe station. The probe station can accommodate up to four DC probes. However, with so many probes crowded around the DUT, the probability of them bumping into each increases exponentially. If you like to measure devices with external supplies and heating or cooling, ask the tool owner or an expert user to install the microchamber cover and DC/RF probes! This will be even trickier and will take more time. You will be charged for these setup times.

11.2 Make sure the DC probes are fully raised and retracted!

11.3 Go through Secs. 1–7 to set up the RF probes and calibrate the setup.

11.4 Follow Steps 8.1–8.13 to load your sample and locate the device.

11.5 Lower the z-lever.

11.6 Contact the DC pads of the DUT by adjusting the DC probe positioners.

11.7 Contact the RF pads of the DUT by finetuning the RF probe positioners, if necessary.

11.8 In the IC-CAP project you loaded in Step 7.1 (Fig. 7.1), under “Setup_external_supplies” of the left menu, click on "Set_SMUs,” then “Extract/Optimize” on the top menu. Double click on “Do All” on the left menu (Fig. 11.2).

11.9 In the "Prompt Dialog" popup window, verify that the GPIB interface is “gpib1.” Click on "OK” to close the window.

11.10 In the second "Prompt Dialog" popup window, verity that the PSPA’s GPIB address is “26.” Click on “OK” to close the window.

11.11 In the "HP4156C Controller" window (Fig. 11.3), set the voltages for SMU1 and SMU2, then click on “FORCE VOLTAGES” to let the PSPA apply voltages to the DUT. The resulting currents can be measured by clicking on “MEASURE CURRENTS.” The SMUs continue to supply voltages until “STOP VOLTAGES” is clicked on. With the SMUs activated, you can now command the VNA to measure S parameters with the DUT under external supplies. Remember to click on “STOP VOLTAGES” when you finish all measurements or before moving to another device! Otherwise, you may shock a device or person with live voltages.

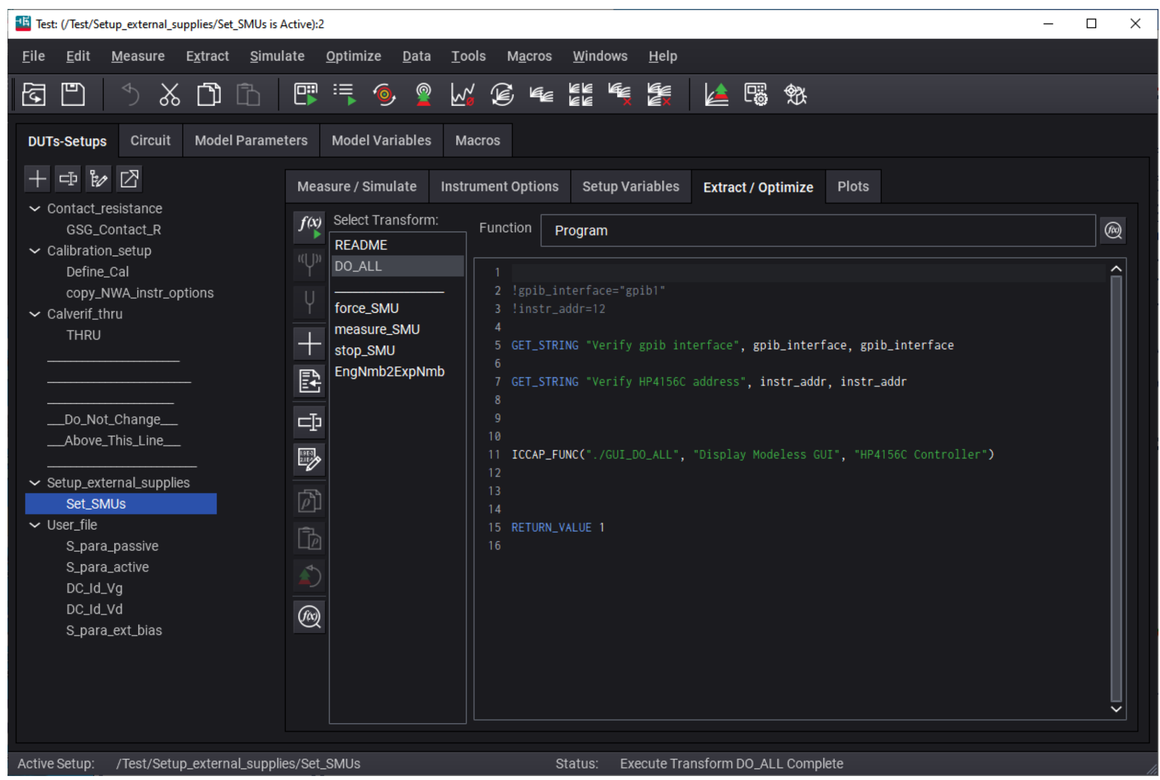


Fig. 11.2. Set up external supplies.

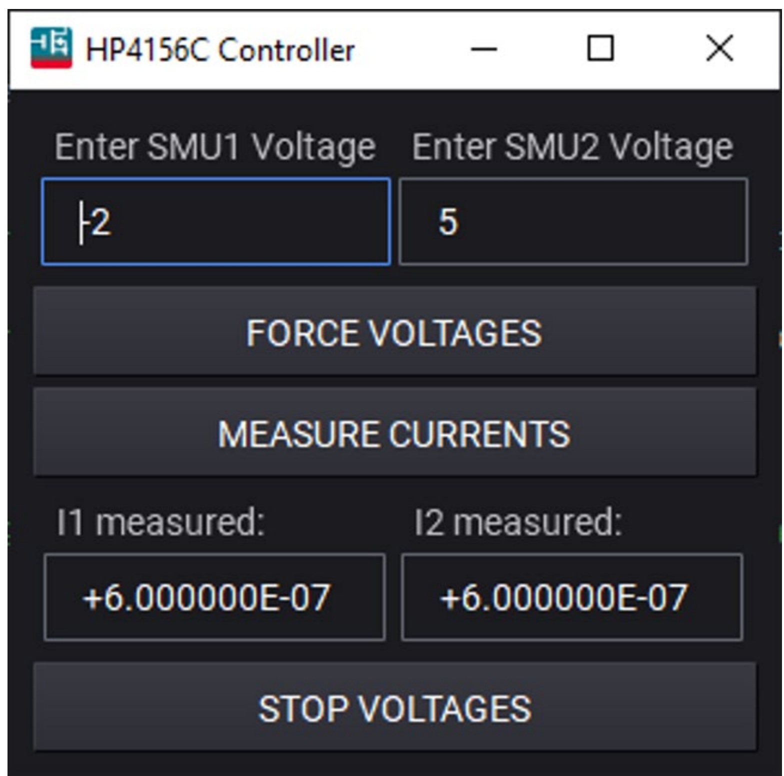


Fig. 11.3. HP4156C controller.

11.12 To measure S parameters, under “User_file” on the left menu, click on "S_para_ext_bias” then , and you should see at the bottom of the screen “Measurement in progress.”

11.13 After the message “Measurement done,” check the data by clicking on “Plot" like in Step 8.16.

11.14 Follow Steps 8.17–8.26 for additional measurements.

11.15 Before exiting IC-CAP, make sure "STOP VOLTAGES" has been clicked on the "HP4156C controller" window shown in Fig. 11.3! If you are not sure, it doesn't hurt to click on it again.

11.16 Ask the tool owner or an expert user to uninstall the DC probes and the microchamber cover if used! Pay close attention to details so you can become an expert user one day.

11.17 Follow Steps 8.26–8.35 and Sec. 9 to uninstall the RF probes and to finish up.