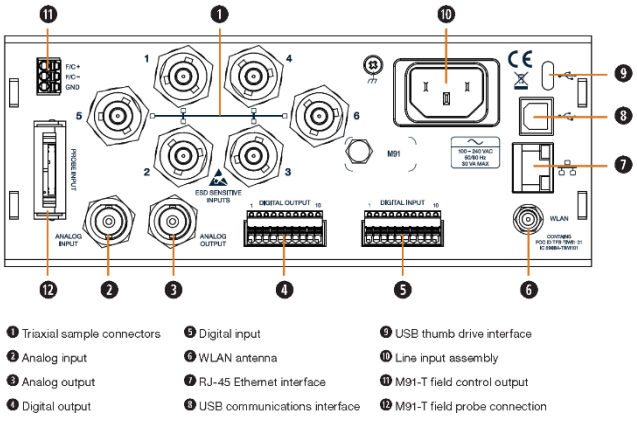
FastHall M91 Quick Start Guide

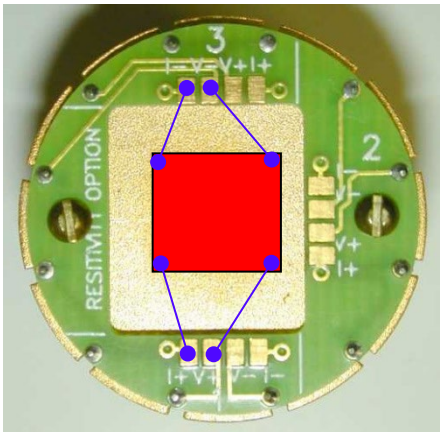
Connect and launch the M91

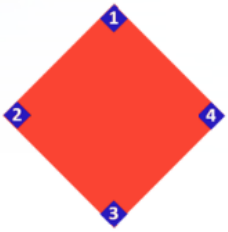
Make the following connections as needed per the application requirement

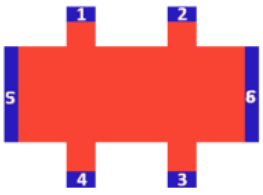
- Supplied USB-B cable (PC to connection 8) is connected to USB extension cable on the right side of the DynaCool cabinet.
- connect 4 yellow triax cables (note bands to match the ports 1...4) from M91 to the M91/PPMS adapter box and use the Resistivity cable to get it plugged into the grey Lemo port on the DynaCool, see photo below. The adapter box is stored in the Transport Accessories drawer in the white cabinet.
- Sample connections
    - USUAL ARRANGEMENT: van der Pauw (connections 1-4 to sample), see diagram below
    - Hall Bar (connections 1-6 to sample), see M91 User Manual



PPMS puck pins (label on puck)	FastHall triax
12 (Ch.3, I-)	1
3 (Ch.1, I+)	2
5 (Ch.1, V+)	3
14 (Ch.3, V-)	4







- example sequences can be found in
  C:\Users\QD User\Documents\MeasureLINK\Example ML sequences
  while your own sequences should be saved in your data folder under:
  C:\QdDynacool\Data\Users

Notes about using sample mounted on MFP probe with 16-pin DIP socket (instead of on PPMS puck):

1) FastHall triax will adapt to BNC at the BNC breakout box on the electronics rack. These adapters must FLOAT the guard instead of shorting to the shield. Shorting would cause ground loops. In addition, only ONE of the BNC shields should be grounded in order to provide the ground reference to the FastHall from just one point. (Wiring table needed below)
2) This allows the Hall bar arrangement: two more triax needed in that case and some guidance from LakeShore

Getting started and Verifying instrument operation

In the above-mentioned example sequences folder is one for field dependent Hall effect. It is always recommended to scan from *positive to negative* fields in order to verify you are measuring the Hall effect and not magnetoresistance or other offsets. The slope of Hall voltage vs. field can be used to most reliably calculate the Hall coefficient R_H:

$$R_H\ [m^3/C] = (\Delta V_{Hall}[Volts]/\Delta B[tesla]) * (film\ thickness[m]) = 1/(ne)$$

Where e = 1.602 x10^-19 C .
There is a reference sample of n-type InAs in the ETO User Kit, in a small Lakeshore black box. The sample properties are written on the box and given again here:

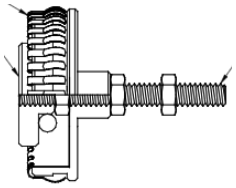
thickness	= 0.25mm
carrier density	n = 7.2 x 10^16 cm^{-3}
resistivity	ρ = 3 mΩ-cm
mobility	μ = 24,000 cm^2/V-s

It is pre-mounted on a puck and ready to measure. *Please do not unmount this sample from the puck!* You can run a field dependent FastHall at T=300 K to verify operation. There is also a p-doped Si sample in the user kit that can be mounted on your own puck, it has lower mobility and positive slope of $V_{hall}(B)$. See table at end of this document for some Hall coefficients of elements.

Inserting the PPMS puck into the chamber

- In MultiVu under *Instrument > Chamber…* or by clicking chamber area at bottom of screen, press the Vent/Seal button and wait for chamber to get above 760 torr.
- Release the KF clamp at the top of the chamber, remove the baffle set, and put the baffle set in one of the clear vertical storage tubes on the side of the PPMS.
- Ensure there is no sample currently in the chamber: step up and look into chamber. If you can't tell whether the chamber is empty, get the extraction tool and try to remove a puck.

- Go back to PPMS, look at the bottom of the baffle set to make sure that the contact baffle (see diagram at right, and Chap. 2 of TTO user's manual) is NOT present, since it has charcoal which will cryopump He gas when T<15 K. Then put the baffle set back into chamber, close the KF plastic clamp, and press *Purge/Seal* in chamber commands dialog. This ensures that the chamber stays free of air and moisture.



- Open chamber as before: press *Vent/Seal*, remove baffle set and put it in the storage tube.
- Using extraction tool to insert your sample into the chamber:
  - The extraction tool is a sensitive instrument, please do not bump or drop it, especially the thin walled stainless steel tube at the bottom, as this can break it.
  - With one hand, hold top of extraction tool and open the lever (vertical position).
  - With other hand, cup the bottom of extraction tool and hold puck between thumb and first finger.
  - Insert puck into extraction tool and gently rotate it to ensure it is seated evenly at the stop.
  - Close the lever at top of tool and see that the puck is held firmly.
  - Note the position of the key on the puck which will face to the front of the chamber when fully inserted.
  - Take the tool to the PPMS chamber, insert fully into the chamber, and rotate around until you feel the key slip into the notch. Once you feel this, push down firmly (a few kg of force) another ~5mm.
  - Release the lever (vertical position) at top of the extraction tool and you should be able to lift it without resistance from the engaged puck.
    - If you feel the puck is still engaged, close the lever again, remove tool/puck from the chamber, and repeat the process of inserting the puck.
    - If it still is not working, then remove tool/puck, put in baffles, purge/seal, and call Neil or Mike.
- Put baffle set back in chamber, close the KF clamp, and press *Purge/Seal* in chamber commands.

After you're done with measurements

- Make sure temperature = 300 K and magnetic field is ZERO before opening the chamber.
- Using extraction tool to remove a sample in the chamber:
  - Put on gloves in preparation for handling the puck.
  - Remove the extraction tool carefully from the storage tube, open the lever at the top (lever in vertical position), and lower the tool down into the chamber until it comes to the bottom. Rotate it a bit to make sure it's at the bottom.
  - Close the lever (horizontal), and if there's a puck in the chamber you will feel resistance when you try to pull up.
  - Pull out the extraction tool from the chamber, which will be carrying the puck, and DO NOT MESS WITH THE LEVER at top of extraction tool in this step. It's critical that we fully remove the puck and not drop it.
  - Once extraction tool is out of chamber, secure it with your other hand and take to the lab bench where you will cup that hand under the bottom end of the tool while you release the lever (put it in vertical position), which releases the puck.
  - Put the extraction tool back in the storage tube to protect it.
- Put baffle set back in chamber, close the KF clamp, and press *Purge/Seal* in chamber commands.

Some notes on working with challenging samples

These are samples with low mobility, high resistance (~mega-ohm), large dR/dT slope, an irreversible transition like metal-insulator, or any combination of these.

- (dR/dT effect) Use care to avoid self-heating at each temperature: there is a “full optimization” mode for the M91 FastHall which does 2-terminal I-V curves between all the pairs to determine how current can be applied before nonlinearity (from self-heating) sets in. I found that requiring a minimum R^2 of .9995 was optimal: if R^2 set much higher it might not meet the requirement (software will quit the sequence) and if too low then self-heating would result.
- (dR/dT effect) Exquisite temperature stability required: the PPMS has a great temperature controller but even after stabilizing we needed to wait another 10 minutes at temperature. Still we can see drift in Rxx vs. time over the field sweep but I found it was small enough so a round trip Rxy(B) curve retraced itself and was not dominated by drift in Rxx.
- (high R effect) Due to RC attenuation in the low T (high R) state, a blanking time of 20 msec was found to be required to get a stable V reading. Blanking time is the wait time between applying a current and starting the voltage reading. This 20 msec is invoked any time the current polarity is switched which is done up to 60x in one measurement so this starts to add up quickly. Do a voltage vs. settle time sequence separately, on each of the pairs, to see how long of a wait is required to get asymptotic voltage value.
- (eddy current heating effect from dH/dt field charging) An extra wait of 10 sec at each field may have been helpful in letting temperature stabilize, though that has not been studied more extensively and in future studies we may try extending that wait time. May also use lower field sweep rate.
- (drifts) ALWAYS do round-trip FastHall vs. H so that you can distinguish drift from real field-driven effects. You may even find that repeating the whole R(H) loop is needed to find the intrinsic sample behavior.
- (thermal hysteresis) When working near MIT with thermal hysteresis, be aware of overshooting temperature and the sample effects this causes. Measure going up in T and down in T through the MIT.

TABLE I. Hall coefficient for alkali metals, alkaline-earth metals, noble and NFE, group-VIII and group-VB and -VIB metals. The unit of R_H is 10^{-11} m^3C^{-1}. Experimental data are from Ref. 1, taken at room temperature.

Element	R_H^{free}	R_H^{calc}	R_H^{expt}
Li	−13.2	−12.8±0.1	−15.0
Na	−24.5	−24.6±0.1	−24.8
K	−44.6	−44.8±0.1	−42.8
Rb	−54.7	−54.2±0.1	−50.0 to −59.2
Cs	−68.6	−53.4±0.2	−73.3
Ca	−54	−60±10	−17.8
Sr	−70	?	?
Ba	−78	−110±20	?
Cu	−7.3	−5.2±0.2	−5.17
Ag	−10.4	−8.5±0.2	−8.81
Au	−10.5	−8.1±0.2	−7.16
Al	−3.4	−1.7±0.3	−3.4±0.5
Pb	−4.7	−2.4±0.3	−0.9±0.2
Rh	−7.5	11±3	5.00
Ir	−8.8	5±2	3.18
Pd	−9.1	−17±3	−7.60±0.2
Pt	−9.4	?	−2.30±0.1
V	−8.6	7.3±0.5	7.9±0.3
Nb	−11.2	7.4±0.5	8.7±0.5
Ta	−11.2	7.4±0.5	9.2±1.0
Cr	−7.4	13.0±2.0	36.0
Mo	−9.7	10.0±2.0	18.0±0.2
W	−9.8	10.0±?	11.5±0.5

Figure 1: from PRB (1992) paper by Werner. Schulz, Philip B.Allen, and Nandini Trivedi