IQRB-3 Handbook

April 2021

REVISION 1.0

Date	Revision	Revision Details	Responsible
12.04.2021	1.0	Initial Release	Rebecca Long

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FIGURES

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ABBREVIATIONS

ADEV .... *Allan Deviation*
DUT .... *Device Under Test*
PN .... *Phase Noise*
TIE .... *Time Interval Error*

1. INTRODUCTION

This IQRB-3 handbook gives an overview of actual tests performed at the IQD test and design centre in Crewkerne, United Kingdom. This report confirms the datasheet content and the capability of the IQRB-3.

This document will be extended as more testing is completed and requested by customers.

The handbook starts with the introduction and an overview of IQD's general test setup followed by the various tests undertaken. The test chapters have a short description of the test, an overview of equipment used and the test method supported by pictures of the test setup followed by results and a conclusion.

Finally, a summary is given.

The IQRB-3 is an atomic clock in a package size of 101.2 x 60.7 x 37.7 mm with a 12 V to 15 V supply voltage. It's perfectly suited as frequency and timing reference for communication base stations, broadcasting or as reference for industrial equipment.

Further details of the specification are on the datasheet of the IQRB-3 which is added at the end of this document.

2. GENERAL SETUP

This section describes the general setup at the IQD facility as well as for the tests undertaken.

2.1 IQD TEST SETUP

All tests are conducted at the IQD headquarters in Crewkerne, Somerset in the United Kingdom.

The test area is equipped with many test systems, all of which are calibrated to traceable national standards. Test jigs and fixtures are custom designed to specific parts and customer needs.

Furthermore, all test space is ESD controlled in accordance with BS EN 61340-5-1.

IQD tests are normally conducted in accordance with BS EN 168000 (Harmonised system of quality assessment for electronic components. Generic specification: quartz crystal units) and BS EN 169000 (Harmonised system of quality assessment for electronic components. Generic specification. Quartz crystal controlled oscillators).

All following tests are performed under the following conditions unless otherwise stated:

Temperature: 25 °C ±2 °C

Relative Humidity: 40 ~ 60 %

2.2 DEVICE UNDER TEST

Model: IQRB-3

Product Item Number: LFRBXO084479

Serial Number: 20032311

Date Code: 30/03/2020

Frequency: 10.0 MHz

3. TEMPERATURE STABILITY

This section shows the measurement results of frequency shift over its operating temperature range for the IQRB-3.

In general, the temperature stability describes the frequency deviation over the complete operating temperature range.

3.1 EQUIPMENT USED

- Thermal chamber: Saunders and Assoc 4220MR
- IQD IQRB-3 temperature test fixture
- Frequency counter, Keysight 53230A
- Power supply, TTI QPX1200
- Power supply, Keysight E3631A
- Pico PT-104 temperature data logger

3.2 METHOD

The IQRB-3 is mounted inside the S&A 4220 temperature test chamber.

The chamber is ramped in temperature using an automated test sequence from -40 to 60 °C in 5 °C steps.

The chamber temperature is allowed to stabilise at each step for 10 minutes.

The frequency is monitored and recorded for 5 minutes at each step on the frequency counter using a 1 second gate time.

An average of 10 measurements is used in the test data to reduce noise.

Photos of the experiment setup can be seen in Figure 1 and Figure 2.

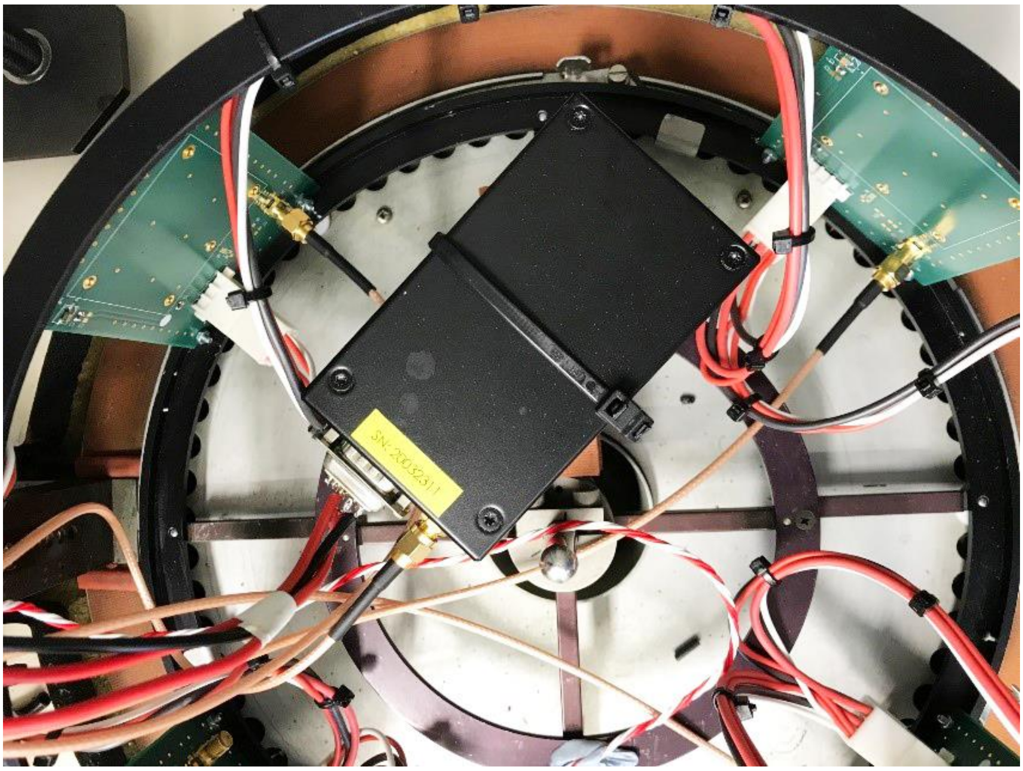

Figure 1: Test setup for stability measurement (1)

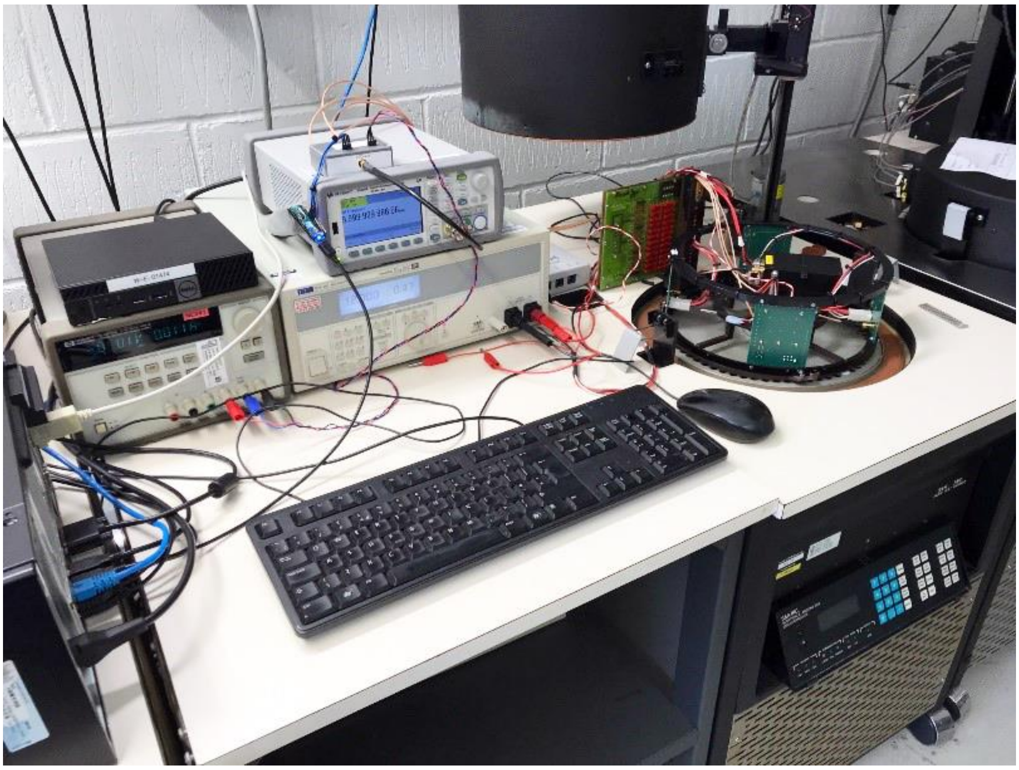

Figure 2: Test setup for stability measurement (2)

3.3 RESULTS

The results of described measurements are displayed in Figure 3: Results of the output frequency over temperature range. The orange line shows the frequency shift during the temperature change while the blue line represents the temperature.

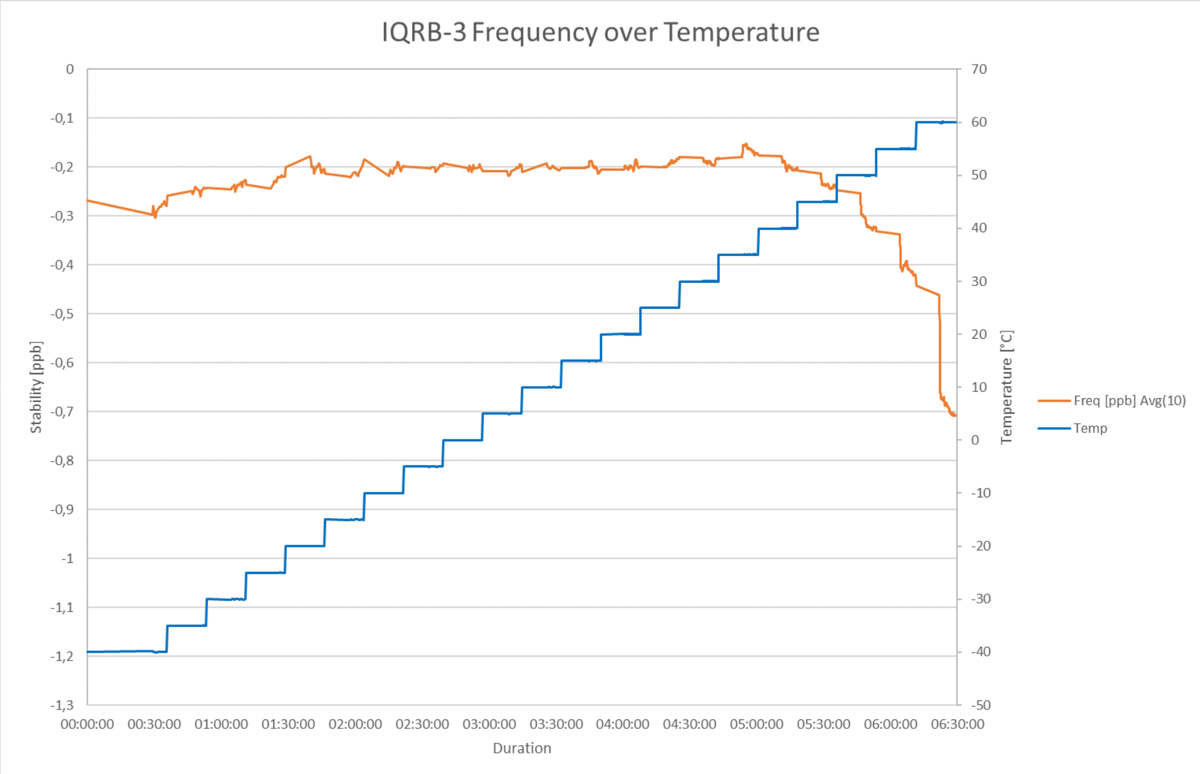

Figure 3: Results of the output frequency over temperature range

3.4 CONCLUSION

The temperature is varied from -40 to 60 °C, however, the standard temperature range is only -20 to 60 °C. Within the standard temperature range the maximum frequency deviation is measured at -0.152 ppb while the minimum measured frequency deviation is -0.709 ppb. This shows that the peak to peak frequency deviation is 0.557 ppb. This equals a frequency stability of

$$\frac{\Delta f_{max}, f_{min}}{2} = \pm 0.279\ ppb$$

4. ADEV MEASUREMENT

This section shows the measurement results of Allan Deviation (ADEV) for the IQRB-3.

In general, ADEV shows the statistical measure of frequency over a given time. Over the specified times the frequency deviations are taken and averaged.

4.1 EQUIPMENT USED

- Power supply, TTI QL355P
- IQD IQRB-3 test fixture
- Pendulum CNT-91 counter timer
- TimeView software

4.2 METHOD

The device under test (DUT) is placed into the IQD IQRB-3 test fixture and powered from the power supply for at least 4 hours to allow the device to stabilise.

A predetermined test protocol is run using the TimeView software to capture a TIE measurement, followed by the calculation of ADEV.

A photo of the experiment setup can been seen Figure 4.

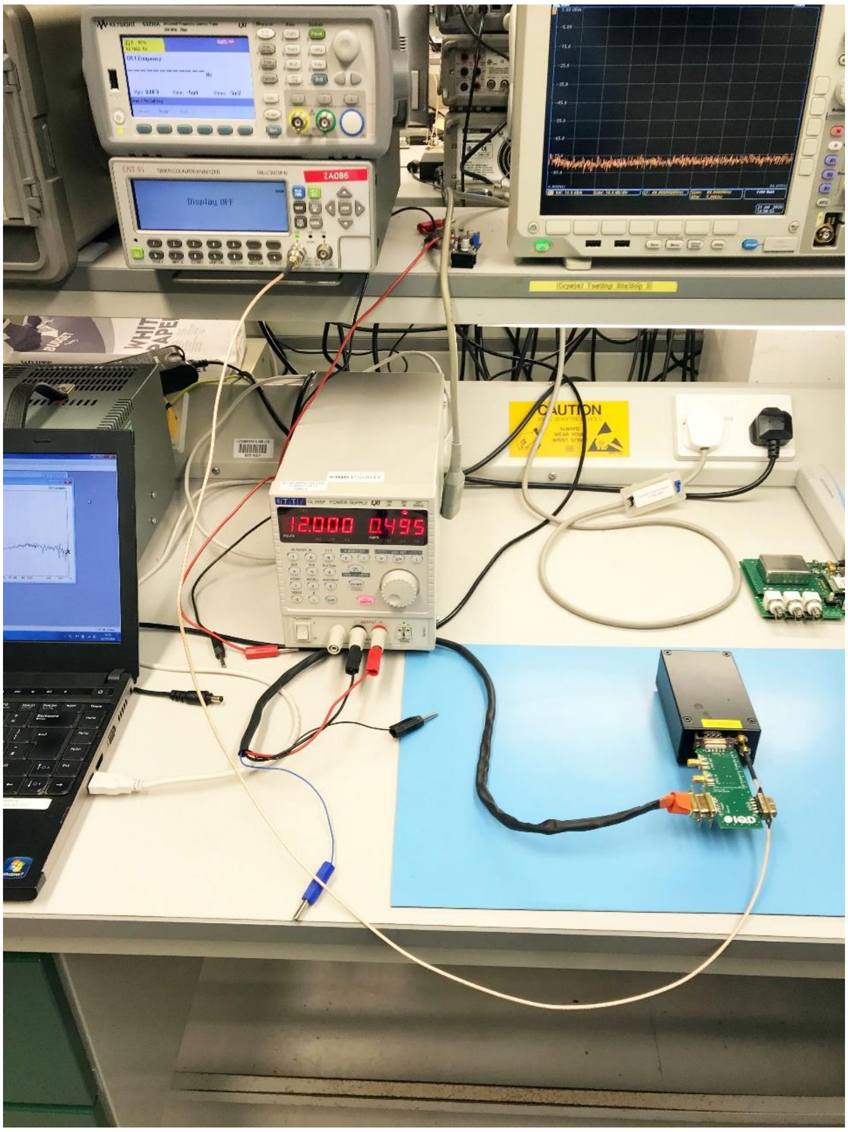

Figure 4: Test setup for ADEV measurement

4.3 RESULTS

The results from described measurements are displayed in below Figure 5: Results of ADEV measurement.

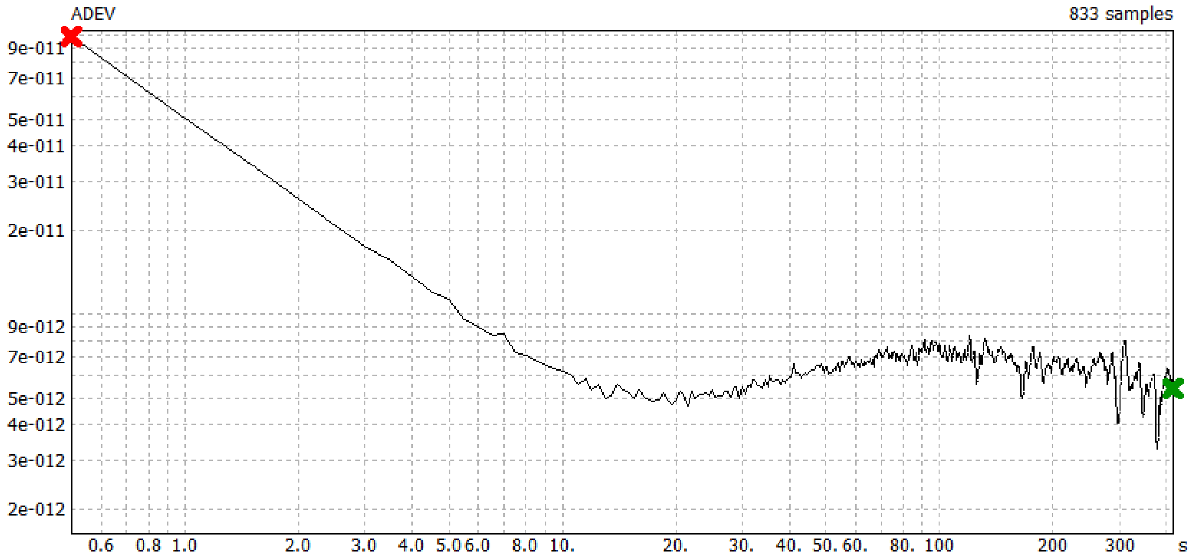

Figure 5: Results of ADEV measurement

4.4 CONCLUSION

As shown in Figure 5 and Table 1 the results from the short term stability tests are in a very good range.

Tau	DUT1
1 s	5.00E-11
10 s	6.00E-12
100 s	8.00E-12

Table 1: Overview of the ADEV measurement results

5. PHASE NOISE

This section shows the measurement results of phase noise (PN) for the IQRB-3.

In general, phase noise determines the short term stability of the oscillator within the frequency domain. It is also mainly dependent on the oscillator's circuit.

5.1 EQUIPMENT USED

- IQD IQRB-3 test fixture
- Phase noise analyser, Keysight E5052B
- Power supply, TTI PL303QMD-P

5.2 METHOD

The DUT is connected to the IQD IQRB-3 test fixture and powered from the power supply.

The device is powered for 1 hour prior to the test to allow for the device to stabilise.

The output of the IQRB-3 is connected to the input of the phase noise analyser and a predetermined test protocol is run with offset frequencies from 1 Hz to 1 MHz, using four correlations with an averaging factor of four.

A photo of the experiment setup can be seen in Figure 6 and Figure 7.

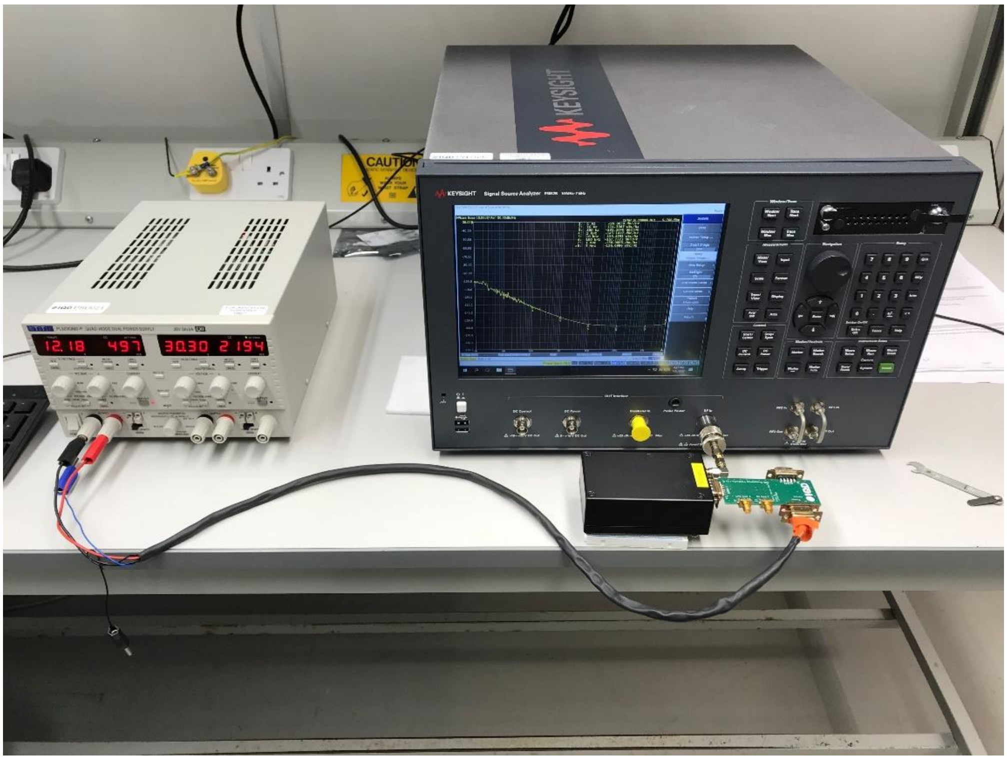

Figure 6: Test setup for phase noise measurement (1)

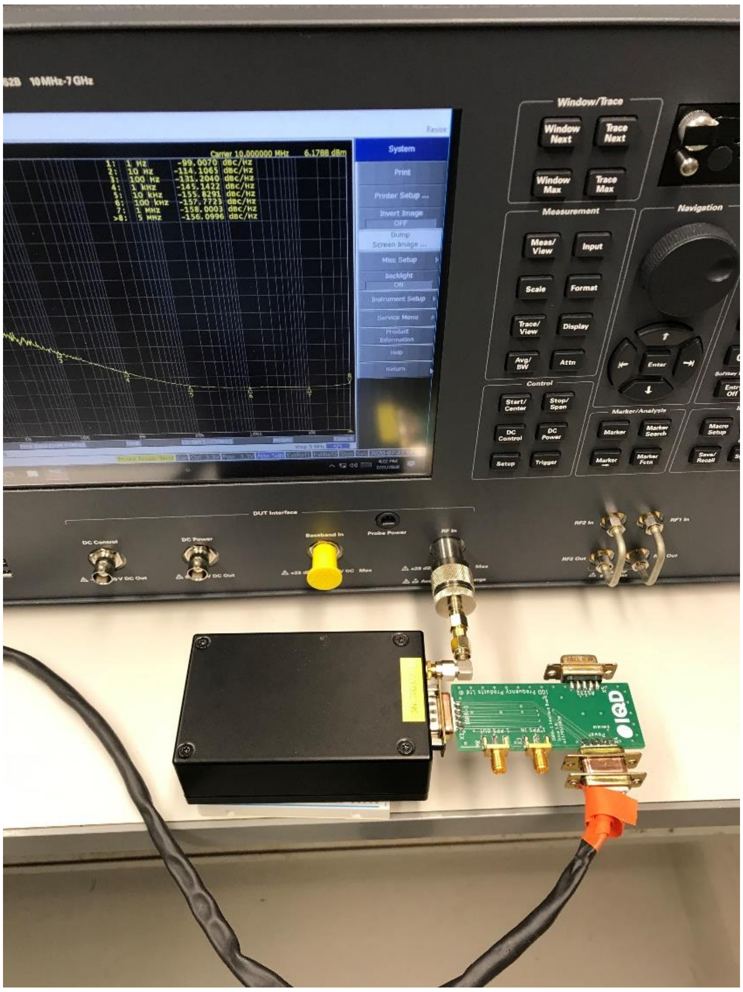

Figure 7: Test setup for phase noise measurement (2)

5.3 RESULTS

The phase noise measurement values are displayed in below Figure 8: Results of phase noise measurement.

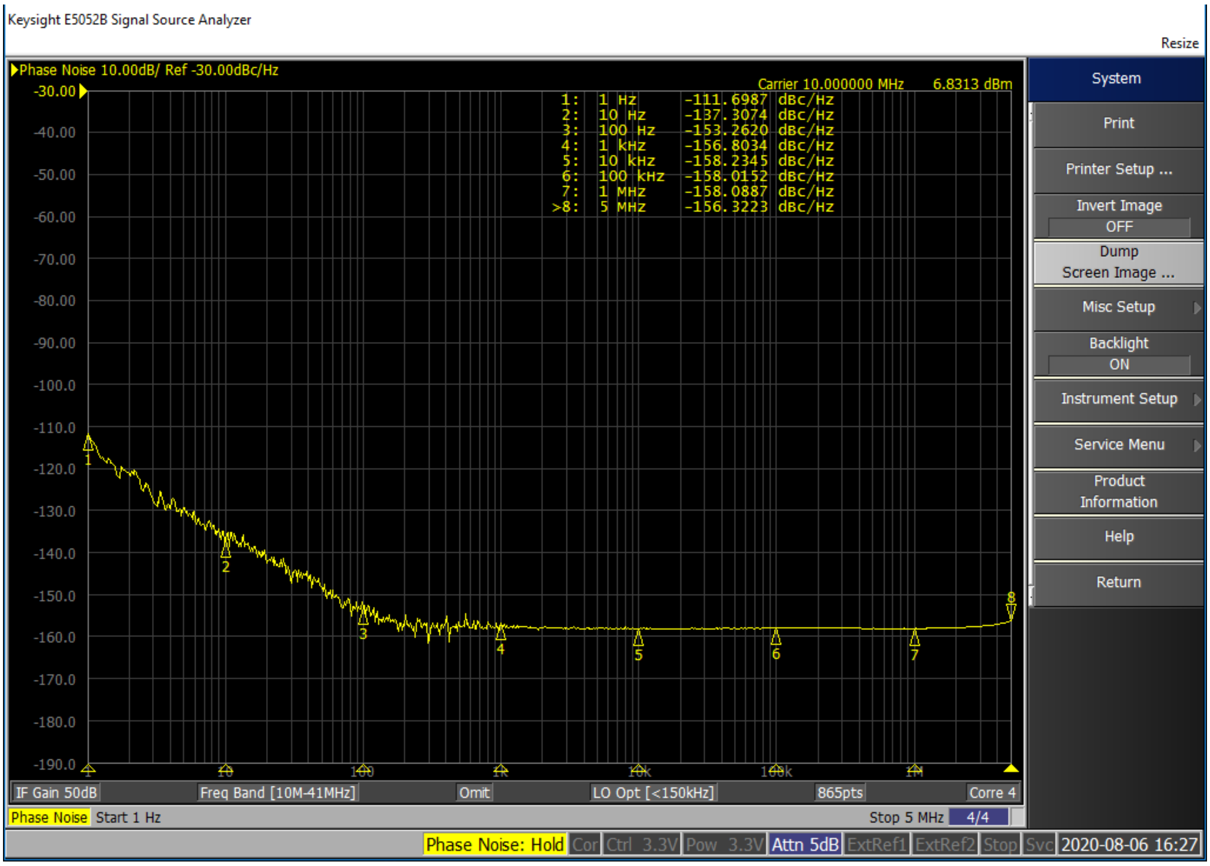

Figure 8: Results of phase noise measurement

5.4 CONCLUSION

The results show that the part is better than its typical values from the datasheet. The overall curve is very smooth and does not show any signs of disturbances. The measured values are summarised in Table 2: Overview of phase noise measurement results shown below.

Offset	Datasheet	Measured
1 Hz	-110 dBc / Hz	-111 dBc / Hz
10 Hz	-135 dBc / Hz	-137 dBc / Hz
100 Hz	-145 dBc / Hz	-153 dBc / Hz
1 kHz	-155 dBc / Hz	-156 dBc / Hz
10 kHz	-158 dBc / Hz	-158 dBc / Hz
100 kHz	-	-158 dBc / Hz
1 MHz	-	-158 dBc / Hz

Table 2: Overview of phase noise measurement results

6. SPECTRAL ANALYSIS

This section shows the measurement results of spectral analysis for the IQRB-3.

In general, spectral analysis shows the characteristics of a crystal's harmonics. Every crystal has harmonics, however, the deflection may be of importance for further usage of the oscillator within a circuit or for EMI sensitive applications.

6.1 EQUIPMENT USED

- IQD IQRB-3 test fixture
- Power supply, TTI QL355P
- Tektronix oscilloscope MDO4054C

6.2 METHOD

The DUT is connected to the IQD IQRB-3 test fixture and is powered from the power supply.

The DUT is connected to the spectrum analyser input on the oscilloscope by a short coax cable left for 1 hour to allow for stabilisation of the device, and the output is recorded.

A photo of the experiment setup can be seen in Figure 9.

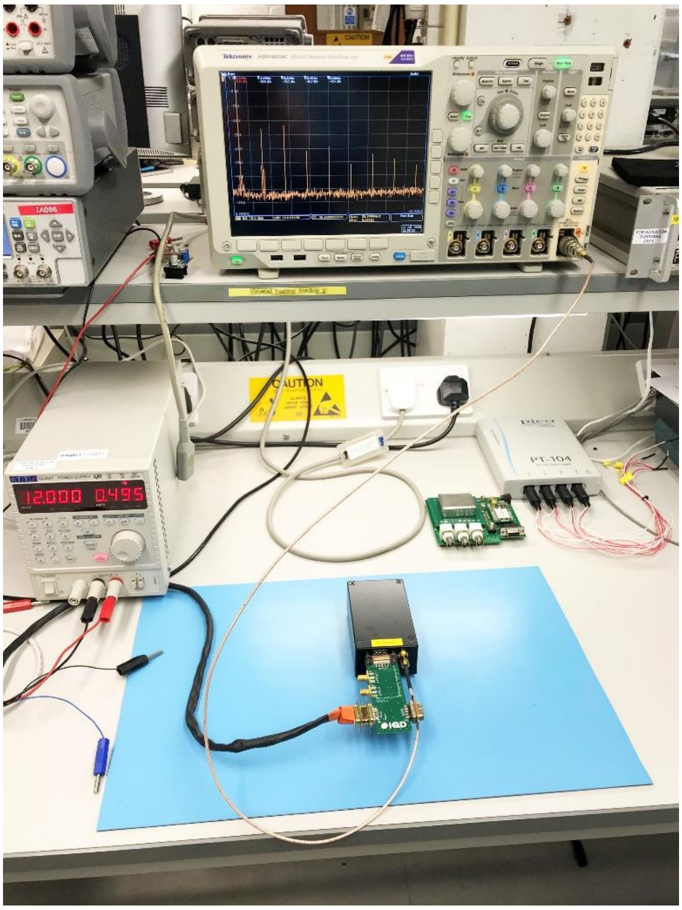

Figure 9: Test setup for spectral analysis

6.3 RESULTS

The results of the spectrum analysis can be seen below in Figure 10: Results of spectral measurement.

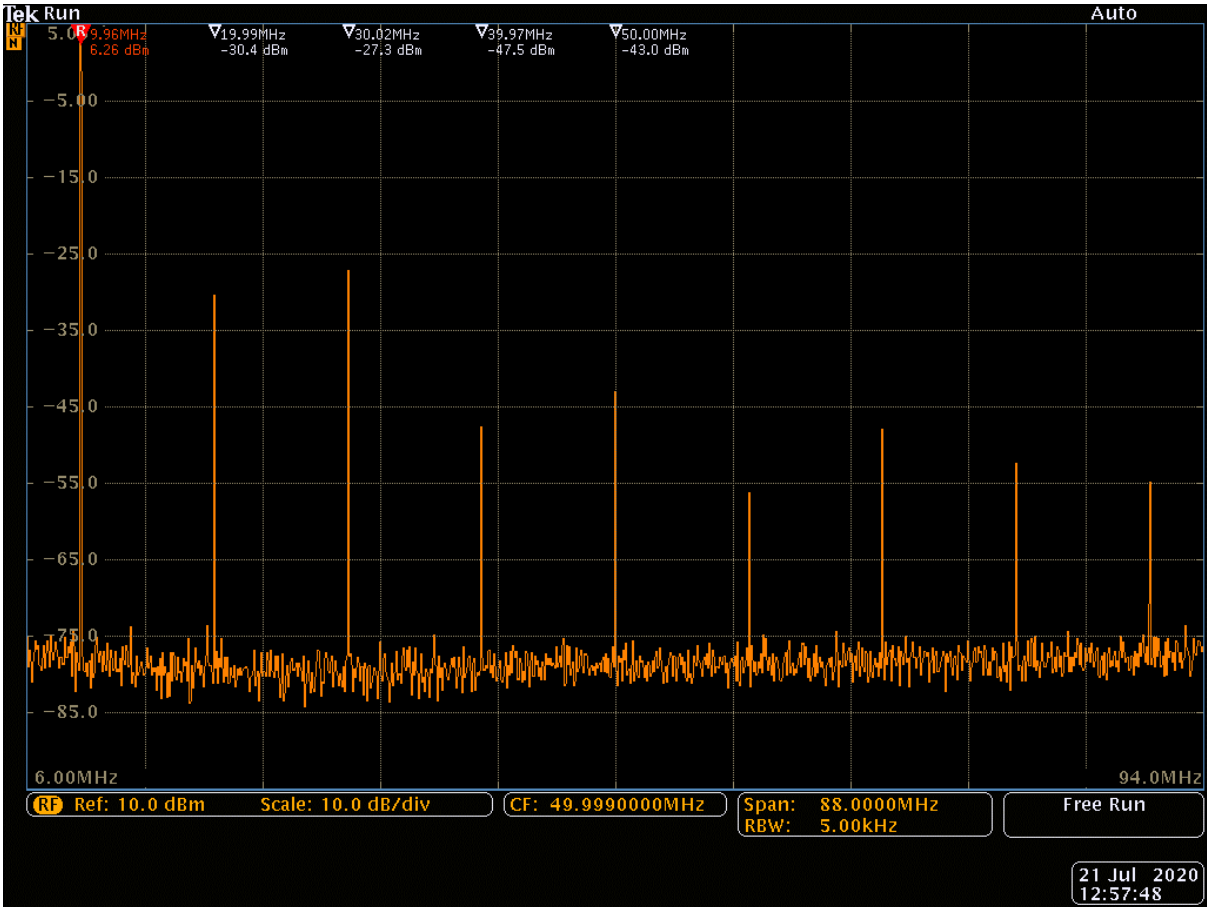

Figure 10: Results of spectral measurement

6.4 CONCLUSION

The 10 MHz – resonance frequency - signal peaks at 6.26 dBm. The next highest peak showing at 30 MHz is -27.3 dBm.

7. POWER CONSUMPTION

This section shows the results from the power consumption measurement of the IQRB-3 during warm-up as well as at steady state.

In general, current consumption is important to know to ensure the application circuit will provide enough power to always keep the rubidium running.

7.1 EQUIPMENT USED

- IQD IQRB current measurement test jig
- IQD IQRB-3 test fixture
- Frequency counter, Keysight 53230A
- Digital multimeter, Keysight 34461A
- Power supply, TTI QL355P
- Tektronix oscilloscope MDO4054C

7.2 METHOD

The DUT is connected to the IQD IQRB-3 test fixture and is powered from the power supply.

The measurement records the current consumption over time. By using the IQD IQRB current measurement test jig, the voltage drop is measured across a 1 Ω resistor. Results of the voltage using the oscilloscope are recorded and power consumption is calculated using Ohms law.

In addition, the output frequency from start-up of the device over approximately a period of 30 minutes is displayed. The frequency is measured to establish the correlation between the input current consumption and the stabilisation of the output frequency.

Photos of the experiment setup can be seen in Figure 11 and Figure 12.

Figure 11: Test setup for current consumption (1)

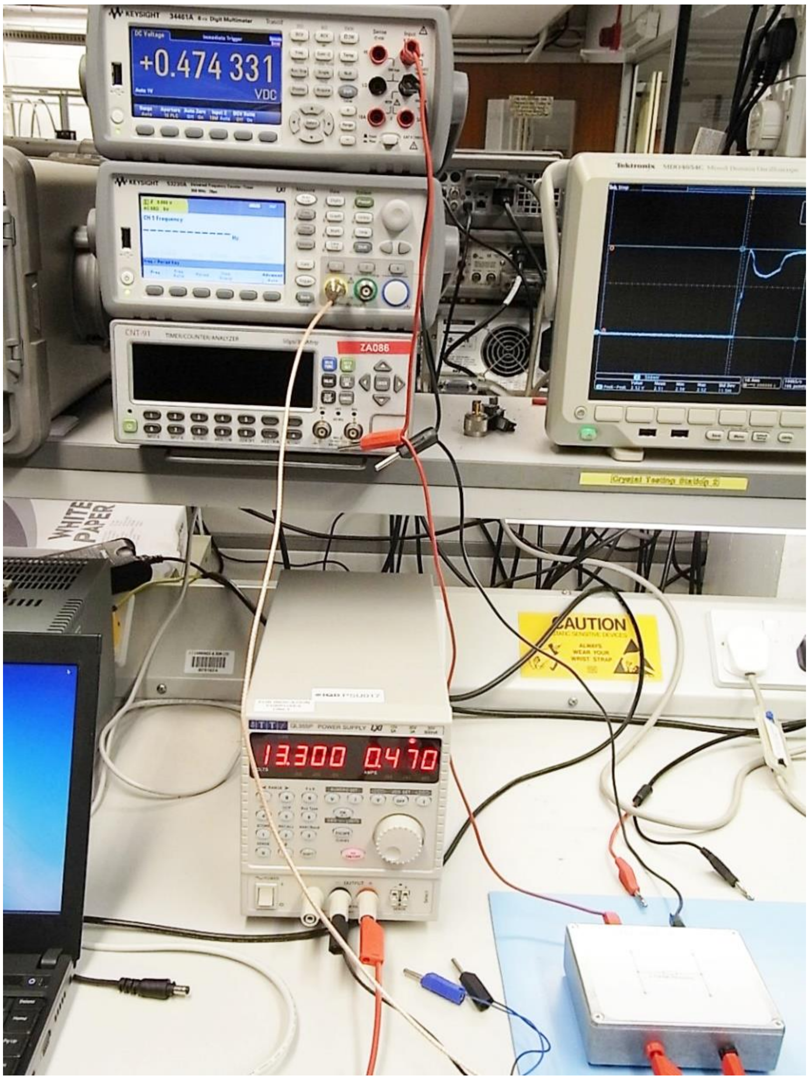

Figure 12: Test setup for current consumption (2)

7.3 RESULTS

The measurement results of the current consumption can be seen in Figure 13: Results of current consumption tests.

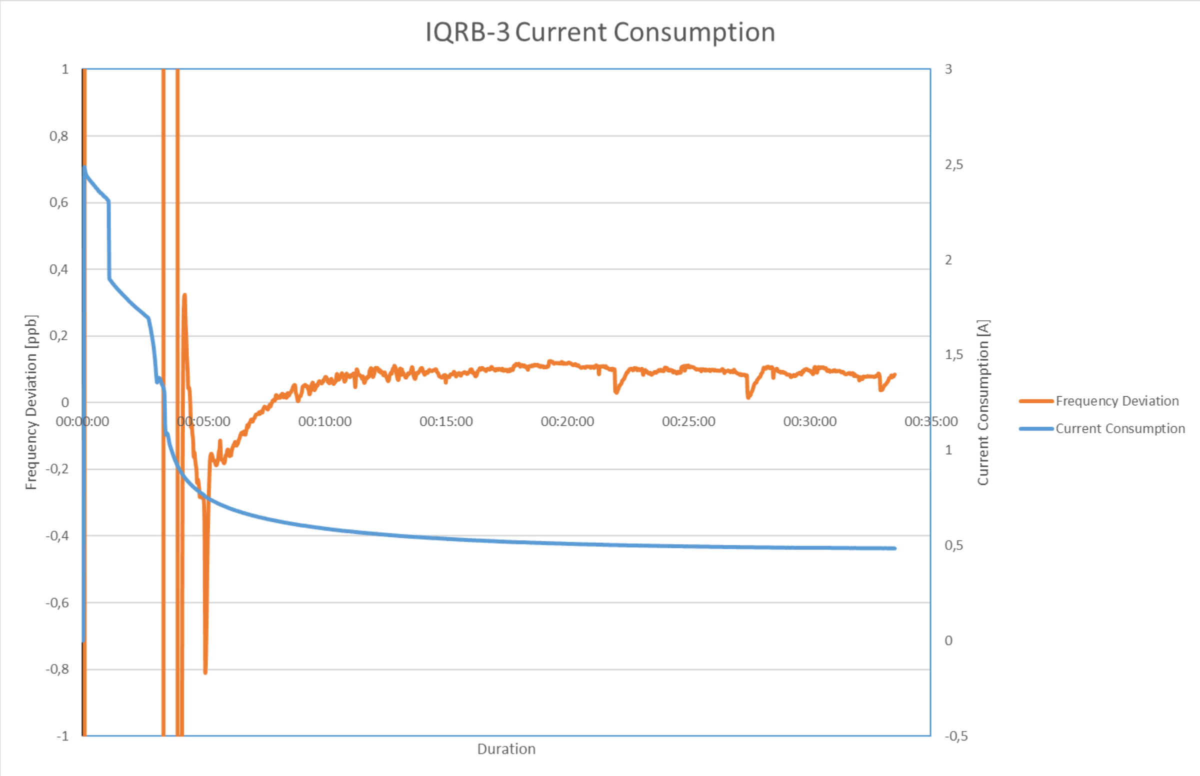

Figure 13: Results of current consumption tests

7.4 CONCLUSION

Warm-up power
The measured results for peak power draw are 30 W (2.48 A * 12.0 V).

Warm-up time
The warm-up time to reach a stability within ±0.5 ppb is measured in less than 6 minutes.

Steady state
Once steady state is reached, the power consumption is down to 6.0 W (0.5 A * 12.0 V).

8. SUPPLY PUSHING

This section shows the result of the measurement for the supply pushing for the IQRB-3.

The standard supply voltage for the IQRB-3 is 12 V, however the oscillator is specified to operate up to 15 V without any impact on its performance. The supply pushing test shows what effect changing the supply voltage within this range has on the frequency deviation. Additionally, the test range is extended to showcase the behaviour in a supply voltage range up to 18 V.

8.1 EQUIPMENT USED

- IQD IQRB-3 test fixture
- Power supply, TTI QL355P
- Frequency counter, Keysight 53230A

8.2 METHOD

The DUT is connected to the IQD IQRB-3 test fixture and powered from the power supply.

The DUT is connected to the frequency counter input by a coax cable and left for 1 hour to allow for stabilisation of the device.

The power supply is controlled via the USB port to allow the adjustment of the output voltage.

The supply voltage to the device is set to 12 V and then incremented in 1 V steps up to 18 V while the output frequency is recorded.

A photo of the experiment setup can be seen in Figure 14.

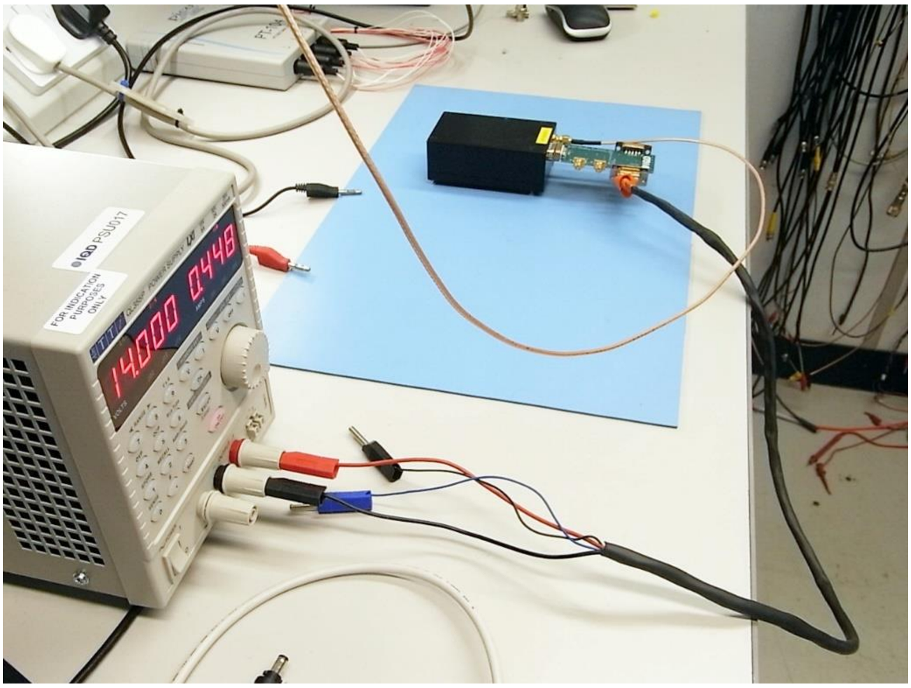

Figure 14: Test setup for supply pushing

8.3 RESULTS

The results of the supply pushing measurements can be seen in Figure 15: Results of supply pushing measurement. The orange line shows the change in the supply voltage over time, while the blue line shows the impact of the change in supply voltage on the frequency.

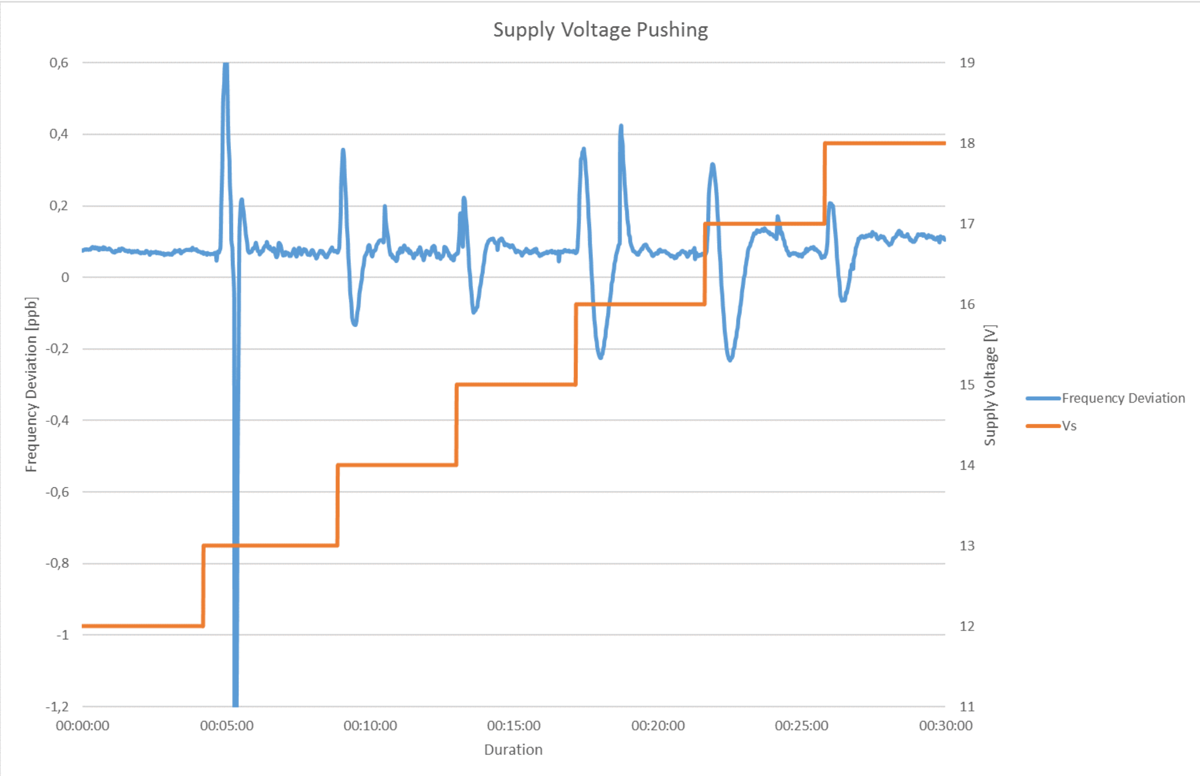

Figure 15: Results of supply pushing measurement

8.4 CONCLUSION

It can be seen in Figure 15 that with every change in supply voltage the frequency reacts with a peak and will take some time to stabilise again. These peaks range from -1.95 ppb to +0.59 ppb.

The IQRB-3 may be used over the supply voltage range of 12 V to 15 V however, once the supply voltage changes it should be given at least two minutes for the frequency to stabilise again.

The test also shows the oscillator being fully functional up to 18 V, however this cannot be guaranteed overall manufacturing batches at this point of time.

9. CASE TEMPERATURE

This section shows the measurement results of the case temperature test for the IQRB-3.

Within the rubidium the circuit is heated and consequently, the case temperature increases. This temperature has to be taken into consideration when planning a PCB layout around it and the housing of the overall application. Customers should allow enough space to avoid overheating of components surrounding the rubidium as well as within the rubidium as well.

9.1 EQUIPMENT USED

- IQD IQRB-3 test fixture
- Frequency counter, Keysight 53230A
- Power supply, TTI QL355P
- Pico PT-104 temperature data logger
- Four PT100 four wire platinum resistance, thin film temperature sensors

9.2 METHOD

The four PT100 sensors are marked with the corresponding PT-104 input channels.

The PT100 sensors are adhered one to each of the four sides of the IQRB-3, as can be seen in Figure 16.

The DUT is connected to the IQD IQRB-3 test fixture and powered from the power supply.

A recording of the four channels of temperature and the output frequency is logged over a period of approximately 50 minutes. The experiment is commenced with the device at ambient temperature, unpowered and the supply voltage is enabled at the start of the experiment.

The frequency is measured to establish the correlation between the device warm-up and the stabilisation of the device's output frequency.

Photos of the experiment setup can be seen in Figure 16 and Figure 17.

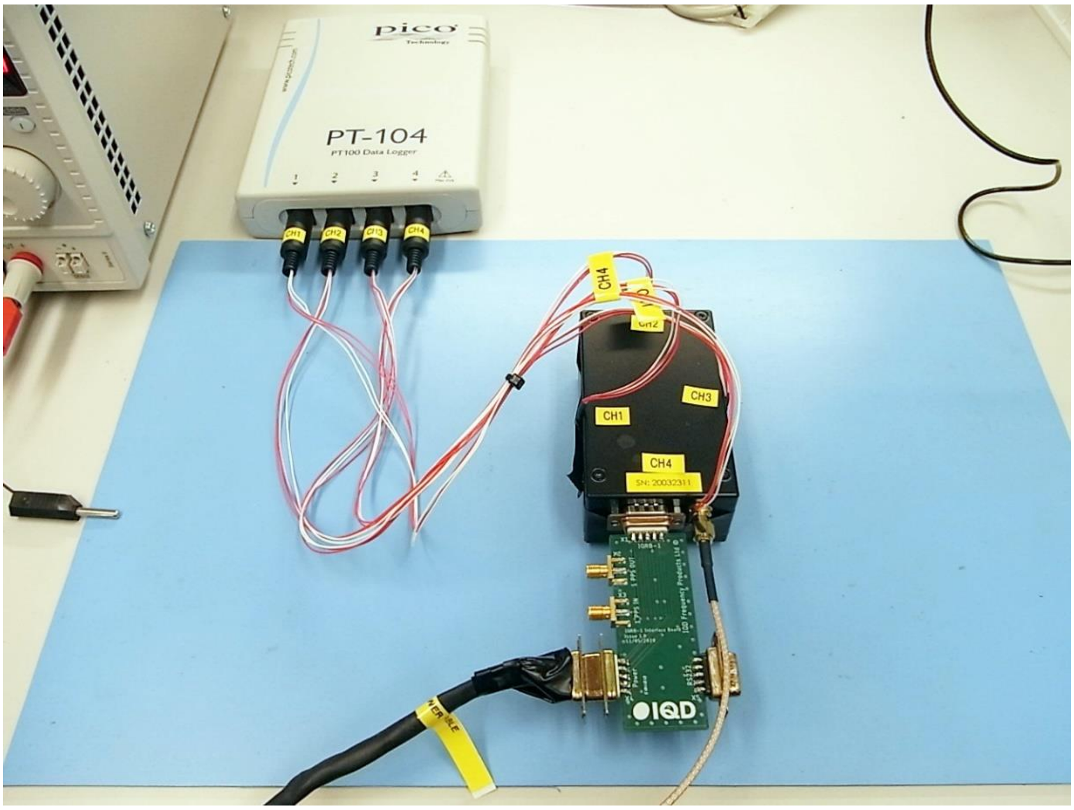

Figure 16: Test setup for case temperature (1)

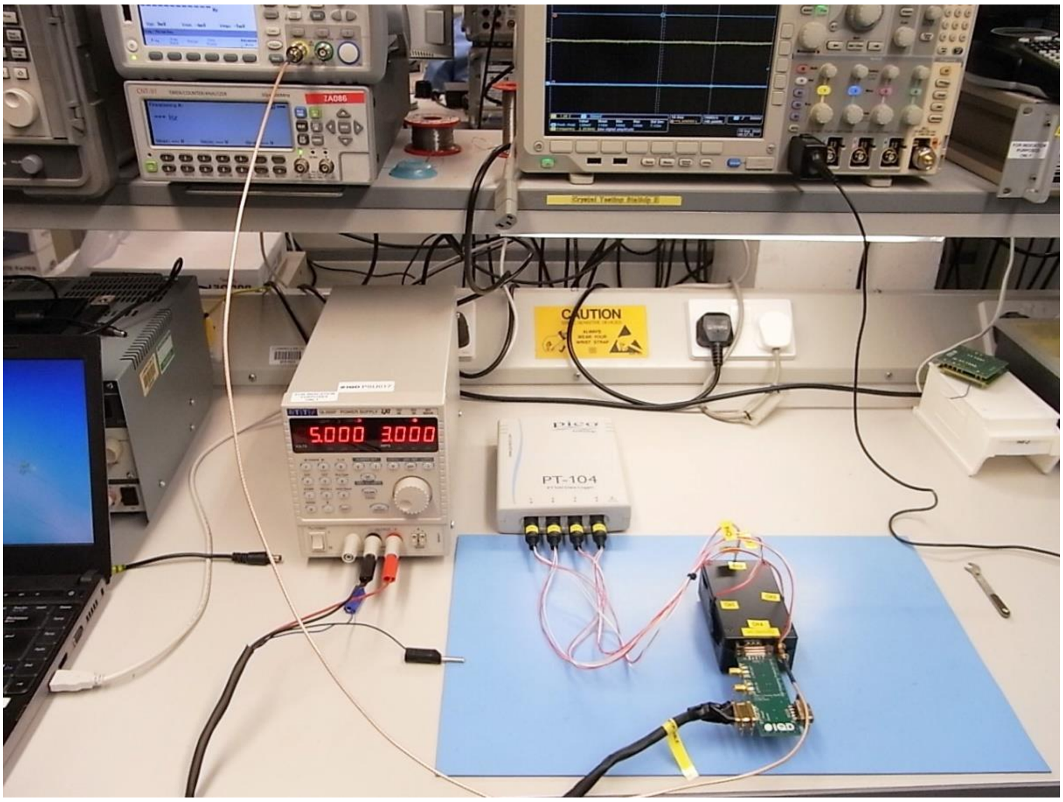

Figure 17: Test setup for case temperature (2)

9.3 RESULTS

The results of case temperature test can be seen in Figure 18: Results of case temperature measurement. The orange line shows the frequency behaviour during the warm-up of the rubidium. As shown before in section 7 POWER CONSUMPTION, for the first approximately 10 minutes the frequency is out of scope. The relation of the case temperature to the internal temperature can be seen – once the temperature closes to the final temperature the frequency does as well.

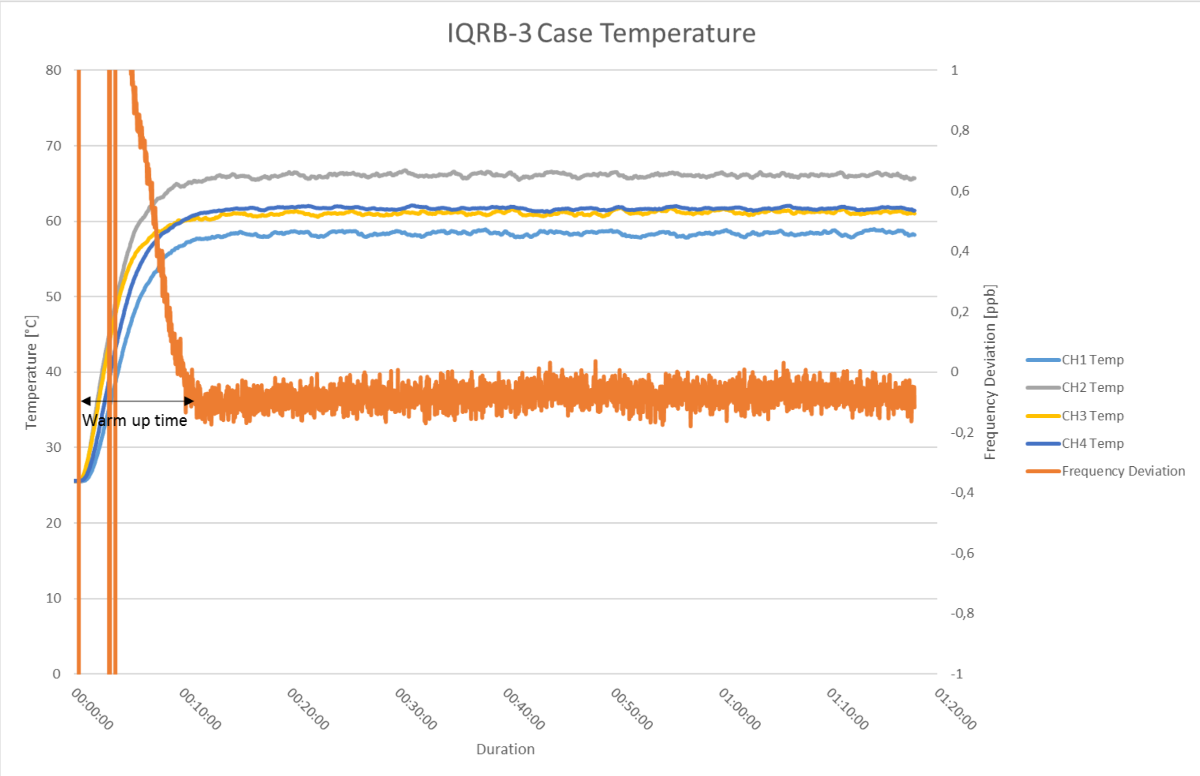

Figure 18: Results of case temperature measurement

9.4 CONCLUSION

The case temperature measurements show an average of around 62 °C after 1 hour of operation within an environmental temperature of 25 °C. The temperature is reached within approximately 10 minutes after start-up of the oscillator.

It can also be seen that the stability of the oscillator is only reached with the temperature close to stable heat state.

10. SUMMARY

This handbook summarises various tests done with the IQRB-3.

The temperature stability measurements are within a peak to peak frequency deviation of 0.557 ppb, which means the stability is in a very good range.

The short term stability measured for tau = 1 s is 0.05 pbb, for 10 s 0.006 ppb and finally, for 100 s 0.008 ppb.

The phase noise measurements show a typical close in phase noise of -111 dBc / Hz and a noise floor of -158 dBc / Hz.

The spectral analysis shows harmonics of -27.3 dBm at 30 MHz.

The power consumption starts with around 30 W and reaching stability within ±0.5 ppb takes less than 6 minutes. Steady state consumption of typically 6.0 W is reached after approximately 10 minutes.

The supply push measurement shows that with every change in supply voltage the frequency reacts with a peak and will take some time to even out again. These peaks range from -1.95 ppb to + 0.59 ppb. However, overall the part can be powered in a range between 12 V and 15 V.

Lastly, the case temperature measurements show an average of around 62 °C after 1 hour of operation within an environmental temperature of 25 °C. The temperature is reached within approximately 10 minutes after start-up of the oscillator.