

Feb 2012



## **Q-Switch Driver**

**Including: AOQ Alignment**

### **Instruction Manual AQS1000 Series, rev 5**

Models -

AQS1004-FC-x	: 4W output
AQS1010-FC-x	: 10W output
AQS1050-FC-x	: 50W output
AQS1080-FC-x	: 80W output

where:

-FC indicates AOQ Frequency

'-x' indicates options

A	:	Fan
W	:	Water cooled

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## 1. GENERAL

The AQS driver is a combined waveform generator, RF oscillator, and power amplifier in a single compact unit.

This driver features Isomet's "Soft-Start" RF amplitude control. The Soft-Start technique applies a mix of digital and analog modulation signals to control the RF amplitude. Almost any envelope or ramp shape can be programmed.

Output timing and pulse widths can be controlled either by an internal PLL based waveform generator or from a user supplied external signal source.

The driver incorporates opto-isolated digital I/O signals and output protection.

This includes:

- load mismatch / poor VSWR detection \*
- driver temperature interlock
- DC supply over-voltage clamp.
- An external interlock (e.g. for connection to the AO device thermal switch)

The AQS1004, AQS1050 and AQS1080 will operate from a +24V to +28Vdc supply.

**The AQS1010 operates from a +15V dc supply.**

Output status bits are supplemented by LED's. These indicate the operating condition of the driver and associated Q-switch. The maximum RF output power is adjusted by means of a pre-set potentiometer.

\* Not available on AQS1004 series.



1.1 MODEL SELECTION

		<b>Freq</b>		<b>Option</b>		<b>Q-Switch</b>
<b>AQS1080</b>	-	<b>FC</b>	-	<b>x</b>		
24.0MHz		<b>24</b>		<b>A</b>	Air cooled	<b>Q1083 series</b>
27.12MHz		<b>27</b>		<b>W</b>	Water cooled	
40.68MHz		<b>40</b>				
<b>AQS1050</b>	-	<b>FC</b>	-	<b>x</b>		
24.0MHz		<b>24</b>		<b>A</b>	Air cooled	<b>Q1083 series</b>
27.12MHz		<b>27</b>		<b>W</b>	Water cooled	
40.68MHz		<b>40</b>				
<b>AQS1010</b>	-	<b>FC</b>	-	<b>x</b>		
24.0MHz		<b>24</b>				<b>Q1087 series</b> <b>Q1119 series</b> <b>Q1123 series</b> <b>Q1133 series</b>
27.12MHz		<b>27</b>				
40.68MHz		<b>40</b>				
80.0MHz		<b>80</b>				
<b>AQS1004</b>	-	<b>FC</b>				
24.0MHz		<b>24</b>				<b>Q978 series</b> <b>Q1080 series</b>
27.12MHz		<b>27</b>				
40.68MHz		<b>40</b>				
80.0MHz		<b>80</b>				

## 2. DESCRIPTION

Figure 1 (page 19) shows the driver, fitted with the fan cover option A and the mounting hole locations. For all models, please ensure a free air flow over the heat sink.

A driver schematic is given in Figure 2. The digital modulation signals and the analog slope signal are combined in a high speed op-amp A1. This op amp controls the RF amplitude via a double balanced mixer. The RF centre frequency is derived from a crystal controlled oscillator(s).

The maximum RF power is adjusted by a pre-set potentiometer, PWR ADJ. This feeds the input to the power amplifier stage.

Figure 3 shows the connection table and typical alignment set-up

Figure 4 describes the fundamental equations for AOQ switch operating in the Bragg regime.

There are a variety of operating modes available with AQS range of drivers.

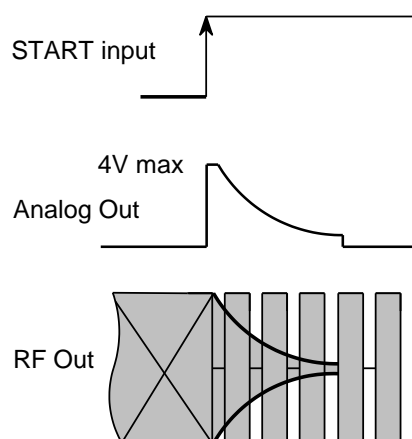
Signals to control the modulation parameters of the RF can be internally generated or applied from an external source.

The first step is to decide on your required mode of operation and configure the control connector pin connections accordingly.

### Analog Input/Output

The ANALOG input defines the depth of the RF “Off” modulation. Typically this is connected to the ANALOG output of the driver. However if desired, the user can apply an alternative external signal to this Analog input. Note: 0.0V = Maximum modulation depth, 4.0V = Minimum Modulation depth

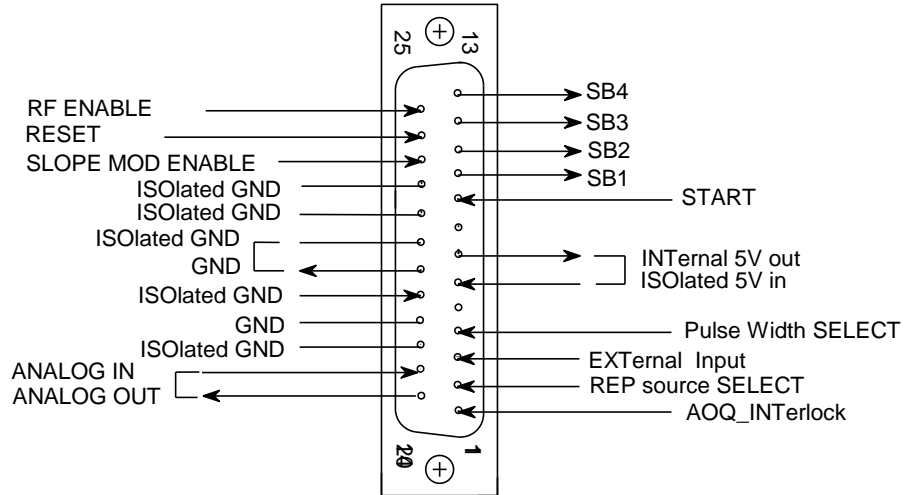
Typical driver generated signals shown =below



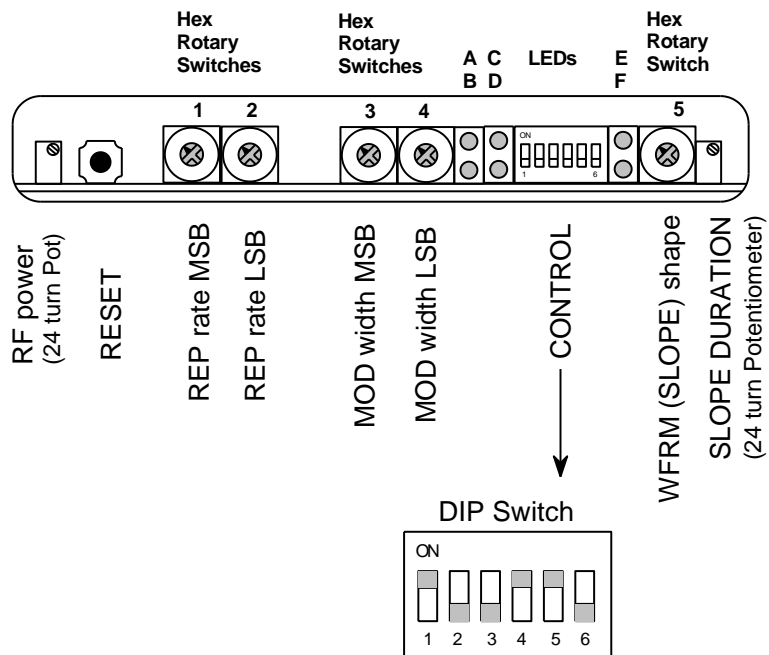
3. CONNECTIONS AND CONTROLS DETAILS

3.1 Control connector pin assignments

CONTROL : 25WAY D type SOCKET (Female)



3.2 User Driver Controls





### 3.3 DIP switch functions

	<u>UP</u>	<u>DOWN</u>
SW1	<b>RF On</b>	RF Off
SW2	CW RF	<b>Modulated RF</b>
SW3	<b>Base Rep_rate</b>	Rep_rate / 5
SW4	<b>Base Rep_rate</b>	Rep_rate / 15
SW5	SLOPE Duration x10	<b>Base Timing</b>
SW6	-	-

(UP position marked as “ON” at the DIP switch)

Default settings in **Bold**

SW1 DOWN will turn the RF output OFF, regardless of other settings.

SW2 UP will force the driver to output a constant (CW) RF power regardless of the modulation inputs. This can be used to force the AOQ on and thus the laser output to zero.

SW3 and SW4 divide the rep-rate frequency (See section 4.2)

SW5 increases the SLOPE duration by 10x (See section 4.1)

SW6 no used.

### 3.4 Supply Connections

<u>Model</u>	<u>DC Supply</u>
AQS1004-FC	: 24Vdc or 28Vdc , < 1A
AQS1004-FC	: 15Vdc , < 2A
AQS1050-FC	: 24Vdc or 28Vdc , < 5.5A
AQS1080-FC	: 24Vdc or 28Vdc , < 8A

**The center pin of filtered DC feed through solder connection is positive**

All drivers feature opto-isolated digital I/O interface.

A separate 5Vdc power needs to be applied to the 25way D-type.

- Input isolated 5Vdc – pin6
- Input isolated 0Vdc – pin20

**Note:**

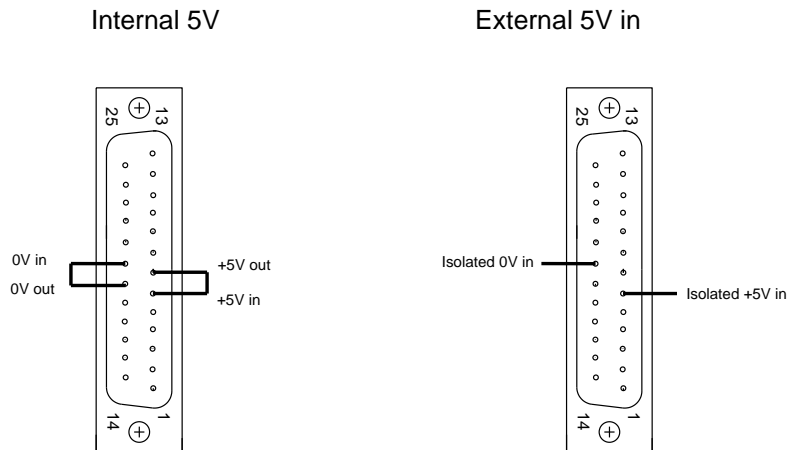
The Reset is designed for use with a remote relay contact switch. It is not opto-isolated in the driver.

For those not requiring complete isolation, a 5Vdc output is provided on the AQS driver D-type.

This output can be linked to the isolated DC input pins above, to avoid the need for a separate isolated 5Vdc supply.

- Output 5Vdc – pin7
- Output 0Vdc – pin19

Figure below illustrates the connection options



#### 4.0 FUNCTION OF THE START INPUT AND WAVEFORM SLOPE

The START input allows the user to define the active modulation of the RF output.

The “Soft start” function helps to quench the leading giant output pulse(s) when Q-switching of the laser is initiated.

This quenching is achieved using a slope waveform. This generates a controlled and gradual decrease in RF power ( i.e. ramped increase in modulation depth) at the start of Q-switching .

The driver contains up to 16 slopes with different shapes and slope rates. These are programmed at the time of manufacture into EEPROM memory. (Custom specific slopes are available).

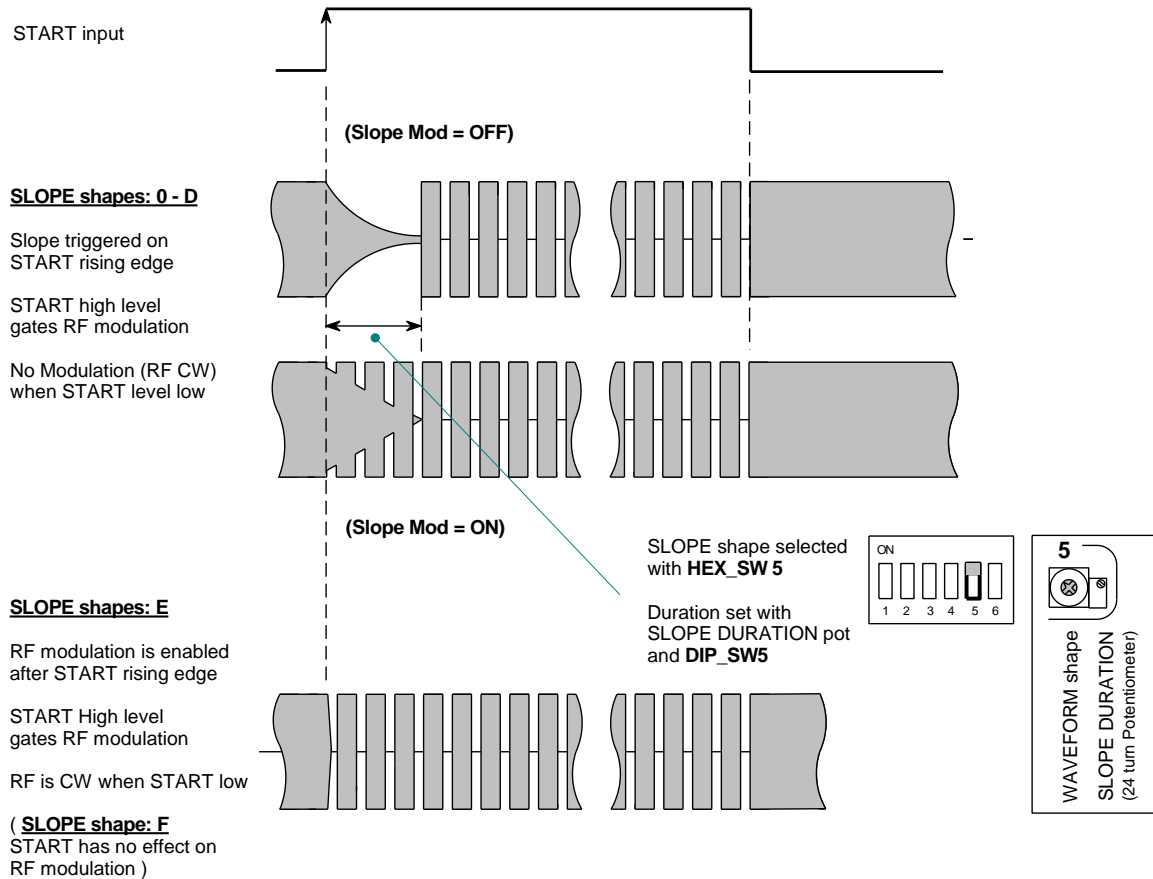
The driver is typically supplied with 12 waveform slopes and 2 non-slope waveforms.

If the START input is held at a HIGH level or not connected when DC power is applied, the RF driver will generate a single START pulse internally at around 1 sec after power-on. This will cause the driver to output the selected RF ramp and then output modulated RF. The modulated RF characteristics will depend on the Rep-Rate trigger source and set-up (see 4.2). This output will continue until the START input is taken LOW or DC power is removed.\*

If the START input is LOW when DC power is applied, the RF driver will generate CW, un-modulated RF power\* .

(\* Except external modulation mode described in section 5.3)

The diagram below shows three examples and illustrates the function of the externally applied START input signal. The START input is internally synchronized to the Q-switch (RF modulation) repetition rate.



The shape of the slope is selected by the WFRM Hex rotary Switch (HEX\_SW 5)

The gradient of the slope is set the SLOPE DURATION multi-turn pot (far right hand side) and the x10 range multiplier option on DIP-SW 5,

The slope start is also synchronized to the Q-switch repetition rate. The end of the slope is not synchronized directly and the slope duration will require adjusting to achieve the desired end point of the slope relative to the (RF) Q-switch modulation

**SLOPE Shapes E and F will not provide a “soft-start” of the RF modulation depth.**

**There will be no First pulse quenching of the laser output in these cases.**

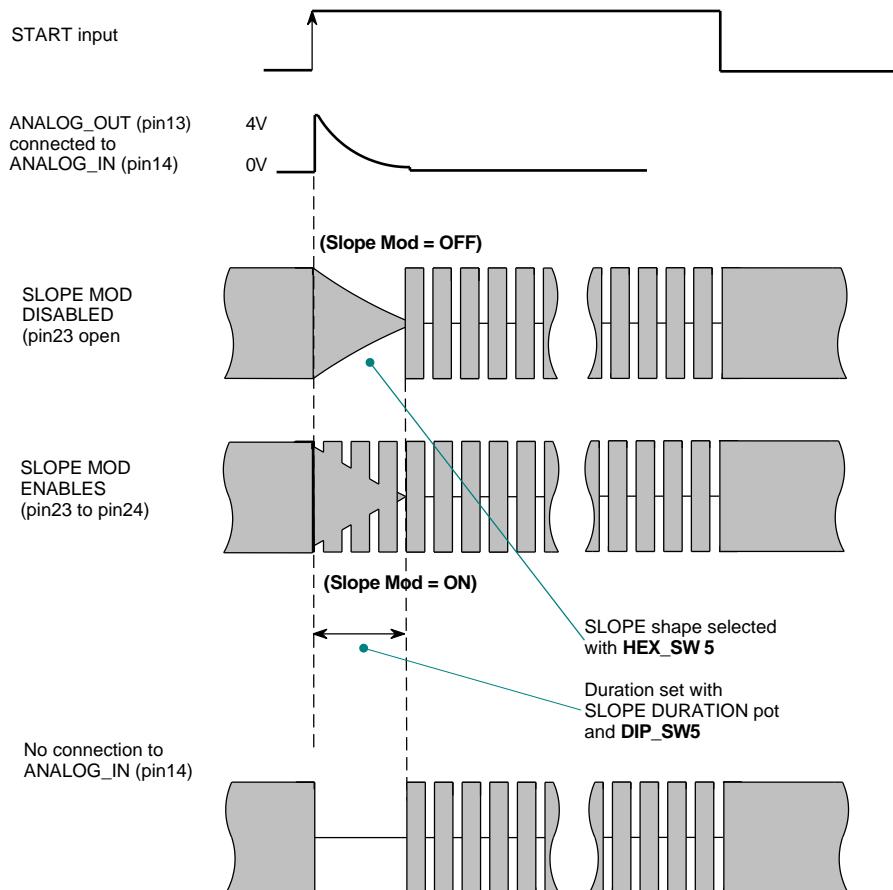


#### 4.1 WFRM SLOPE Specifications

<u>Hex SW 5 Position</u>	<u>Slope shape</u>	<u>Duration</u> Multi-Turn Pot adjustment range (DIP-SW 5 <b>DOWN</b> )
0	Curve-Linear	280usec - 1.78msec
1	Curve-Linear	70usec - 448usec
2	Curve-Linear	17usec - 112usec
3	<i>Offset Exponential</i>	<i>72usec - 448usec</i>
4	Exponential	91usec - 448usec
5	Cosine	91usec - 448usec
6	Exponential	34usec - 220usec
7	Linear	17usec - 112usec
8	Linear	72usec - 448usec
9	Linear	280usec - 1.78msec
A	Cosine	280usec - 1.78msec
B	Cosine	70usec - 448usec
C	Cosine	17usec - 112usec
D	DC	No modulation
<b>E</b>	<b>MINIMAL</b>	<b>&lt;10usec initial fall time, modulation gated with START</b>
F	None	(No START input required)

Durations are x10 longer with the Control DIP-SW 5 **UP**

During the “Soft Start” slope, RF modulation can be enabled using the SLOPE MOD input pin-23 on the 25way D-type. See figure below:





#### 4.2 SETTING THE INTERNAL REP-RATE CONTROL

This is based a PLL controlled oscillator. The internal rep-rate set by HEX-SW 1 and 2

Output rate is further scaled by DIP-SW 3 and 4

- SW 3 **UP** and SW 4 **UP** : Rep-rate increments in 0.5KHz steps
- SW 3 **DOWN** and SW 4 **UP** : Rep-rate increments in 0.1KHz steps
- SW 3 **UP** and SW 4 **DOWN** : Rep-rate Increments in 0.033KHz steps

Examples:

<u>DIP Switches</u>	<u>Hex Switch</u>	<u>Rep- Rate</u>	
Range setting	SW1 / SW2	KHz	
SW3 UP / SW4 Down	F 2	1.0	Minimum stable rate for this range
	C 4	2.0	
	A 6	3.0	
	8 8	4.0	
	6 A	5.0	
	4 C	6.0	
SW3 DOWN / SW4 UP	2 E	7.0	Minimum stable rate for this range
	B 0	8.0	
	9 C	10.0	
	8 7	12.0	
	7 4	14.0	
	6 0	16.0	
	4 C	18.0	
SW3 UP / SW4 UP	3 8	20.0	Minimum stable rate for this range
	D C	18.0	
	D 8	20.0	
	9 C	50.0	
	3 8	100.0	
	1 0	120.0	Maximum stable rate



#### 4.3 SETTING THE INTERNAL PULSE WIDTH CONTROL

Based on a precision digital counter. Resolution = 61nsec steps.  
 Pulse width set by HEX-SW 3 and 4. Minimum pulse width = 1usec.

The RF OFF pulse width can be calculated from:

$$\text{Pulse Width (us)} = (255-N) \cdot 0.061 + 1$$

where N is the decimal value of Hex SW\_3 (MSB) and SW\_4 .

Examples:

	<u>Hex Switch</u>		<u>Pulse Width</u>
	SW3 / SW4	N (Dec)	usec
(Minimum width)	F F	255	1.0
	E E	238	2.0
	C E	206	4.0
	6 B	107	10.0
(Max width)	0 0	0	16.6

#### 5.0 OPERATING MODES

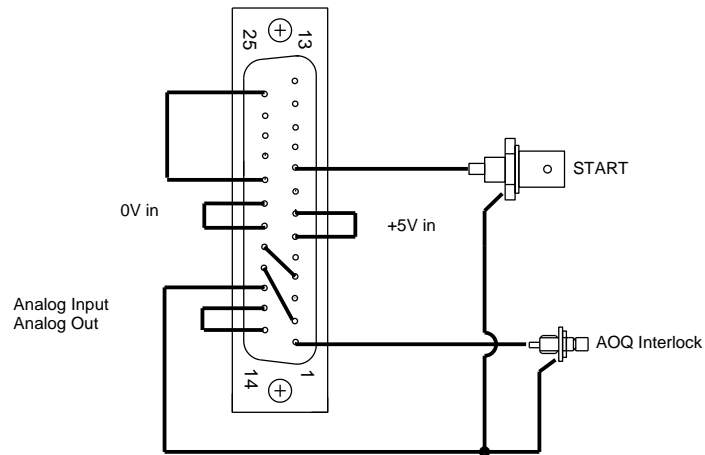
##### Pulse repetition rate and Modulation Pulse width.

There are three modes of operation, determined by the wiring of the 25way D-type.(25D)

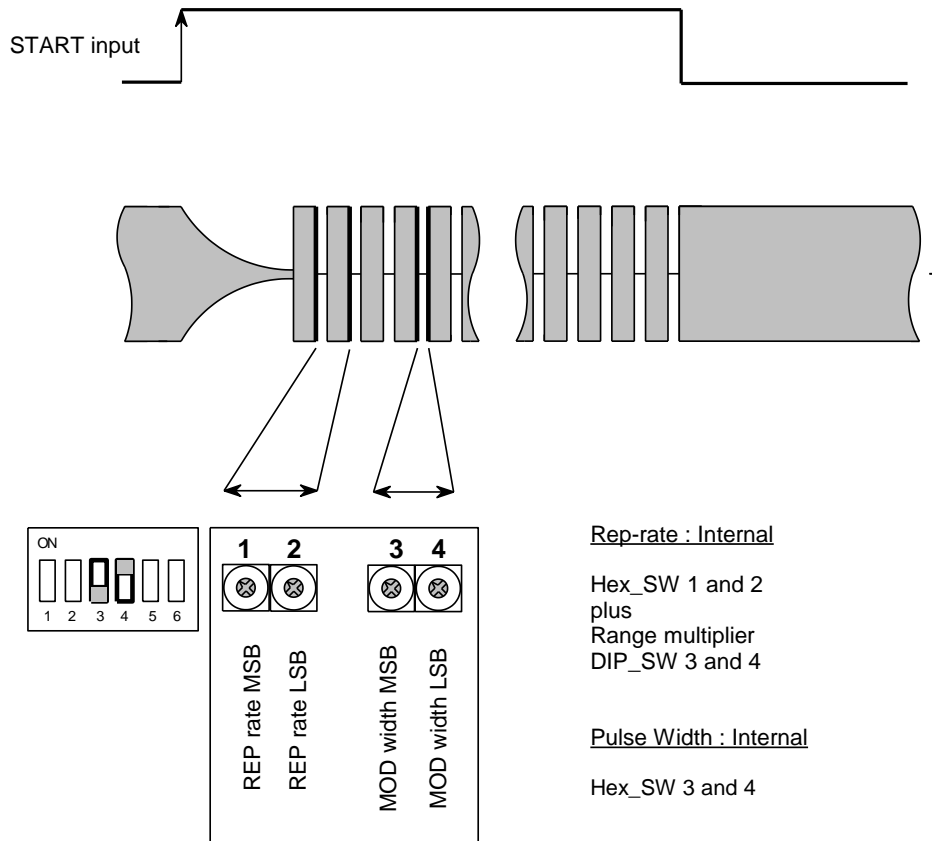
- 5.1 Rep rate and Pulse width generated internally
- 5.2 Rep rate defined by an external input and Pulse width generated internally
- 5.3 Rep rate and Pulse width defined by a single external input

<u>Configuration</u>	<u>25D conn Mode Selection</u>		<u>Control Source</u>	
	<u>Rep-rate pn2</u>	<u>Puls Wid pn4</u>	<u>Rep Rate</u>	<u>Modulation Pulse Width</u>
5.1	Low	Low	Internal, HEX_SW 1 & 2	Internal, HEX_SW 3 & 4
<i>Not Valid</i>	<i>Low</i>	<i>High (NC)</i>	<i>Internal, HEX_SW 1 &amp; 2</i>	<i>Unknown Duty Cycle</i>
5.2	High (NC)	Low	External, (25D_pn3)	Internal, HEX_SW 3 & 4
5.3	High (NC)	High (NC)	External, (25D_pn3)	External, (25D_pn3)

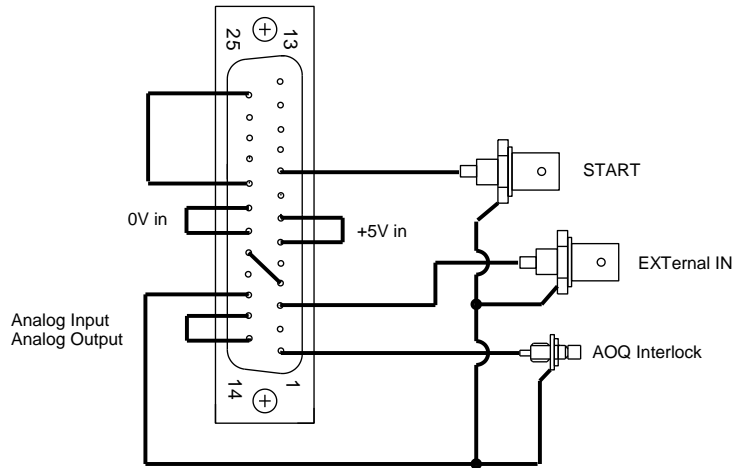
5.1 REP RATE AND PULSE WIDTH GENERATED INTERNALLY



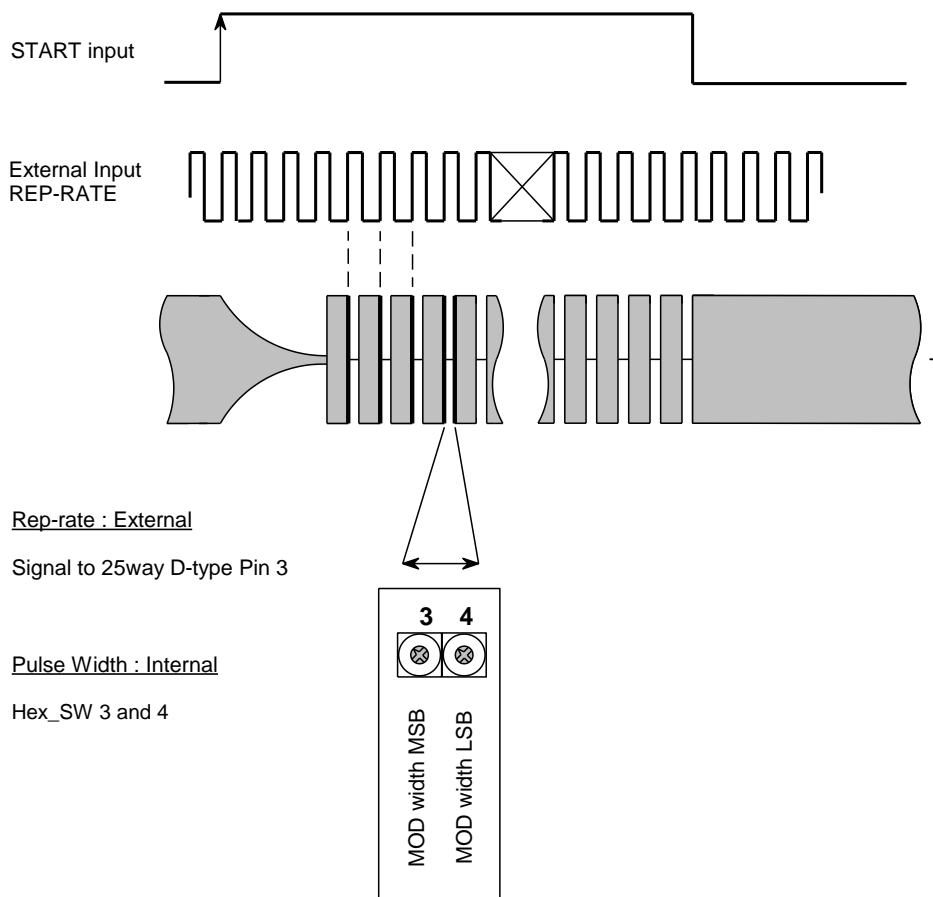
(As shown, the 5V DC supply for the opto-isolated input circuitry is provided from the driver. Thus the input signals are not truly isolated.)



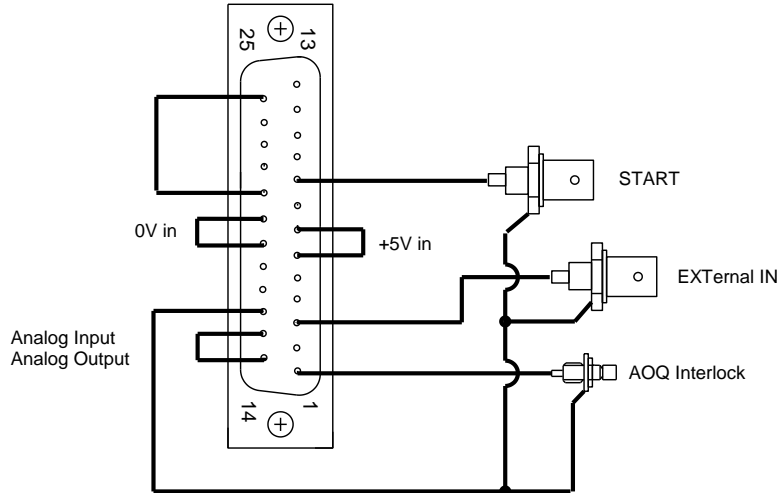
5.2 REP RATE DEFINED BY AN EXTERNAL INPUT  
PULSE WIDTH GENERATED INTERNALLY



(As shown, the 5V DC supply for the opto-isolated input circuitry is externally provided. Thus the input signals are isolated.)

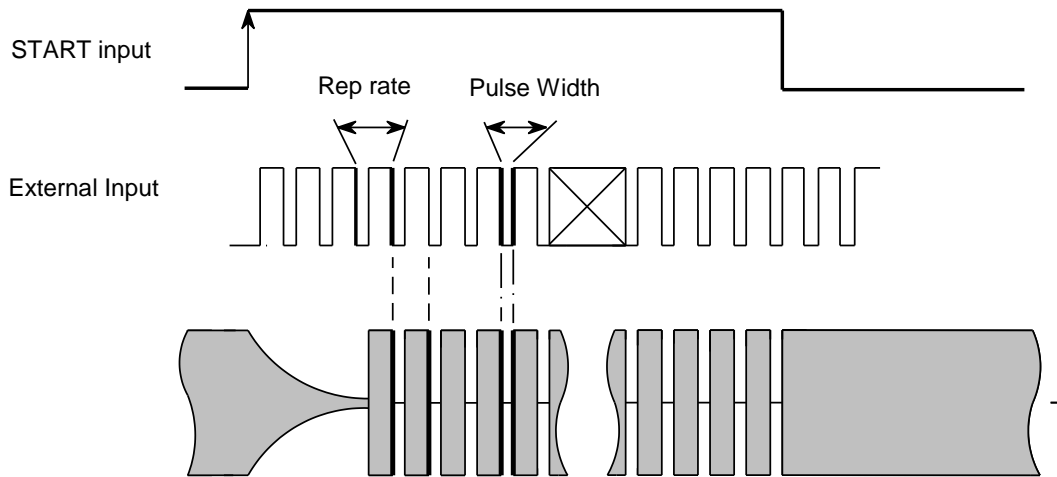


### 5.3 REP RATE AND PULSE WIDTH DEFINED BY A SINGLE EXTERNAL INPUT



(As shown, the 5V DC supply for the opto-isolated input circuitry is externally provided. Thus the input signals are isolated.)

The RF is modulated “OFF” when the external digital input is low. The duration and repetition rate are both defined by the externally applied input signal.

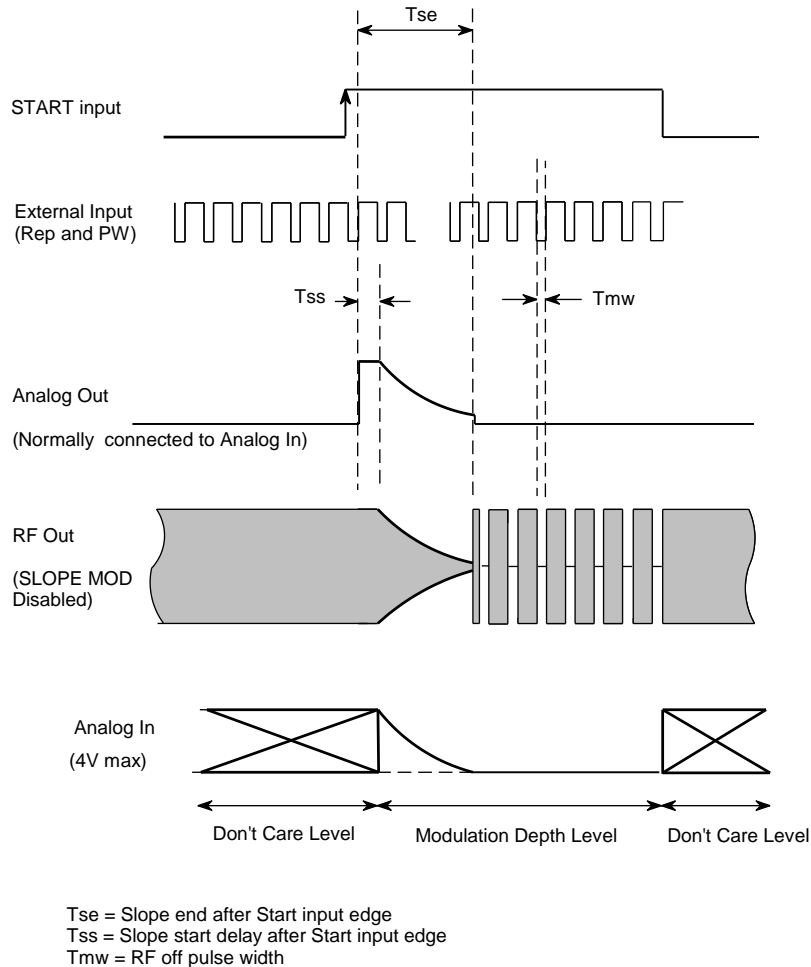


Rep-rate : External  
+  
Pulse Width : External

Signal to 25way D-type Pin 3

## 5.4 EXTERNAL INPUT TIMING AND ANALOG I/O

External signals are influenced by the drivers internal control logic.



**Tse** = time to slope end

RF modulation starts after this period  $T_{se}$ , as shown in the diagram. This duration depends on the settings of DIP\_SW5, HEX\_SW5 and the SLOPE DURATION adjustment pot.

**This delay applies even when an external slope voltage is applied to the ANALOG IN**

(Normally there is no requirement for the user to generate an external slope voltage for first pulse killing. The ANALOG OUT should be directly connected to ANALOG IN).

**Tss** = slope start delay. This also depends on DIP\_SW5 setting,

DIP\_SW5 UP,  $T_{ss} = 4.2\mu\text{sec}$  minimum

DIP\_SW5 DOWN,  $T_{ss} = 42.0\mu\text{sec}$  minimum

**Tmw** = "Off" modulation pulse width. This period only depends on the external input low period.



6.0 FAULT INDICATION, STATUS BITS AND LED'S

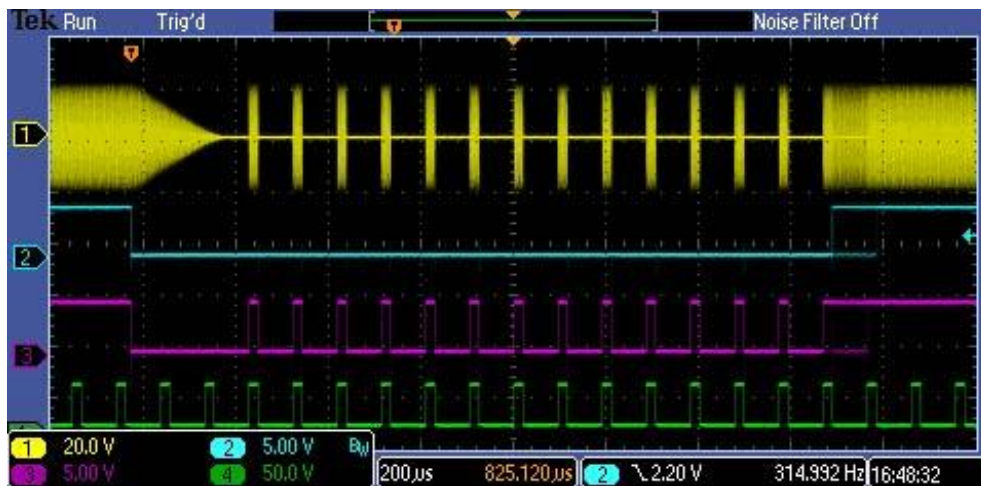
6.1 Viewing timing and pulse width of modulation signals.

Test signals are available on SB3 (pin 12) and SB4 (pin 13)

SB3 is the inverted START input signal, synchronized to the Repetition rate (Internal or External)

SB4 is a composite TTL waveform combining the SLOPE DURATION and the REP RATE pulse train

These signals can be used to view the modulation of the RF output and set the slope end point timing. The plot below illustrates. In this example the driver is configured for both external repetition rate and external pulse width control.



Trace 1: RF output                      Trace 2: SB3  
Trace 3: SB4                              Trace 4: External input

6.2 Fault Status Bits

Status bits are available on the 25way D-type connector and supplemented using LED indicators. All signals are opto-isolated TTL . **Faults signals are prioritized**

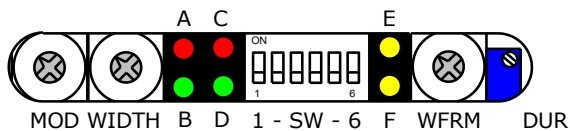
Fault	LED				LED		Status Bit	
	A (SB2)	B	C (SB1)	D	E (AO_INT)	F (RF_En)	SB1 Pin10	SB2 Pin11
No Fault (START input Low) (START input High)		- G		- G	Y	Y	H	H
Low Forward Power			R		Y	Y	L	H
Amplifier Temp Interlock	R		R		Y		L	L
AOQ Temp Interlock	R		R		Y	Y	L	L
High Reverse Power	R				Y	Y	H	L

LED code : R = Red illuminated , G = Green illuminated, Y = Yellow illuminated



In addition to the Fault signals, two further LEDS indicate operation of the driver

LED E : ON when AOQ (normally closed) Interlock is OK  
 LED F : Normally ON = RF Enabled



### 6.3 Interlocks

The thermal interlock input (pn1) on the 25way D-type needs to be connected to the AOQ thermal switch or connected to 0V at the 25way D-type connector.

Over temperature is a non latching condition. The driver will self reset if the thermal interlock cools to valid state following an over-temperature fault. i.e. switch from non-valid (open contact, over temperature state) to a valid (normally closed contact ) condition.

### 6.4 VSWR Indication (Not available on AQS1004 series)

- Low Forward power

The Driver will generate a **Low Forward Power** fault signal if the transmitted RF output power falls below approximately 50% of the maximum driver RF power.

There is no effect on the driver operation.

- High reverse power.

The Driver will output a **High Reverse Power** fault signal if the reflected RF power from the AOQ exceeds approximately 10% of the maximum driver RF forward power.

This fault is latching and the driver is disabled (RF power will be at zero).

This fault will also occur if the RF connection between the AOQ and driver is broken.

Once the fault condition is corrected, it will be necessary to reset the driver.

- 1: Turn the DC power OFF and ON or
- 2: Press RESET button on driver or
- 3: Close contact on pin 24 to 0V on 25way D-type.



## 7. INSTALLATION AND ADJUSTMENT

The required RF modulation Pulse Width, WFRM shape and SLOPE duration are a function of the laser cavity gain and operating parameters. The procedure below outlines one technique for aligning the AOQ and setting the optimum RF drive power.

- 7.1 If applicable connect cooling water to the Q-switch at a flow not less than 0.5 litres/minute at < 27 deg.C.

Due to the high RF power dissipated in the water cooled AOQ switches, it is paramount that the AOQ is operated only when water cooling is circulating.

- 7.2 With no d-c power applied, connect the positive DC supply to the centre terminal of the feed-thru terminal. DO NOT APPLY POWER.

- 7.3 Connect the BNC RF output to the acousto-optic Q-switch (or a 50Ω RF load, if it is desired to measure the RF output power).

- 7.4 If applicable connect the Interlock of the acousto-optic Q-switch to the enable input (pn1) on the 25-pin D-type connector of the AQS driver.

If the temperature of the modulator exceeds 32°C or the internal driver temperature exceeds 70°C then the interlock connection becomes open circuit, disabling the RF output. An LED indicator illuminates when the Interlocks are closed and the RF is enabled. (see 6.3).

If there is no Interlock on the AO Q-switch, connect the AQS interlock inputs to 0V.

- 7.5 Adjustment of the RF output power is best done with amplifier connected to the acousto-optic Q-switch. The Amplifier maximum output power is factory preset to approx 2/3rds maximum output.

The optimum RF power level required for sufficient hold-off and stable Q-switch operation will depend on the laser cavity design and gain parameters. Applying RF power in excess of this optimum level may cause undesired thermal loading and possible unstable laser behaviour. It is therefore recommended that initial alignment be performed at a low RF power level.

- 7.6 Locate the PWR ADJ on the driver .

With an insulated alignment tool or screwdriver rotate the PWR ADJ potentiometer fully anti-clockwise (CCW) i.e. OFF, then clockwise (CW) approx 12 – 16 turns.



7.7 Apply DC to the amplifier.

7.8 Apply a constant RF power to the AOQ by placing SW2 of the DIP switch in the UP position.

7.9 Align the laser beam toward the centre of (either) aperture of the AOQ. Refer to AOQ data sheet. Ensure the polarization is correct for the AOQ being used. Adjust the beam height so that it is central to the active aperture height of the AOQ.

7.10 Start with the laser beam normal to the input optical face of the AOQ and very slowly rotate the AOQ (either direction). See Figure 4 for one possible configuration.

Observe the CW laser output (= the undeflected zeroth order beam from the AOQ). Adjust the AOQ Bragg angle (rotate the device) to minimize the laser output beam intensity.

If no extinction is observed check the RF driver is operating and applying a CW RF signal to the AOQ. If this is OK, increase the RF power a little and repeat the procedure.

After the AOQ angle has been optimized, slowly increase the RF power by turning PWR ADJ clockwise until maximum extinction of the laser output is obtained.

On the threshold of the optimum RF power, the laser output will flicker On and Off

If possible adjust the beam height relative to the mounting surface in order to optimize efficiency.

The goal is to achieve the best hold off and extinction for the least RF drive power.

7.11 Introducing an AOQ into the laser cavity may affect the oscillation properties of the laser. This is due to the refractive index of the AOQ and consequential path length change. It is quite possible that a negative insertion loss is recorded simply by placing the AOQ into the laser cavity !

7.12 After the AOQ is introduced into the cavity, some adjustment of the laser mirror(s) may be required to peak the CW laser power, prior to AOQ operation.



## 8. MAINTENANCE

### 8.1 Cleaning

It is of utmost importance that the optical apertures of the AOQ are kept clean and free of contamination. When the device is not in use, the apertures may be protected by a covering of masking tape. When in use, frequently clean the apertures with a pressurized jet of filtered, dry air.

It will probably be necessary in time to wipe the coated window surfaces of atmospherically deposited films. Although the coatings are hard and durable, care must be taken to avoid gouging of the surface and leaving residues. It is suggested that the coatings be wiped with a soft ball of brushed (short fibres removed) cotton, slightly moistened with clean alcohol. Before the alcohol has had time to dry on the surface, wipe again with dry cotton in a smooth, continuous stroke. Examine the surface for residue and, if necessary, repeat the cleaning.

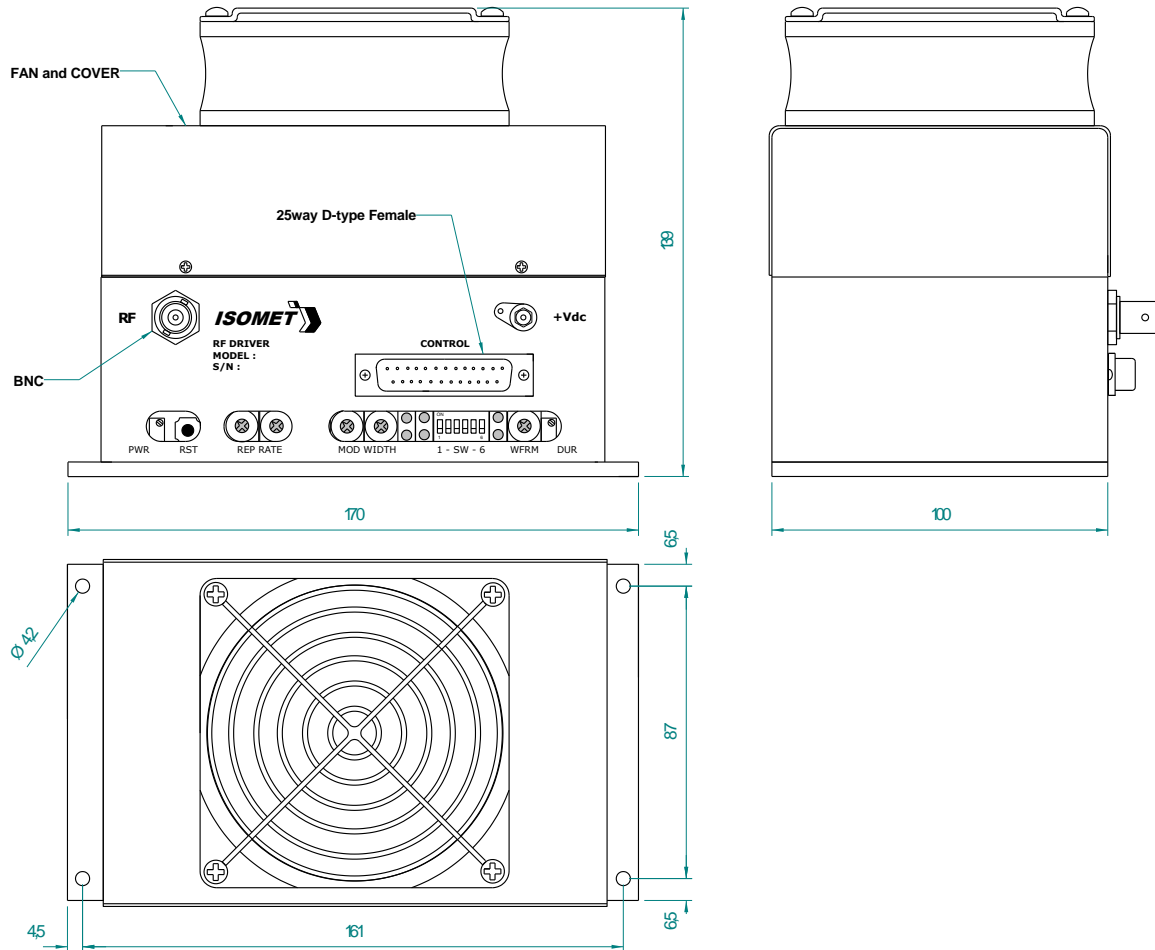
### 8.2 Troubleshooting

No troubleshooting procedures are proposed other than a check of alignment and operating procedure. If difficulties arise, take note of the symptoms and contact the manufacturer.

### 8.3 Repairs

In the event of deflector malfunction, discontinue operation and immediately contact the manufacturer or his representative. Due to the high sensitive of tuning procedures and the possible damage which may result, no user repairs are allowed. Evidence that an attempt has been made to open the optical head will void the manufacturer's warranty.

**AQS1000 Series**



Fan is fitted to higher power versions such as the AQS1080.

Figure 1: Driver Installation

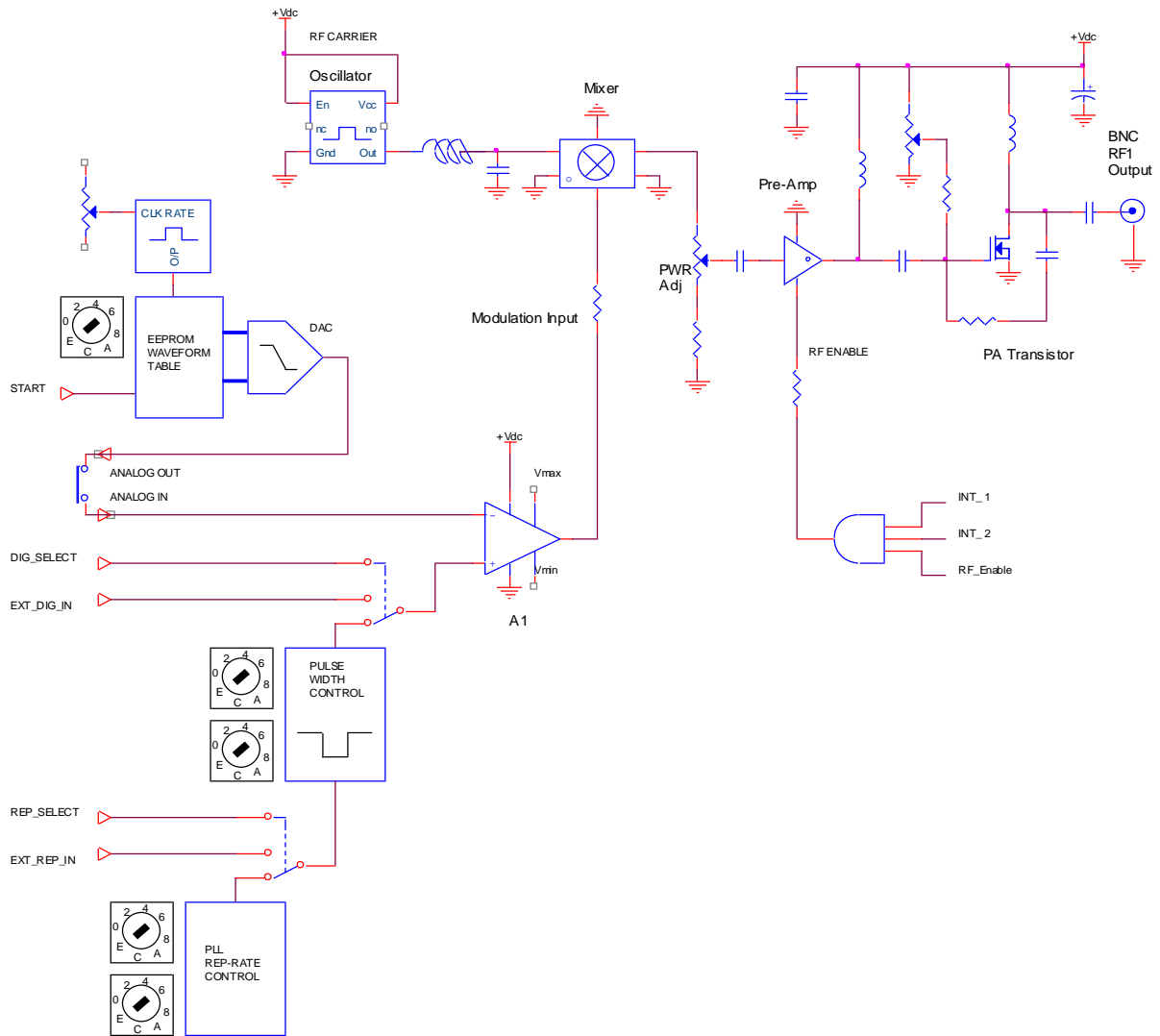
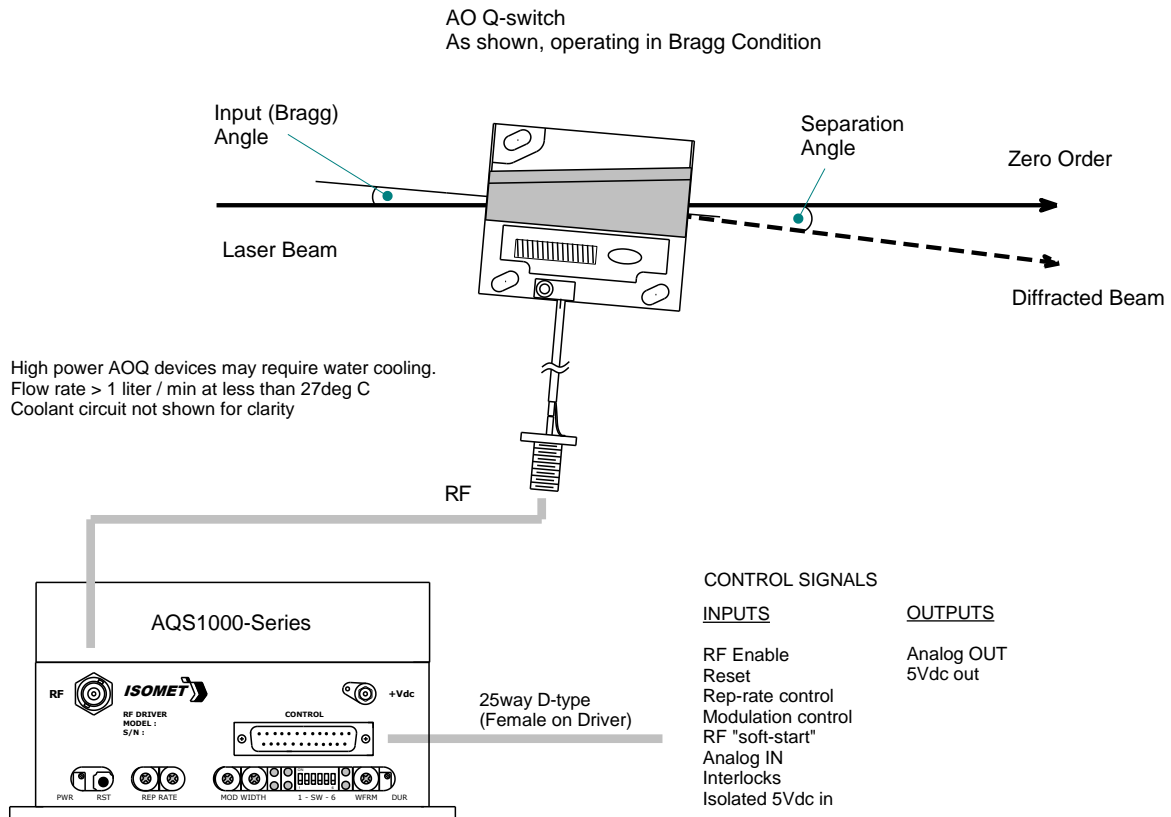


Figure 2: Driver Block Diagram

<u>Function</u>	<u>Adjustment</u>	<u>Specification</u>
Rep Rate	8-bit via 2 Hex Rotary Switches 1 & 2 plus Range Select Switch	1 – 120KHz
Pulse Width	8-bit via 2 Hex Rotary Switches 3 & 4	1 – 16.5 usec
RF On/Off RF CW/Modulated Rep-Range Select (2) Slope-Range Select Osc Select	DIL 6-way Lever Switch	Select Function
Waveform Shape	1 of 16 via Hex Rotary Switch 5	EPROM stored
Shape Period	24 turn potentiometer plus Range Select Switch	17usec – 1.8msec
RF Power	24 turn potentiometer	< 25% - 100%



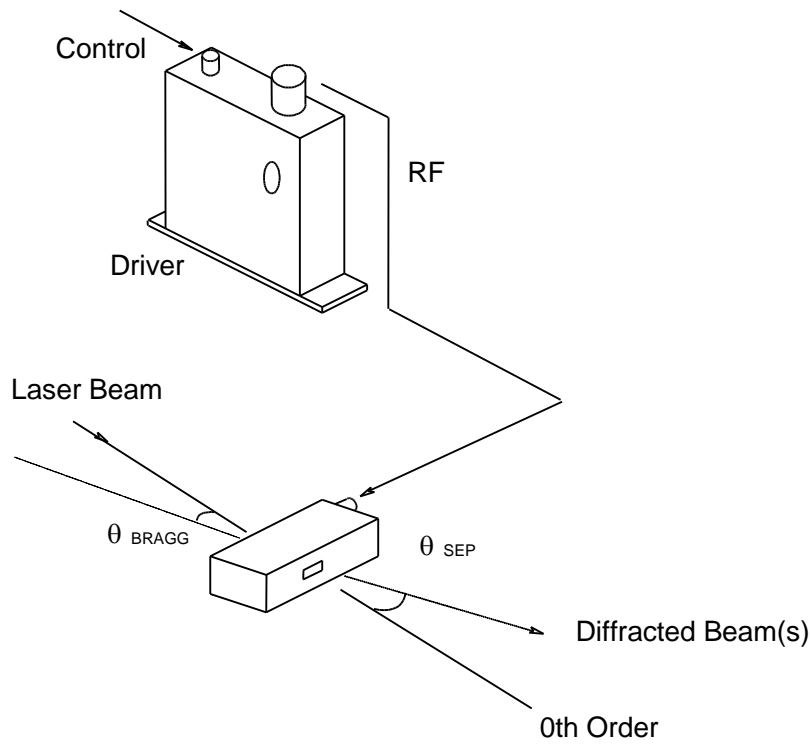
**Control signals : 25 pin 'D' type Female**

Pin	Signal	Pin	Signal
1	Slope/Modulation Start	14	Analog Modulation Input
2	Internal/External Rep Rate Select	15	Analog Voltage Output
3	External Rep Rate Input	16	Isolated 0V input, (opto supply)
4	Internal/External Dig'l Mod'n Select	17	Gnd
5	(Not used)	18	Isolated 0V input, (opto supply)
6	Isolated +5Vdc input, (opto supply)*	19	Gnd
7	+5Vdc output *	20	Isolated 0V input, (opto supply)
8	(Not used)	21	Isolated 0V input, (opto supply)
9	AOQ Thermal Interlock Input 1	22	Isolated 0V input, (opto supply)
10	Status Bit 1	23	Slope Modulation Enable
11	Status Bit 2	24	Reset
12	Status Bit 3	25	RF Enable
13	Status Bit 4		

\* Internal 5V and Isolated 5V supplies can be linked at the connector

Figure 3: Typical Connection Configuration

**Basic AO Q-Switch Parameters, operating in the Bragg Condition**



The input Bragg angle, relative to a normal to the optical surface and in the plane of deflection is:

$$\theta_{BRAGG} = \frac{\lambda \cdot fc}{2 \cdot v}$$

The separation angle between the Zeroth order and the +/- First orders is:

$$\theta_{SEP} = \frac{\lambda \cdot fc}{v}$$

Optical rise time for a Gaussian input beam is approximately:

$$t_r = \frac{0.65 \cdot d}{v}$$

where:

- $\lambda$  = wavelength
- fc = centre frequency of AOQ = 24.0, 27.12, 40.68, or 80MHz
- v = acoustic velocity of interaction material
  - = 4.2mm/usec (TeO2)
  - = 5.7mm/usec (a-Quartz)
  - = 5.96mm/usec (Fused Silica, Compressional mode)
  - = 3.76mm/usec (Fused Silica, Shear mode)

$$d = 1/e^2 \text{ beam diameter}$$

Figure 4. AOQ Equations