SERIES 5000 BIRD CONTROL GAINS

In moderate sea conditions in areas with uniform salinity and temperature the 5000 series DigiBIRDS birds have been found to give effective depth control, coupled to a reasonable battery usage rate, when using the default values for the control gains. However, as sea states increase or the streamer is towed through areas of variable salinity and/or temperature, a greater rate of response becomes desirable. Also if the prospect calls for shallow cable depth the birds will be required to work harder to ensure the streamer does not surface when surface currents or swell is encountered. Conversely, in calm, uniform conditions less response becomes desirable in order to optimise battery life.
To achieve this flexibility the frequency, magnitude and direction of the wing angle corrections have been made dependant on the calculated DEPTH ERROR along with the values of control gains which are stored in the birds memory and can be adjusted by the on board operator.

Note that several of these control gains are functions of other control gain values and therefore require entry of a GAIN INDEX from which the actual gain is calculated.

CONTROL GAIN	DEFAULT VALUE	GAIN INDEX @ DSR = 2
Depth/Heading Sample Rate (DSR)	2.0 seconds	~
Depth Averaging	14.0 seconds	2
Proportional Gain	0.8^{O}/ft depth error	5
Integral Gain	64	~
Rate Gain	0	~
Controller Update Rate	20.0 seconds	10
Fin Angle Dead Band	0.4^{O}	3

Figure 1: Default gain settings, appropriate for streamer depths of 8-10 meters or deeper.

1. Depth/Heading Sample Rate (DSR)
This is the fundamental time base for depth control of 5000 series birds. It defines the time period, in seconds, between successive readings of the birds' depth sensor and, if fitted, its' compass. Valid inputs for it value are 0.5 seconds to 25.5 seconds. This value is used to calculate values of DEPTH AVERAGING, INTEGRAL GAIN, CONTROLLER UPDATE RATE and HEADING TIME CONSTANT from their respective gain indices.

Since it is usually possible to achieve the desired level of streamer control in virtually all operating conditions by adjustment of other gain parameters **it is recommended that the Depth Sample Rate is left at its' default value of 2 seconds.** This should avoid the possibility of confusion caused by other control gains changing their values as the DSR is altered.

The only cases in which the DSR should be changed is when a prospect requires unusually short shot point intervals or a shallow cable depth. Here it may be necessary to reduce the DSR to 1 second and change the heading time constant to 3 in order to collect sufficient heading data samples per shot point to ensure good data quality (too few samples per shot causes noisy compass reading and may lead to the erroneous belief that there is a compass problem). In these cases, the following control gain indices should also be changed in order to keep their recommended default values:

> Increase Depth Averaging index to 3
> Decrease Integral Gain to 32
> Increase Controller Update Rate index to 20

This will produce the same depth keeping characteristics as the original default settings shown in Figure 1, **however there will be an observable decrease in battery life.**

2. Depth Averaging

This utilises a rate-corrected rolling exponential filter to provide a rolling average of the measured depth over a selected number of readings. The effective time over which the depth readings are averaged (the so called Effective Averaging Time) is equal to the number of samples averaged multiplied by the DSR.

With the DSR at its' default value of 2 seconds the following figure shows the number of samples averaged and the effective averaging time for each index setting.

Averaging Index	Effective No. Of Samples Averaged	Effective Averaging Time
0	NONE	NONE
1	3	6
2(default)	7	14
3	15	30
4	31	62
5	63	126

Figure 2: Depth Averaging Settings

The default value of 2 giving an effective averaging time of 14 seconds (with DSR=2) should provide good results in moderate to rough conditions, suppressing the tendency of the bird to follow sea swells, thus keeping the streamer running level while conserving battery life.

Increasing averaging delays the response to rapid depth changes such as those encountered when high wing angles (usually in birds at the head of the streamer) combine with sudden changes in the streamer velocity at the start and end of a turn. This can result in streamer instability in the form of target depth overshoot and oscillation.

Decreasing averaging improves the response to depth changes and decreases overshoot but at the expense of increased battery usage.

Do not use an index of 0 (no averaging).

NOTE: Depth averaging is applied to the depth measurements logged to the host computer. Thus any changes to depth averaging will affect the quality of recorded data and hence it is not desirable to alter this index far from the default value of 2.

3. Proportional Gain

This determines the amount of wing angle change that occurs in response to the calculated DEPTH ERROR. With the integral and rate gain values set to zero, wing angle is simply the product of the calculated depth error and proportional gain.

DEPTH ERROR = MEASURED DEPTH - TARGET DEPTH

WING ANGLE = PROPORTIONAL GAIN X DEPTH ERROR

The table below shows the relationship between proportional gain value and proportional gain index.

Proportional Gain Index	Proportional Gain (deg/ft depth error)	Proportional Gain (deg/meter depth error)
0	0	0
1	0.05	0.16
2	0.1	0.3
3	0.2	0.6
4	0.4	1.2
5 (default)	0.8	2.5
6	1.5	4.9
7	3	9.9

Figure 3: Proportional gain index verses value

Proportional gain counters the effects of sea state and fluctuating tow speed. The default value of 5 has proved acceptable for sea states of up to 3 meters (assuming 8-10 meters streamer depth). Shallow cable depths may require you to regard a value of 6 to be appropriate. In flat calm seas it may be possible to maintain the streamer within contract depth specifications with a lower index and as there is a direct relationship between proportional gain setting and battery life, it is advisable to keep the index as low as conditions and contract permit. A flat calm sea may allow an index as low as 3, while an extreme swell may require an index of 7.

When experimenting with the effects of changing the proportional gain index it is best to make changes in increments of one.

In order to maximise battery life and provide adequate streamer control, the proportional gain index should be adjusted as often as sea state changes allow.

4. Integral Gain

This counters the effects of any long term force (bias) that tends to hold the streamer away from its' assigned target depth. Such forces are always present to some degree and are usually due to heavy or light streamer ballasting, or the effect of the tow cables leading to the paravane or tail buoy trying to lift the ends of the streamer.

Because wing angle correction from proportional gain only is always zero when a bird is at its' target depth (depth error = zero) and a zero wing angle cannot provide the lift needed to maintain depth when biases are present, proportional gain cannot bring an 'unbalanced' streamer to its' target depth.

Integral gain provides a time-dependant correction to the wing angle calculated from proportional gain. As long as there is a depth error, this second correction or 'offset' accumulates at a constant rate that is determined by the integral gain index. The integral gain term is added to the proportional term if the bird is below the target depth and is subtracted from the proportional term if the bird is above target depth.

The rate of change of wing angle due to integral gain is independent of proportional gain and is a function only of the integral gain index and the DSR.

Note: the figure below shows examples only, the integral gain is not limited to these values. Permitted values are from 0 and 255 in increments of 1.

Integral Gain Index	Integral Gain in degrees/minute
0	0
32	0.58
64 (default)	1.15
96	1.73
128	2.3
160	2.88
192	3.45
224	4.03
255	4.6

Figure 4: Integral gains with DSR = 2 seconds

The value of integral gain determines how quickly the depth control system adjusts for these biases. In areas of uniform salinity and temperature a lower value of integral gain is sufficient as once the streamer is settled, its' buoyancy does not change appreciably. Areas with fresh water currents (river mouths etc.) result in constantly changing streamer weight which requires a higher value of integral gain in order to correct in a short period of time.

The default value of 64 has proved to be satisfactory in waters of uniform salinity and temperature. In areas where fresh water currents are encountered, or differing temperature layers, the integral gain can be increased to a maximum of about 128, which increases the rate of accumulation. Higher settings usually result in unacceptable oscillations about the target depth. A good value for a tricky prospect is 100.

There is no net benefit to increasing integral gain for high sea states. Adjust proportional gain as sea state changes, adjust integral gain as fresh water currents are encountered.

5. Rate Gain

Rate gain provides an additional wing angle correction that is proportional to the rate of change of depth error and would, in theory, provide quick response to sudden changes in depth. This type of response is undesirable for streamer depth control and experience has shown that use of this term can cause extreme instability.

Always ensure that Rate Gain is set to zero.

6. Controller Update Rate

This determines how often the wings move. The update rate **index** defines the number of depth sample intervals between wing angle adjustments, so the controller update **value** (the time period, in seconds, between possible wing angle adjustments) is simply the product of the Controller Update Rate index and the DSR.

Increasing the Update Rate index causes the wings to move less often, decreasing battery usage but also decreasing the overall effectiveness of the depth controller. Valid inputs for the index are from 1 to 255. The default value is 10 which allows wing movement every 20 seconds if the DSR is at the default value of 2 seconds.

To extend battery life when shooting in areas with no currents and during periods of flat calm seas, try increasing the Update Rate index. A good starting value is 15 with a maximum of 25.

A vessel on standby with birds in the water can reduce battery consumption by increasing the Update Rate index to 20 in rough seas, 35 in moderate seas and 50 in flat calm seas.

It is important to ensure the index is lowered before starting a line.

Use extreme caution when increasing the Update Rate as control of the streamer could be lost if the Update Rate is set too high. For the sake of safety do not increase the Update Rate index above 20 in a shallow water area or in a shipping lane.

If cable control cannot be maintained by adjustment of the other control gains the update rate index can be decreased with care to a minimum of 5. This should be regarded as a last resort as battery life is virtually halved when the Update Rate is halved. If the index is decreased to a low value is suggested that it be returned to the default value (10) during line changes.

7. Fin Angle Dead Band

Fin Angle Dead Band defines the minimum wing angle correction that can be applied at a wing update cycle. If the wing angle correction calculated by the depth control logic is less than the dead band value no wing motion takes place. By ignoring minor wing corrections battery usage can be reduced with very little loss of streamer depth control.

Index (degrees)	Dead Band	Index (degrees)	Dead Band
0	0	8	1.2
1	0.1	9	1.3
2	0.3	10	1.5
3 (default)	0.4	11	1.6
4	0.6	12	1.8
5	0.7	13	1.9
6	0.9	14	2
7	1	15	2.2

Figure 5: Dead band indexes

The dead band can be increased in calm weather from the default setting of 3 but be careful if the update rate has also been increased. Dead band settings over 6 impair cable control but extend battery life. Do not use values above 8 as loss of streamer control is likely.

Decreasing the dead band, along with increasing proportional gain, improves depth control in rough weather. This is preferable to a decrease in the update rate, which should be done as a last resort only. The dead band index can be set as low as one to increase depth control. A zero value is not recommended, as it results in an extreme drop in battery life.

8. Heading Time Constant (applies only to compass birds)

Averaging of the compass data is carried out by a single stage rolling exponential (unlike the depth averaging which uses a two stage Browns' filter) and as such is not rate corrected. The averaging time constant is an operator input and is based on the effective averaging time divided by the Depth/Heading Sample Rate. The table below shows the effective averaging times for the six possible indexes, assuming a DSR of 2 seconds.

Averaging Index	Effective Number Of Samples Averaged	Effective Averaging Time (seconds)
0	NONE	NONE
1	3	6
2 (default)	7	14
3	15	30
4	31	62
5	63	126

Figure 6: Effective averaging time for DSR = 2 seconds

It is recommended that the default value of 2 is used with a DSR of 2 seconds. If the DSR is changed the Heading time constant must also be changed in order to maintain the same effective averaging time.

9. Summary

- Depth/Heading Sample Rate (DSR)

Use the default value of 2 seconds. Exception to this is if using a shallow streamer or short shot point intervals.

- Depth Averaging

As this affects data logging it is recommended that this is kept at the default index of 2 (14 seconds averaging with DSR = 2). Decreasing the value will increase the response to sudden depth changes or reduce overshoot. Affected by changing the DSR. Exception to this is if using a shallow streamer or short shot point intervals.

- Proportional Gain

Increase in high sea states, decrease for calm seas. Adjust as necessary, keeping as low as operationally possible in order to maximise battery life, not altering by more than 1 at a time.

- Integral Gain

Where fresh water currents are encountered this should be increased up to a maximum of 128.(Too much higher could result in unacceptable oscillation about the target depth). Changing the DSR will change the Integral Gain.

- Rate Gain

Always keep at zero.

- Controller Update Rate

Increase to save batteries when off line for long periods in moderate to light seas. As a last resort in extreme conditions decrease the update rate to increase depth control. Always attempt to keep control of the streamer in rough weather using the Fin Angle Dead Band and the Proportional Gain first. Affected by changing the DSR.

- Fin Angle Dead Band

Decrease in rough weather along with an increase in Proportional Gain. Increase again when weather improves.

- Heading Time Constant

Use the default value along with the default DSR unless using a shallow streamer or short shot point intervals. Affected by changing the DSR.

- Off Line Settings

When on a line change or down for weather with the streamers deployed it is suggested that the streamers are dived. This takes the streamers below any swell or surface currents and means that gain settings can be employed to reduce the power usage without compromising streamer control, as the bird does not have to work as hard to maintain depth. Even if the gains are not going to be altered it is advisable to dive the streamer before turns as it reduces the likelyhood of the streamer coming to the surface during the turn.

Remembering, of course, to download production settings for gains and depth in sufficient time to have good control of the streamers prior to the start of subsequent lines!

When off line the suggested methods of battery conservation are to lower the proportional gain, raise the controller update rate and raise the fin angle dead band. This should only be done in conjunction with diving the streamers and obviously the reduction in control that the gain settings will result in must be monitored throughout the time they are in operation. The table on the last page of this document shows suggestions for the control gain settings. These are suggestions only and should be tailored to the conditions the vessel is operating in.

CONTROL GAIN	INDEX RANGE	VALUE RANGE	VALUE UNITS	DEFAULT VALUE	DEFAULT INDEX
Depth/Heading Sample Rate (DSR)	n/a	0.5 - 25.5	seconds	2	2
Depth Averaging	0 - 5	DSR*(2^(N+1)-1)	seconds	14	2
Proportional Gain	0 - 7	0 - 3.0	deg/ft DT error	0.8	5
Integral Gain	0 - 255	-	-	-	64
Rate Gain	0 - 7	-	-	-	0
Controller Update Rate	1 - 255	N x DSR	seconds	20	10
Fin Angle Dead Band	0 - 15	0 - 2.2	degrees	0.4	3
Heading Time Constant	0 - 5	DSR*(2^(N+1)-1)	seconds	14	2

Figure 7: Control Gain Information

CONTROL GAINS

NORTH SEA

CONTROL GAIN	INDEX RANGE	UNITS	DEFAULT VALUE	MODERATE SEAS	HIGH SEAS	EXTREME SEAS	OFF LINE MODERATE SEAS	OFF LINE EXTREME SEAS
Depth Sample Rate (use default)	0.5 - 25.5	seconds	2	2	2	2	2	2
Depth Averaging (Decr. to incr. response to sudden depth changes - use default except in extreme seas - CAUTION: affects depth data logging)	0 - 5	seconds	2	2	2	1	2	2
Heading Time Constant (use default)	0 - 5	seconds	2	2	2	2	2	2
Proportional Gain (Incr in high seas, decrease in calm seas to save batteries)	0 - 7	deg/ft DT error	5	6	7	7	4	6
Integral Gain (Incr. with salinity changes)	0 - 255	-	64	64	64	64	64	64
Rate Gain (ALWAYS set to zero)	0 - 7	-	0	0	0	0	0	0
Controller Update Rate (Decr. for incr. depth control - try prop. gain & fin angle dead band first)	1 - 255	seconds	10	10	7	5	15	10
Fin Angle Dead Band (Decr. for rough weather)	0 - 15	degrees	3	2	2	1	3	3