

Dual Quad PCB

Part Number:	Xevo TQ-S Xevo TQ-XS	700005355 700011102	Where Used:	Xevo TQ-S / Xevo TQ-XS
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Functional description

- Controls and generates the quad DC and RF drive used for the quadrupole-driving RF generators.
- Generates RF drive signal up to 12 V peak-to-peak for the RF generator.
- The DC voltages of up to ± 1300 V are made with two separate (hybrid) amplifiers mounted on the board. Each amplifier provides half of the differential DC outputs to the quadrupole, via the RF generator.
- Converts the digital signals from the software resolution slider control into analog DC voltages that are fed through the RF generators to drive the quads.
- The 48 V from the backplane supplies the RF generators and instrument fans.

CAUTION: Follow suitable antistatic precautions at all times. Ensure the instrument electronics are switched off before removing/installing this PCB.

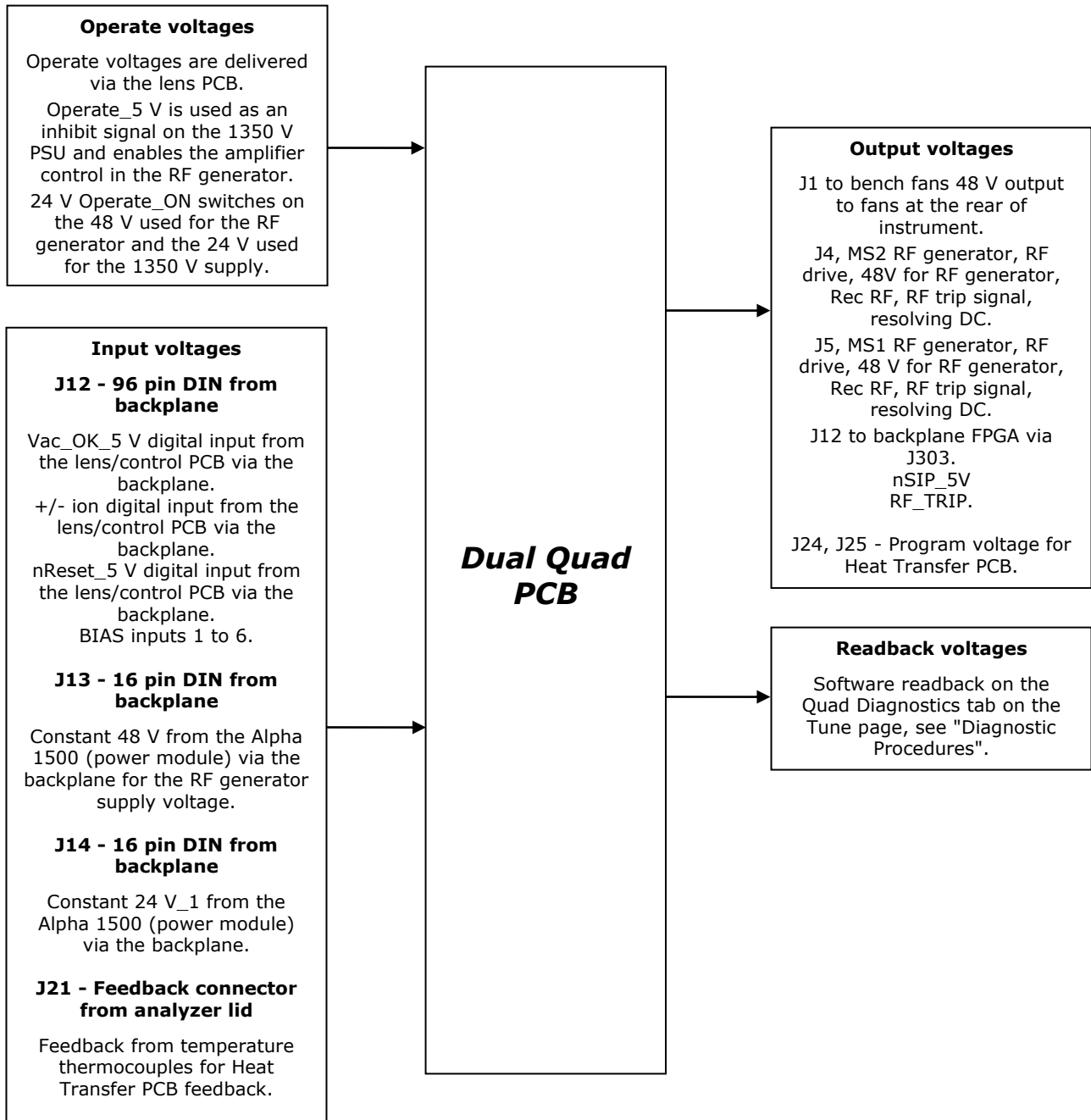
WARNING: Lethal voltages are present on this board and on the outputs to the RF generator.

Location



Figure 1 - Top internal view of the instrument (Xevo TQ-S shown)

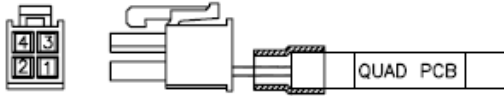
Inputs/outputs



The dual quad PCB relies on two interlock signals generated on the lens control PCB from the backplane to switch on the 24 V used for the 1350 V PSU and the 48 V used to supply the RF generators.

NOTE: *The 48 V switch is only enacted on PCBs revision E and beyond (initial production instruments do not have this switch).*

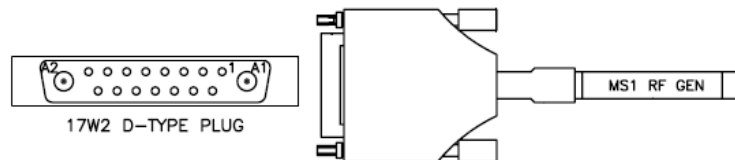
J1 - 48 V to fans at rear of instrument - 4265045BC1 (700004240)



Pin	Signal	Direction	Note
1	48 V return	Input	Return
2	48 V	Output	Supply

J5 - MS1 RF generator connector - 4185030CC5 (700005368)

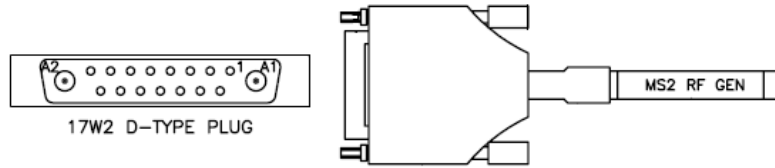
NOTE: It is not possible to measure any of these voltages inline.



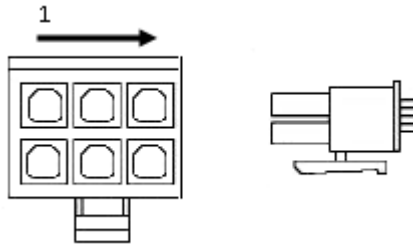
Pin	Signal	Direction	Note
1	RFDRIV1A	Input	RF1 Drive B
2	+48 V to RF generator	Input	48 V Supply
3	+48 V to RF generator	Input	48 V Supply
4	48 V return	Return	48 V Return
5	RECRF1_OUT	Output	Raw Rectified RF1 Out
6	RECRF1_RTN	Output	Raw Rectified RF1 Rtn
7	RFDRIV1B	Input	RF1 Drive A
8	RFDRIV1A	Input	RF1 Drive B
9	+48 V to RF generator	Input	48 V Supply
10	48 V return	Return	48 V Return
11	48 V return	Return	48 V Return
12	RF_TRIP_MS1	Output	5 V Trip signal MS1
13	Trip return	Input	Trip Return
14	Not connected	-	Not connected
15	RFDRIV1B	Input	RF1 Drive A
A1	DCOUT1A	Input	MS1 Resolving DC B
A2	DCOUT1B	Input	MS1 Resolving DC A

J4 - MS2 RF generator connector - 4185030CC4 (700004268)

NOTE: *It is not possible to measure any of these voltages inline.*

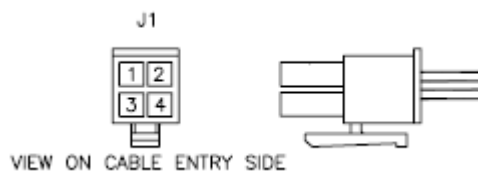


Pin	Signal	Direction	Note
1	RFDRIV2A	Input	RF2 Drive B
2	+48 V to RF generator	Input	48 V Supply
3	+48 V to RF generator	Input	48 V Supply
4	48 V return	Return	48 V Return
5	RECRF2_OUT	Output	Raw Rectified RF2 Out
6	RECRF2_RTN	Output	Raw Rectified RF2 Rtn
7	RFDRIV2B	Input	RF2 Drive A
8	RFDRIV2A	Input	RF2 Drive B
9	+48 V to RF generator	Input	48 V Supply
10	48 V return	Return	48 V Return
11	48 V return	Return	48 V Return
12	RF_TRIP_MS2	Output	5 V Trip signal MS2
13	EGND	Input	Trip Return
14	Not connected	-	Not connected
15	RFDRIV2B	Input	RF2 Drive A
A1	DCOUT2A	Input	MS2 Resolving DC B
A2	DCOUT2B	Input	MS2 Resolving DC A

J21 – Feedback connector 4300010BC1 (700005369)

This is a 6-way micro Mini-Fit connector

Pin	Signal	Direction	Note
1	+3.3V	Output	+3.3V
3	MS1 Temperature feedback	Input	-
5	MS2 Temperature feedback	Input	-
6	ground	Input	AGND

J24, J25 – Program voltage for heat transfer PCB

This is a 4-way Mini-Fit connector.

Pin	Signal	Direction
1	HEATER_SENSE-	Input
2	HEATER_SENSE+	Output
3	GATE	Input
4	NC	-

NOTE: J24 for MS1, J25 for MS2. The 24 V power for the heat transfer PCB originates from J1 of the turbo midplane PCB.

Diagnostic procedures

Readbacks can be viewed on the Tune page.

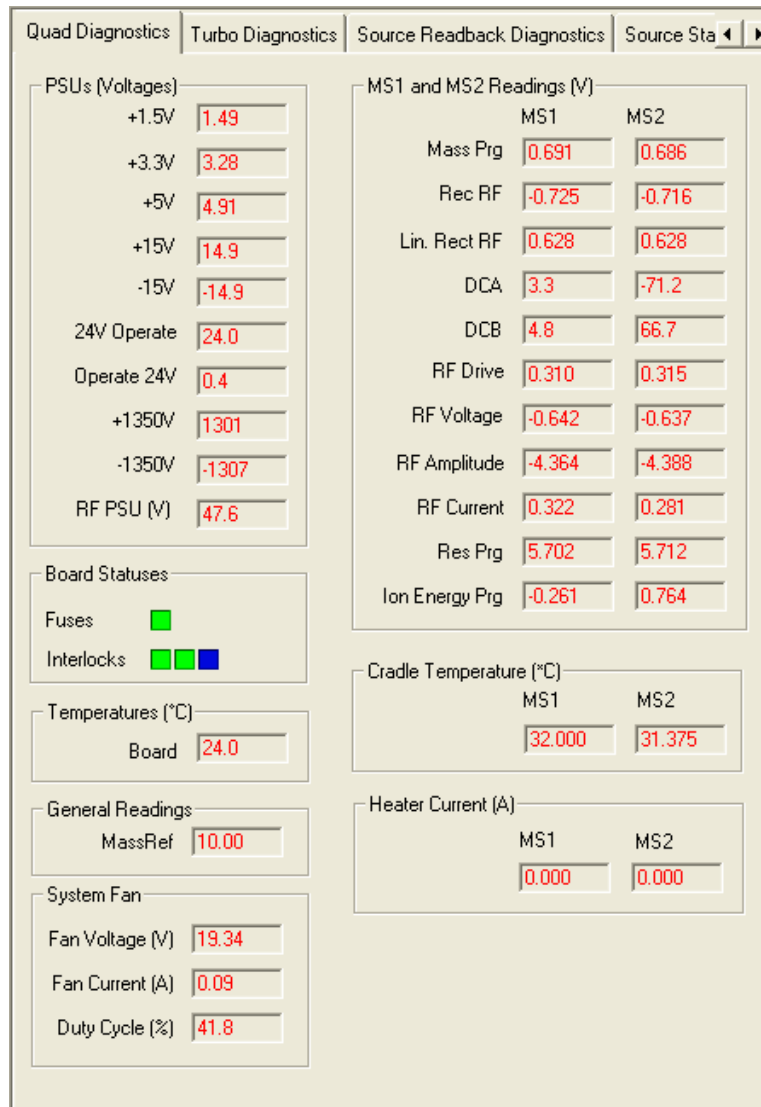


Figure 2 - Quad Diagnostics tab on the Tune page: Diagnostic readbacks

Table 1: Diagnostic readbacks

Parameter	Note	Readback	Standby	Operate
+1.5 V	Reg *** 1V5 3 A, for FPGA etc	+1.5 V	On	On
+3.3 V	Reg *** 3V3 1 A, used a normal logic supply, MCU, FPGA etc	+3.3 V	On	On
+5 V	DC/DC ***5 V 1 A, 5 V logic circuits, LED drivers etc.	+5 V	On	On
+15 V	DC/DC *** ± 15 V 0.265 A, supply for op-amp	+15 V	On	On
-15 V	DC/DC *** ± 15 V 0.265 A, supply for op-amp	-15 V	On	On
24 V Operate	24 V Operate high side switch, 24 V Operate_EXT, 24 V Operate_INT	+24 V	Off	On
Operate 24 V	24 V Operate			
RF PSU (V)	Power module for RF generator	+48 V	On	On
+1350 V	Spellman PSU on quad PCB	+1350 V	Off	On
-1350 V	Spellman PSU on quad PCB	-1350 V	Off	On
TEMP - BOARD	Temperature sensor read by MCU	** <40 °C	On	On
Mass Prg	Combined DAC signals of mass, mass function, ramp and span	0 to 10 V, linear scale	On	On
Rec RF	The return from the generator (actual rectified RF)	0 to 10 V, linear scale	Off	On
Lin. Rect RF	The rectified RF added into the mass program and the resolution/mass scale settings	0 to -10 V, linear scale	Off	On
DCA	Applied DC	0 to 1000 V, linear scale	Off	On
DCB	Applied DC	0 to 1000 V, linear scale	Off	On
RF Drive	Program voltage for RF generator	0 to 10 V, linear scale	Off	On
RF Amplitude	Control amplifier input	Used in Align (see below) -10 V in Standby	Off	On
Res Prg	= Mass x HM Res + LM Res	With MS1 HM and LM Res sliders set to 0V, 0 to -10 V, linear scale	Off	On
Ion Energy Prg	= Bias (analog input from the control PCB) + IE ramp x mass (DAC) + IE (DAC)	Readback is from the program and not a "Readback": ranges from -10 to 10 V.	On	On
Mass Ref	Used for the (start) mass DAC + mass function DAC + ramp DAC x span DAC	Must always be 10V +/- 0.01%	On	On
System Fan	Variable output dependant on cooling demand up to 48V	Fan duty cycle should increase with increased instrument temperature	On	On
Cradle Temperature	Fix at close to 32 °C	-	-	-
Heater Current	This is proportional to heater demand	-	On	On

NOTE:

** The ambient temperature is below 40 °C. If the temperature significantly increases beyond this value, the instruments cooling system and fans must be investigated.

***DC/DC conversion is used to produce the +/-15 V and 5 V supplies. The 3.3 V and 1.2 V are produced by regulating the 5 V supply.

Board status software LED on quad diagnostics

Table 2: LEDs

	Feature	Color	Meaning
Fuse	48 V RF generator fuse	Green 	OK
		Red 	Bad
Interlock LEDs	*Operate 5 V	Green 	OK
		Red 	Bad
	Vacuum	Green 	OK
		Red 	Bad
	Ion mode	Dark Blue 	Positive ion mode
		Light Blue 	Negative ion mode

NOTE: In Standby mode, only the Operate LED turns red. The 48 V RF generator fuse relates to F3, see [Figure 3](#).

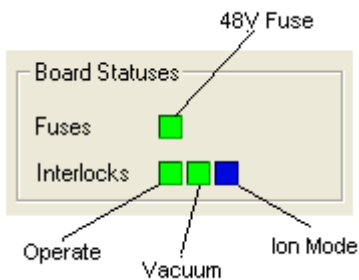


Figure 3 - Voltage routes and board fuses

Local voltages

The 48 V supply is used for the three instrument fans at the rear and is routed through for the RF generators.

The 24 V₁ is put through two DC/DC converters to produce the lower voltage supplies:

- +5 V
- +15 V
- -15 V

The +5 V voltage then generates +3V3 and +1V5.

In addition the 24 V₁ input will generate the 24 V operate_{INT} for the ± 1350 V.

Table 3: Local voltages

Fuse number	Voltage	Rating	Fuse type
F1	24 V	1.1 A	Resettable
F2	24 V	3 A	Resettable
F3	48 V	5 A	Surface mounted
F4	24 V INT	3 A	Resettable
F5	-15 V	0.5 A	Resettable
F6	+15 V	0.5 A	Resettable
F7	5 V	1.6 A	Resettable
F8	24 V EXT	5 A	Ceramic
F9	24 V	8 A	Resettable
F10	24 EXT	5 A	Surface mounted
F11	DC/DC	3 A	Resettable

PCB status

The LEDs are viewable from the front of the electronics unit. Check all LEDs with the instrument in Operate mode.

Table 4: PCB LEDs

Feature	Color	Note
POWER OK	Green 	On (green) when all rails voltages are within $\pm 5\%$. If the LED is off, check the other PCBs in the unit. If the Power OK LED is off on all PCBs it suggests a PSU failure and not the PCB.
MCU ERROR	Red 	On (red) when there is an error. Error could be caused by the dual quad PCB, check the Power OK and 24 V Operate LEDs are on. If they are not, it suggests a fault elsewhere.
HT OK	Green 	On (green) when ± 1350 V supply rails are within tolerance. If the LED is off, it could be caused by the dual quad PCB, check the Power OK and 24 V Operate LEDs are on. If they are not, it suggests a fault elsewhere.
FPGA CONFIG	Green 	On (green) when FPGA configuration is successful. If the LED is off, it could be caused by the dual quad PCB, check the Power OK and 24 V Operate LEDs are on. If they are not, it suggests a fault elsewhere.
SCAN I P	Green 	On (green) when SIP is low. Blinks continuously at the rate of the scan and ISD when MassLynx is launched. If not blinking, the most likely cause is loss of communication.
RF O/LOAD	Red 	On (red) when too high current limits the RF amplitude. The quad PCB, RF generator or the RF generator cable could cause this failure. Check link 1 is removed.
24V OP	Green 	On (green) when voltage present. If the LED is off, the cause could be due to a dual quad PCB error. If the Power OK LED is off, it suggests a fault elsewhere.

Other relevant information

Mass scale and resolution

The quadrupole circuit must be tuned and optimized to ensure that all masses across the mass range have good transmission through the quadrupole with the correct resolution. The setup of the mass scale and resolution must be checked and adjusted when ever the dual quad PCB, RF generator, or associated ion optics are changed or modified.

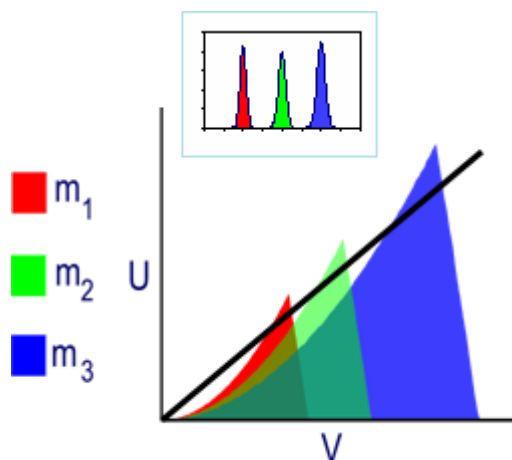


Figure 4 - U/V is the DC/RF ratio; the region of stability for the ions is above the marked line

The tuning of the mass scale and resolution is accomplished through the use of the onboard Digital to Analogue Converters (DACs) on the dual quad PCB via the following parameters, found on the Tune page Resolution tab (click **System > View** and enter the password **1147**).

- Low mass position (scale adjust)
- High mass position (scale adjust)
- Low mass resolution (LM Res)
- High mass resolution (HM Res)
- Resolution linearity
- High mass DC balance
- DC polarity

NOTE: The Xevo TQ, Xevo TQ-S, and Xevo TQ-XS, unlike previous Waters quadrupole instruments, scans the quads backwards (from high mass to low). This has no impact on the practicalities or methods by which the instrument is operated, tuned, or maintained. Refer to the [ScanWave Collision Cell Technical Reference Sheet](#) (p/n 715002816) for more detail.

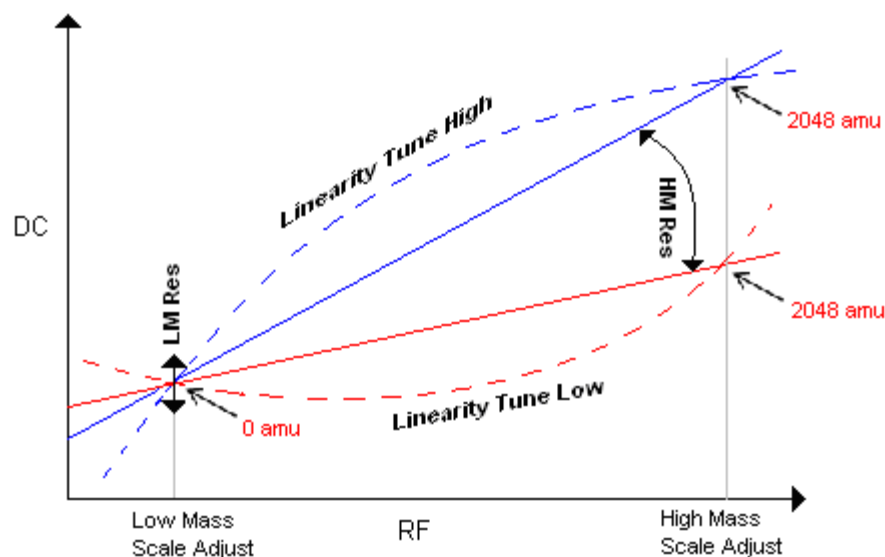


Figure 5 - Effects of the tune sliders on the stability line

The red and blue lines indicate the difference/change in the RF/DC ratio achieved by adjusting the tuning sliders within the MassLynx software. The mass program is used with the rectified RF to generate the RF drive; this signal is amplified within the RF generator to generate the RF applied to the quadrupole.

The RF drive is generated according to the difference between the mass program and the rectified RF, so that the mass program and rectified RF become the same value.

NOTE: The only time this is not the case is in Bias or Align.

The Rec RF signal is then modified by the tuning parameters on the Resolution Control tab to produce the Lin Rect RF. It is this signal that is used to generate the resolving DCs applied to the quadrupole.

The RF/DC ratio is fairly constant across the mass range and this is maintained through the use of the rectified RF feedback loop. It is the amplitude of the RF/DC ratio that governs which m/z has stable transmission through the quadrupole.

The ion energy operator tuning parameter adjusts the resolving DCs bias applied to the quadrupole rods; the polarity is opposite to the ion mode. Increasing the ion energy has the effect of increasing the potential energy gradient experienced by the ions as they travel with a corkscrew trajectory through the quadrupole. This has the effect of moving the ions more quickly through the quadrupole.

Ion energy spread test

1. Set the instrument up for MS1 ionization (no collision gas).
2. Infuse QP leucine enkephalin setup solution and open a single window of mass **1080.8 Da** with a span of **5**.
3. Set LM resolution to **3** and HM resolution to **10**.
4. Adjust the MS1 ion energy to achieve maximum intensity.
5. Reduce the ion energy until the peak intensity is **90%** of its maximum value.
6. Further reduce the ion energy until the peak intensity is **10%** of its maximum value.

NOTE: *The difference between the 90% and 10% values represents the ion energy spread.*

7. The ion energy spread for MS1 must be less than **1 V**.
8. Record the value in the record sheets.
9. Return the LM and HM resolution sliders to **3** and **15** respectively.
10. Set the beam up for MS2 (Collision gas on – Function = MS mode).
11. Use a collision gas flow rate of **0.15** for this test.
12. Repeat the ion energy spread procedure for MS2.
13. The ion energy spread for MS2 must be less than **3 V**.
14. Record the value in the record sheets.
15. Return the LM and HM resolution sliders to **3** and **15** respectively.

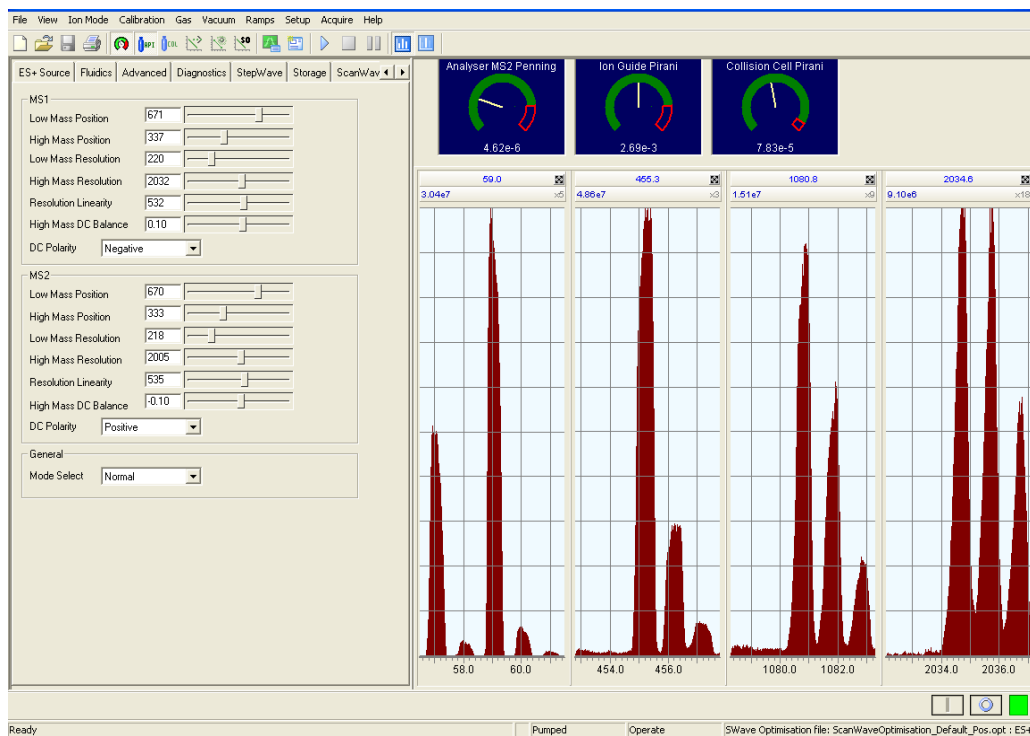


Figure 6 - Example of Xevo TQ-S setup solution MS1

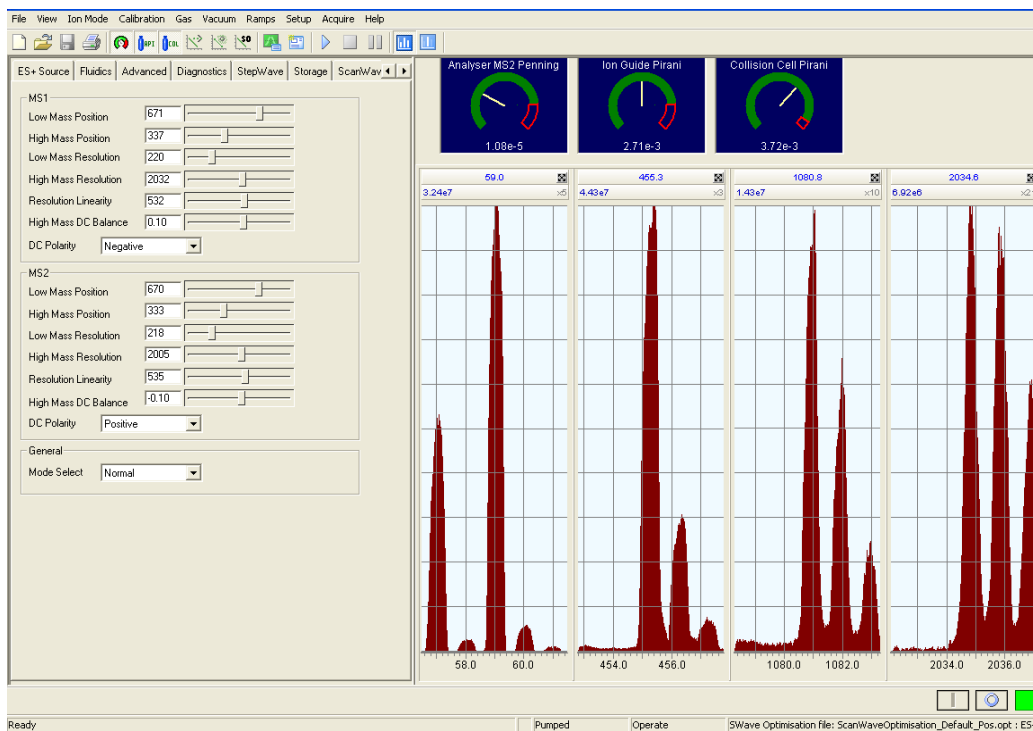


Figure 7 - Example of Xevo TQ-S setup solution MS2

Mode selection

The screenshot shows a software interface for mode selection. At the top, there are tabs: ES+ Source, Fluidics, Advanced, Diagnostics, StepWave, Storage, and ScanWav. The 'Advanced' tab is selected. Below the tabs, there are two main sections: MS1 and MS2. Each section contains several parameters with numerical input fields and sliders. The 'General' section at the bottom is highlighted with a red box and contains a 'Mode Select' dropdown menu set to 'Normal'.

MS1 Settings:

- Low Mass Position: 671
- High Mass Position: 337
- Low Mass Resolution: 220
- High Mass Resolution: 2032
- Resolution Linearity: 532
- High Mass DC Balance: 0.10
- DC Polarity: Negative

MS2 Settings:

- Low Mass Position: 670
- High Mass Position: 333
- Low Mass Resolution: 218
- High Mass Resolution: 2005
- Resolution Linearity: 535
- High Mass DC Balance: -0.10
- DC Polarity: Positive

General Settings:

- Mode Select: Normal

Figure 8 - Mode selection

Use the Mode Select option on the Tune page Resolution tab to select one of the following modes.

Table 5: Mode selection options

Mode	Function
Normal	RF and DC change according to mass program.
Bias	RF and DC voltages are off, and a small voltage applied to the FET(s). The amplifier circuit containing the FETs are optimized and balanced by setting the bias voltage. The bias voltage is preset. The RF current must not exceed 635 mA when the instrument is set to bias mode. If this value differs significantly then it suggests that the FETs within the RF generator are at fault.
Align	Fixed drive program is applied. See the RF Generator Technical Reference Sheet (p/n 715002749) for a detailed explanation of how to align the RF generator.

Rec RF and Lin. Rect RF readback explanation

The mass program is used to drive the RF generator circuits; RFINA and RFINB from the dual quad PCB are used to drive each phase of the RF generated. These inputs are power amplified to produce the RF applied to the quadrupole.

The rectified RF readback (Rec RF) is generated inside the RF generator from the raw RF voltage applied to the quadrupole. The RF is sampled with the air capacitors and then undergoes AC to DC conversion using a bridge rectifier.

The rectified RF voltage is sent back to the dual quad PCB and is used to generate the resolving DC voltage applied to the quad. The RF:DC ratio is maintained by the rectified RF feedback loop, so the RF:DC ratio is relatively constant across the mass range for constant resolution.

Table 6: Readback parameters

Parameter	Note
LM Resolution	DC offset from RF
HM Resolution	RF/DC ratio
Ion Energy	Quadrupole DC bias, polarity is the opposite to the ion mode

The resolution and mass position sliders on the Tune page Resolution tab modulate the rectified RF very slightly. This signal can be monitored using the Lin. Rect RF readback on the Quad Diagnostics tab. The Lin. Rect RF signal is used to generate the resolving DC applied to the quadrupole. The ion energy parameter is used to bias the resolving DCs applied to the rods; the polarity is opposite to the ion mode.

When acquiring, the displayed rectified RF on the Quadrupole tab does not change or ramp with the scan time. The readbacks are updated during the inter scan delay.

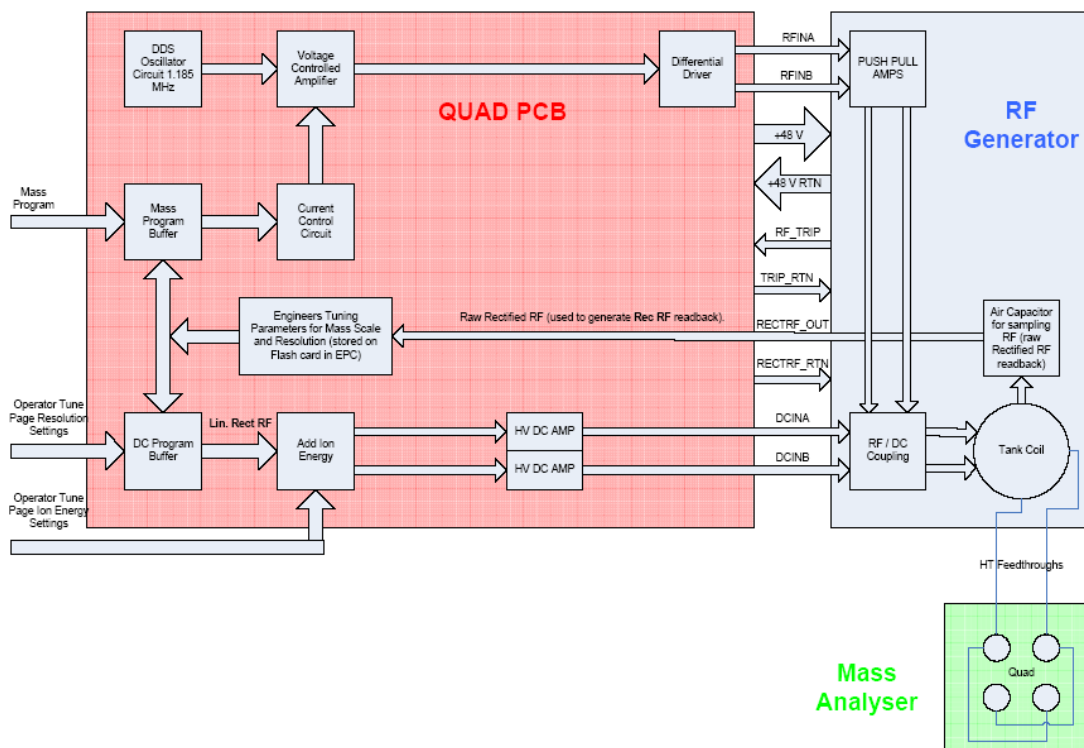


Figure 9 - Relationship between the quadrupole, RF generator, and dual quad PCB

The unit requires a two phase balanced inputs (RFINA and RFINB, also known as RF Drive A and RF Drive B) that are proportional to the RF output produced. The operating frequency of the RF generator is 1.185 MHz, produced in the quad PCB by a DDS oscillator circuit, see Figure 9.

This input is power amplified and applied to the RF coil, forming a series tuned circuit and boosting the RF voltage up to the required output. This is possible because the quadrupole load is capacitive, and its reactive power requirement is provided by the coil inductance. Once the generator is fitted to the instrument, fine-tuning of the coil inductance is necessary. This is achieved using moving iron powder cores in the center of the coil and is known as the align procedure. The RF generator only needs to be aligned when the RF generator or quadrupole is replaced; each circuit is slightly different and needs to be tuned accordingly. As the quadrupole gets dirty through use these tuning parameters will not be affected.

The DC output is added to the RF using a low pass LC filter network. Since the output load is purely capacitive, in steady state conditions the DC output equals the DC input.

The RF output amplitude is sampled using an air spaced capacitor, then rectified, filtered and made available as a feedback signal for the quad PCB. A closed loop system results from the action of the control electronics, so that the stability of the generator is dependent on this feedback signal.

The generator connects to the control electronics/power amplifier via a single cable containing analog high voltage signals, RF signals, and power supplies.

Combined, the coil compartment and power amplifier dissipate 150 W or more at full output, and require forced air-cooling. Temperature variations within the generator must be kept to a minimum to ensure that mass stability specifications are met.

Potential energy explanation

The Xevo TQ, Xevo TQ-S, and Xevo TQ-XS are not configured the same way as the previous tandem quadrupole instruments. The legacy products applied the collision energy to the collision cell and everything after it resulting in the collision energy being applied to the entrance, exit, MS2 prefilters and MS2 DCs.

The Xevo TQ, Xevo TQ-S, and Xevo TQ-XS apply the collision energy to the front of the instrument before the collision cell. The collision cell remains at ground potential and the collision energy is added to the MS1 DCs, MS1 prefilters, step wave including differential apertures, sample cone and capillary.

Removing the dual quad PCB

CAUTION: *Follow suitable antistatic precautions at all times. Ensure the instrument electronics are switched off before removing/installing this PCB.*

There are hot components on the dual quad PCB when in Operate mode. To avoid burns allow time to cool before removing the PCB.

1. Flip the pump override toggle switch at the rear of the power distribution unit into the override (down) position.
2. Switch off the instrument electronics and ensure that all the PCB LEDs are off.
3. Remove all the cables that either block access to the quad PCB, or are connected to it.
4. Simultaneously press the red tabs of the card ejector clips on either side of the board, and swing the ejector clips outwards (Figure 10).
5. Gently pull out the PCB to remove.



Figure 10 - Card ejector

Installing the quad PCB

NOTE: *The quad PCB fits into the third rail slot within the electronics unit.*

CAUTION: *To avoid damage to the loom wiring, do not trap any of the wiring when fitting the PCB into the electronics unit.*

1. Align the sides of the PCB with the red spacer supports at either side.
2. Slowly insert the PCB and guide and lock into place with the card ejector clips.
3. Reconnect all the cables.
4. Turn on the instrument electronics and wait for comms to be established.
5. Once the comms have been established and verified by checking the Tune page then turn the override switch to the auto position.

Testing after replacing the quad PCB

Perform the following checks if the lens control enhanced PCB is replaced:

1. Ensure that communications are established.
2. Run the MS SWAT software to ensure the PCB firmware is current.

NOTE: *Refer to the service notes database for the latest information.*

3. Ensure that the mass scale and resolution is setup within specification, as described in the relevant installation manual:
 - [Xevo TQ MS Installation Manual](#) (p/n 715001890)
 - [Xevo TQ-S Installation Manual](#) (p/n 715002461)
 - [Xevo TQ-XS Installation Manual](#) (p/n 715005249)

NOTE: *Complete the RF align setup and the RF run as described in the [RF Generator Technical Reference Sheet](#) (p/n 715002749).*