PocketPico Picoammeter

INSTRUCTION MANUAL

Version 1.0

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1 INTRODUCTION

The PocketPico is a wide-range, portable ammeter that is capable of measuring currents from 20pA to 2mA with 100fA resolution in the pico-ampere range that interfaces to a computer via a USB 2.0 interface. The PocketPico is suitable for a range of applications; some of these are semiconductor testing and demonstration, microprocessor leakage measurement, and solar cell testing. The PocketPico connects via USB and creates a virtual serial port that recognizes SCPI commands. This allows one to easily integrate the device to legacy GPIB-based code for automated testing.

1.1 PACKAGE CONTENTS

The product package should contain the following items:

- PocketPico Picoammeter
- RG-58C/U low-noise BNC cable
- USB-A to Mini-B cable
- Custom carrying case
- Installation instructions

1.2 GETTING STARTED

Familiarization with the front and rear panels of the ammeter

1.2.1 FRONT PANEL

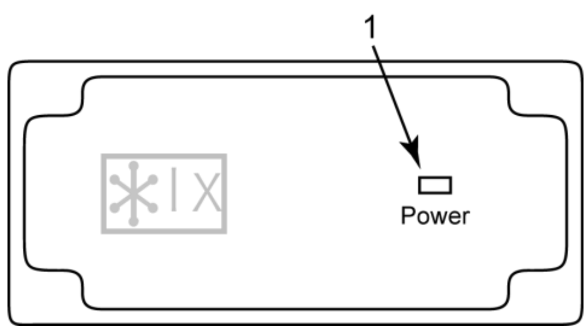


Figure 1: Illustration of the front panel of the device

1. Power Indicator
   The Power Indicator is illuminated if the device successfully completes USB enumeration.

1.2.2 Rear Panel

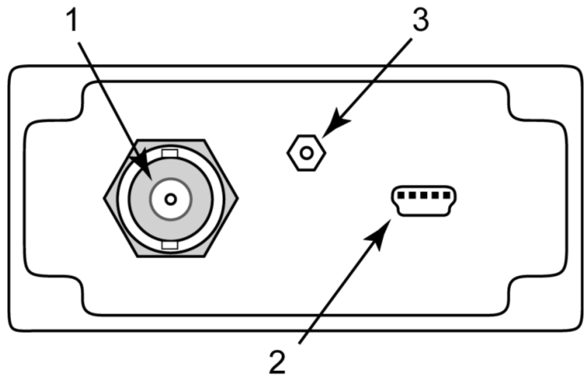


Figure 2: The rear panel of the device

1. Measurement Input Connector (Female BNC)
   The measurement input connector is the current input to the device.

2. USB Connector (Mini USB Type-B)
   The Universal Serial Bus (USB) connector. Use a shielded USB cable for best results.

3. GND Nut
   The GND nut is used to ensure a common GND between devices.

2 MEASUREMENT

The PocketPico measures current through a current node summing technique; therefore, considerations must be taken testing devices, or designing for test. The ammeter device is unidirectional and must sink current. The current is then read by an Analog to Digital Converter (ADC), and the calculated current result is then sent to the PC via USB. The voltages seen at the inputs to the ammeter referenced from the ammeter ground must not exceed 5V.

2.1 MEASUREMENT INPUT CONNECTOR

The rear panel input connector is a 2-lug female BNC connector. Make connections using a male terminated BNC cable. An illustration is shown in Figure 3. The inner terminal of the BNC connector is current input (I_{IN}), and the outer BNC shield is the reference terminal (V_{REF}).

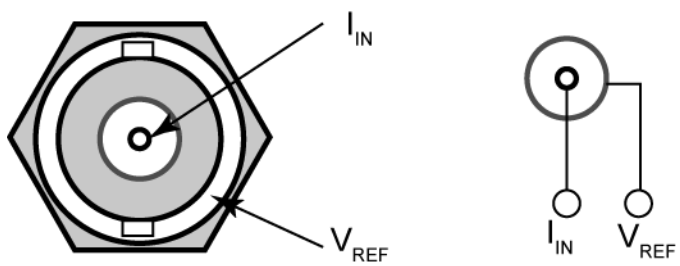


Figure 3: BNC connector with the schematic representation shown at right

2.2 MEASUREMENT CONCEPTS

The ammeter uses a “current sink” circuit concept to measure current, resulting in a unidirectional current measurement where a current flows into the ammeter device. A conceptual schematic of the ammeter is shown in Figure 4. Current calculation is achieved by current summing at a CMOS amplifier input. The voltage required at the output of the amplifier to achieve a node sum of zero is the voltage representation of the current.

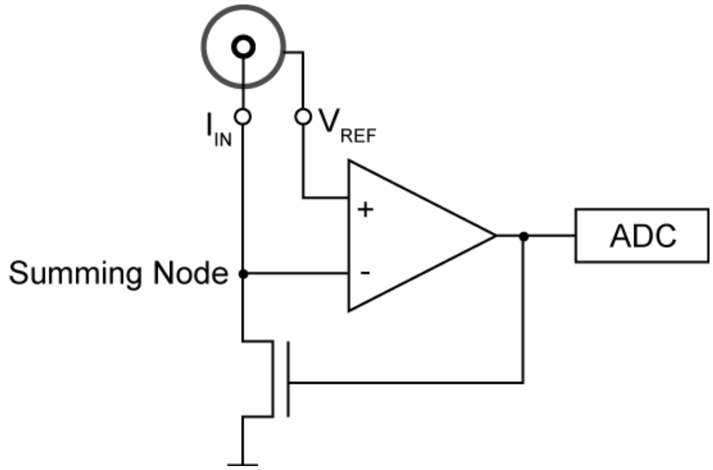


Figure 4: Simplified representation of the ammeter circuit.

2.3 DEVICE UNDER TEST

The device under test (DUT) should source current to the ammeter. The reference terminal (V_{REF}) must be lower potential than voltage source of the DUT. The potential of V_{REF} must be between 0V and 5V for correct unit operation.

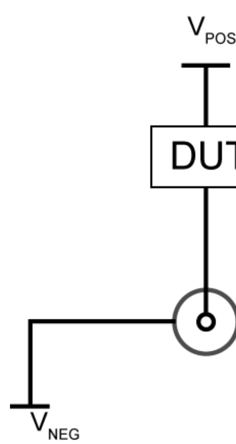


Figure 5: For correct unit operation, the DUT must source current to the ammeter, which acts as the current sink

CAUTION: The maximum voltage seen at V_{REF} or I_{IN} must between 0V and 5V when referenced to the USB ground. The Pocket Pico does not internally limit this voltage and instrument damage, electrical shock or death can occur.

2.4 Other Considerations

- The device should be powered on for at least 10 minutes so that the ammeter circuit becomes temperature stable.

- Care should be taken with the device under test so that oil from one's hands does not decrease resistance between terminals.

- Device should have a common ground. The GND from the USB should be common with the GND of the Device Under Test (DUT) to avoid ground loops. When the DUT and the PocketPico are powered from the same USB source, a GND tie to the case is not needed; however, the GND tie on the PocketPico case is necessary when the DUT has a different GND.

- One needs to be mindful of other noise sources on the USB bus. Actions that require substantial current draw, such as synchronization of an iPod, may cause noise on the ammeter readings.

3 COMMAND SUMMARY

3.1 READ?

The “READ?” command is a SCPI compatible command that returns the current and returns the value in a format of +XX.YYYE-P, where P is the logarithmic power. For instance, if handle for the ammeter is “s”, one of the following will result in a value depending on the version of Windows.

Most versions of Windows:

```
fprintf(s,'READ?'); %send the read command
fscanf(s);
result=fscanf(s);
fscanf(s);
```

Other versions of Windows:

```
fprintf(s,'READ?'); %send the read command
result=fscanf(s);
```

3.2 *IDN

The “*IDN” is a SCPI compatible command that returns the device information in the format of: <provider>,<device>,<serial number>,<firmware version>

3.3 INFO

Returns the device information, such as hardware version, firmware version, device name and calibration date.

3.4 SETNUMREAD

The “setnumread” command is of the format “setnumread(<arg>)” where <arg> is the 2 to power of the averages. As an example, “setnumread(8)” would do 256 averages upon a read.

MATLAB example:

```
fprintf(s,'setnumread(10)'); %set the averages reads to 1024
```

4 Software

4.1 Overview

The PocketPico Reader is a free, lightweight, and easy-to-use virtual display panel application. The PocketPico Reader displays real-time current readings and enables data output in .csv format.

4.2 System Requirements

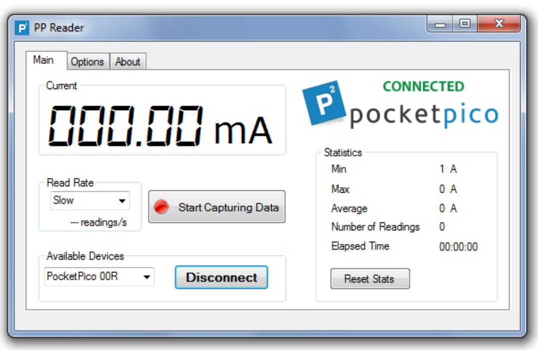
- Windows XP or greater
- 1GHz processor
- 512MB RAM
- Windows .NET framework version 2.0 or later

4.3 Installation

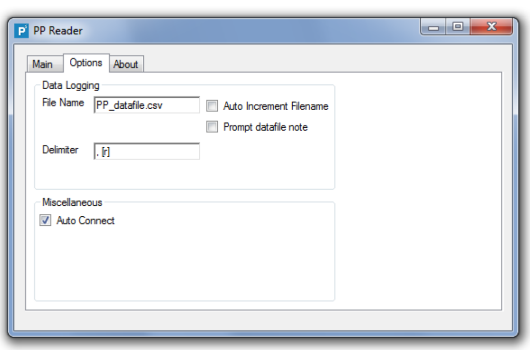
Refer to separate *Installation Guide* for driver and software installation instructions (also available on pocketpico.com/support).

4.4 Screenshots

Main Screen



Options Screen



About Screen

4.5 Connecting & Measuring

Once a PocketPico is connected to the computer, you will see the device listed under ‘Available Devices’ on the Main screen. Click on ‘Connect’ to immediately begin taking measurements.

Alternatively, you may enable the PocketPico to auto-connect by selecting this option in the Options screen.

4.6 Reading Rates

While the PocketPico always reads as fast as possible, the PocketPico Reader application can be set to average readings at 4 different rates:

- Slow (each sample averages last 256 readings)
- Medium (each sample averages last 32 readings)
- Fast (each sample average last 4 readings)
- Turbo (no averaging)

When measuring very low current (<100nA), we recommend using a “slower” read speed with more averaging to ensure more accurate data.

4.7 Capturing Data to Comma Separated Values (csv) File

To capture measurements to a .csv file, click ‘Start Capturing Data’ on the Main screen. It will begin recording to a file in the same folder as the PocketPico Reader executable file (i.e. C:\PocketPico). The filename may be changed on the options page and may be set to auto increment if desired.

If you would like to include a short note to precede the measurement data in the .csv file, select “Prompt datafile note” on the Options page before capturing data. Once the ‘Start Capturing Data’ button has been clicked, a window will prompt you to enter a short note.

You may also change the delimiter for the .csv file on the Options screen. The default delimiter “, [r]” will be reset upon application restart.

4.8 VIEWING DEVICE INFORMATION

Click on the About tab to view hardware, firmware, software and calibration information.

5 EXAMPLES

5.1 NFET CURRENT MEASUREMENT

In order to demonstrate the current sensing range of the PocketPico, a nFET transistor sweep is an ideal method. The CD4007 complementary MOSFET pair is works well for this application. The subthreshold current through the nFET device is much lower than can be measured by the PocketPico, and then can be used to determine the measurement bounds of the device through the schematic shown in Figure 9.

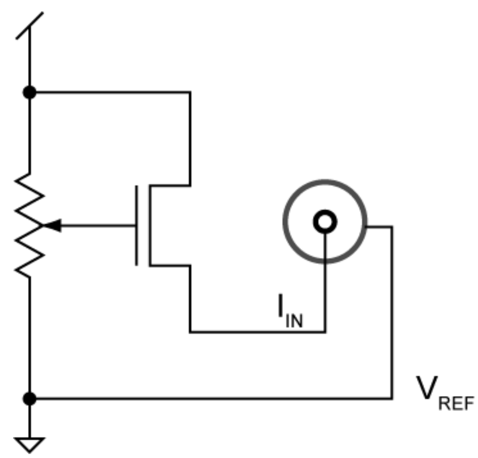


Figure 9: An example of how to sweep the gate of an nFET

The current through the device for a specific gate voltage can be obtained by sending the device the “READ?” command.

5.2 AUTOMATED pFET GATESWEEP

The PocketPico works well for automated testing of semiconductor devices. In the example below, MATLAB was used to generate a gatesweep of a pFET device using a computer controlled DAC.

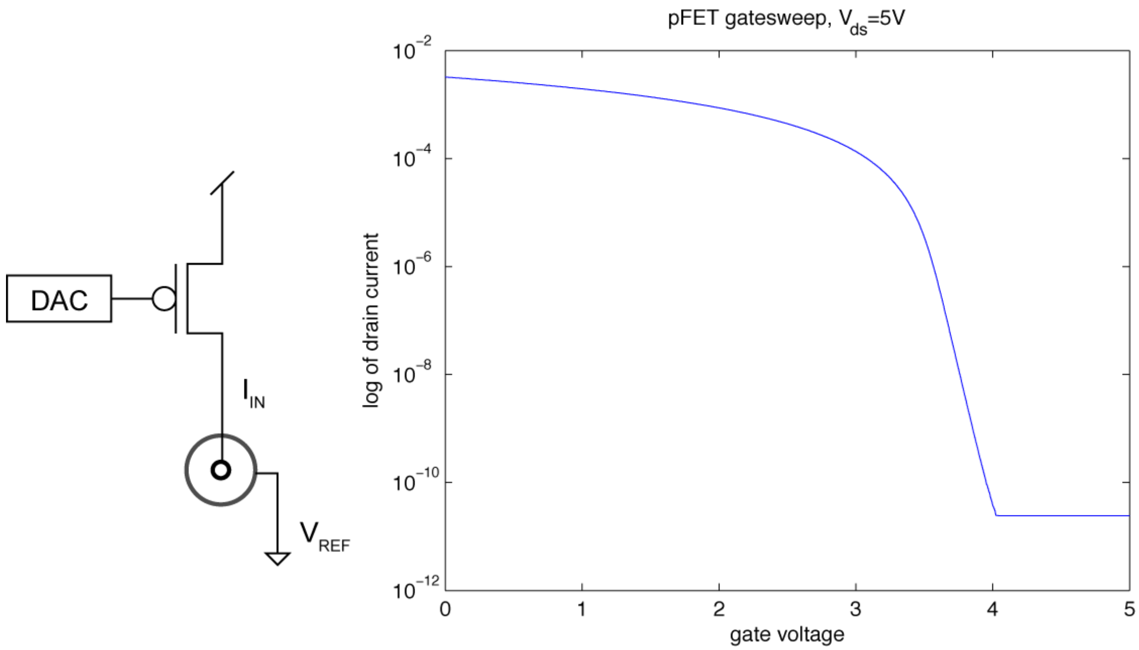


Figure 10: The circuit (a) was used to generate the plot (b)

5.2.1 GATESWEEP DESCRIPTION

When one sweeps the gate of the pFET device, one would expect the current to change. The gate voltage (V_g) is described in equation 1 for the pFET and the results of sweeping the gate from 0V to 5V for a drain-source difference across the pFET is shown in Figure 10 (b). This behavior is modeled by the compact EKV model [1,2]

$$\begin{aligned} I &= I_f - I_r \\ I_{f,r} &= \frac{W}{L} 2U_T^2 \frac{\mu C_{ox}}{2\kappa} \ln^2 \left(1 + e^{\frac{V_{dd} - \kappa V_g - (1-\kappa) V_w + \kappa V_{T0} + V_{s,d}}{2U_T}} \right), \end{aligned} \quad (1)$$

which combines all regions of operation into a single equation. The mathematical form of ln^2 $(1 + e^{(x/2)}$ interpolates between regions, and in saturated, subthreshold operation, (1) reduces to

$$I_f \approx \frac{W}{L} \frac{U_T^2 \mu C_{ox}}{\kappa} e^{\frac{\kappa V_{T0}}{U_T}} e^{\frac{V_{dd} - \kappa V_g + V_s}{U_T}}. \quad (2)$$

The current described by (2) can clearly be seen in Figure 10 (b) as the change is linear on a log scale for a gate voltage of approximately 3.5V to 4.0V.

5.2.2 EXAMPLE MATLAB CODE

The MATLAB code that was used to generate this sweep follows.

```
function data = gatesweep
s=serial('COM5'); %define which serial port to use in Windows
fopen(s); %open a the device
vg = [0:0.001:5]; %create an array from 0 to 5 in 0.001 steps
for vgi = 1:length(vg) %loop 5001 times to set the gate DAC
set_DAC(vg(vgi)); %set the DAC connected to the gate
fprintf(s,'READ?'); %send the read command
buf=fscanf(s); %return a value, the form is +12.123e-12
current=eval(char(buf(2:11))); %strip and convert the string
data.gatevoltage(vgi)=vg(vgi);
data.current(vgi)=current;
end %end the for loop
fclose(s); %close the device
```

[1] S.C. Liu, "Analog Vlsi: Circuits and Principles", Bradford Books, 2002.
[2] Degnan, B.P., Wunderlich, R.B., Hasler, P.E., "Passgate resistance estimation based on the compact EKV model and effective mobility" IEEE International Symposium on Circuits and Systems, 2009 pp. 2765-2768, 2009.

6 TROUBLESHOOTING

6.1 CONNECTION PROBLEMS

COMPUTER DOES NOT RECOGNIZE POCKETPICO

Check device manager.

- If PocketPico not listed, reinstall device drivers, reconnect
- If PocketPico listed:
    1. Reconnect device to computer (try a few times, wait 10 seconds)
    2. Change port number
    3. Restart Windows

CANNOT CONNECT TO POCKETPICO READER OR MATLAB

1. Reconnect device to computer (try a few times, wait 10 seconds) & restart application
2. Change port number of PocketPico in Device Manager
3. Restart Windows

POCKETPICO READER CRASHES OR WON'T START

Make sure you have the latest versions of PocketPico Reader (available at pocketpico.com/support) and Microsoft .NET Framework

6.2 MEASUREMENT PROBLEMS

READINGS ARE NOISY

Due to realities of measuring very low current, readings are expected to be noisier at the low end. However, there are several steps you can take to reduce noise levels:

1. Reduce read speed to slow at low-end
2. Use the shortest possible low-noise cable
3. Ensure you are not touching cables and/or device during measurement
4. Ensure you are not using the USB bus connection for other purposes during measurement
5. Minimize movement, mobile phones, etc.

READING ARE CHANGING

Wait until the PocketPico is warmed up before taking measurements (at least 10 minutes)

READINGS ARE NOT AS EXPECTED

1. Check calibration information
    - Is the calibration out of date?
    - Was the calibration information loaded properly
2. Are you recording measurements outside of the device range?

DEVICE RETURNS A MEASUREMENT WHEN NOTHING IS CONNECTED
This is normal

6.3 SOFTWARE PROBLEMS

APPLICATION CRASHES
1. Latest PocketPico Reader version
2. Latest .NET Framework

APPLICATION WILL NOT CLOSE
Disconnect PocketPico and try again

CSV NOT EXPORTED PROPERLY
- Reset delimiter to default (reset the app)

POCKETPICO READER READS CALIBRATION ERROR
- Unplug the PocketPico and re-connect

7 TECHNICAL SUPPORT CONTACT INFORMATION

For further support, contact Ix Innovations support@pocketpico.com or at 734.926.5900.