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AIM104-MOTION-1

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Notice:

This product note applies to Arcom's AIM104-MOTION-1 PC/104 motion control module.

Introduction

This product note is intended to give users of the board guidance on:

· The various types of motor that the module can be used to control,
· Suitable encoder feedback devices,
· Digital control loops and motor responses,
· Practical setups,
· Programming the AIM104-MOTION-1 module and calculating register values,
· EMC issues.
(*The AIM104-MOTION-1 Technical Manual should be read in conjunction with this document.*)

Motor Types

The AIM104-MOTION-1 can drive both brushed DC motors and (bipolar) stepper motors up to 1A maximum per phase. Additionally, other motors can be driven using an external drive amplifier that has inputs for (TTL level) PWM and direction inputs. See table 1 (page 13).

The module is intended for closed loop operation only. That is, the AIM104-MOTION-1 board requires feedback from a suitable encoder in order to control the motor as a closed loop system. (Limited open loop control of both DC motors and stepper motors is possible; see the section on 'open loop control', below).

Stepper Motors

Stepper motors come in a variety of different classes. The AIM104-MOTION-1 can only drive 2-phase (bipolar) stepper motors. However, all the most common types of stepper motor can be wired to be 'bipolar' stepper motors. 'Hybrid' stepper motors are the most common stepper motor for industrial applications, and are normally available with 8 wires (and four phases). An 8 wire configuration gives the most flexibility when deciding upon the manner in which the stepper motor is to be wired up. Other stepper motors with 4 or 6 wires can be wired to be 'bipolar', but the wiring options are more limited. Bipolar operation gives superior performance over 'unipolar' operation.

Hybrid stepper motors have four phases (windings). These four phases are wired either in series or in parallel in order to achieve a 'bipolar' stepper motor. Figures 1 to 4 show how to wire up a stepper motor in either configuration. If more details are required on stepper motors see the bibliography at the end of this product note.

A six wire stepper motor with windings in series.

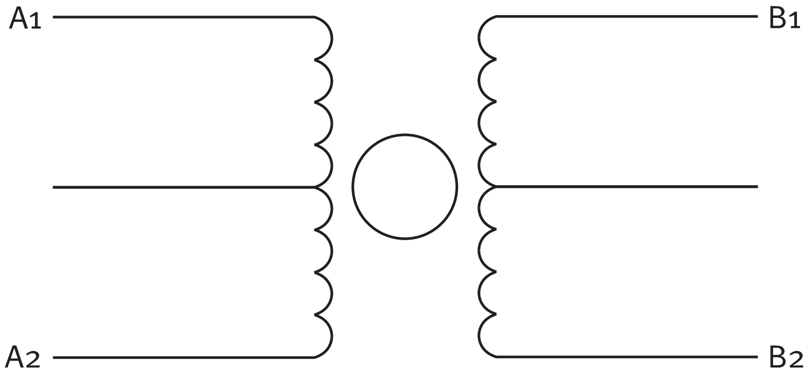

Figure 1.

An eight wire stepper motor with windings in series.

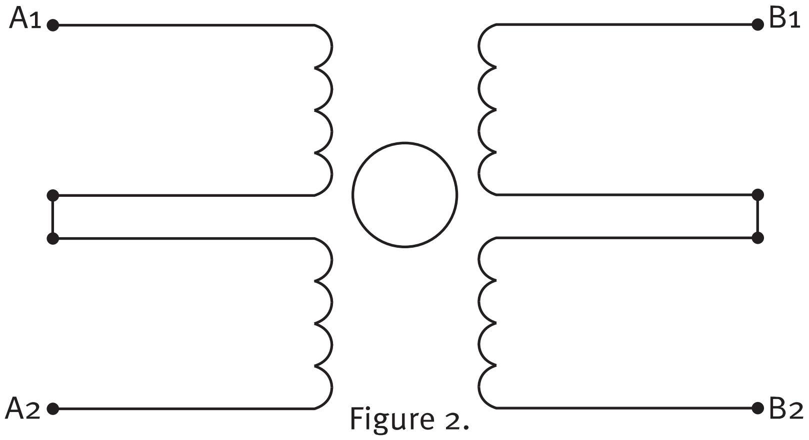

Figure 2.

An eight wire stepper motor with windings in parallel.

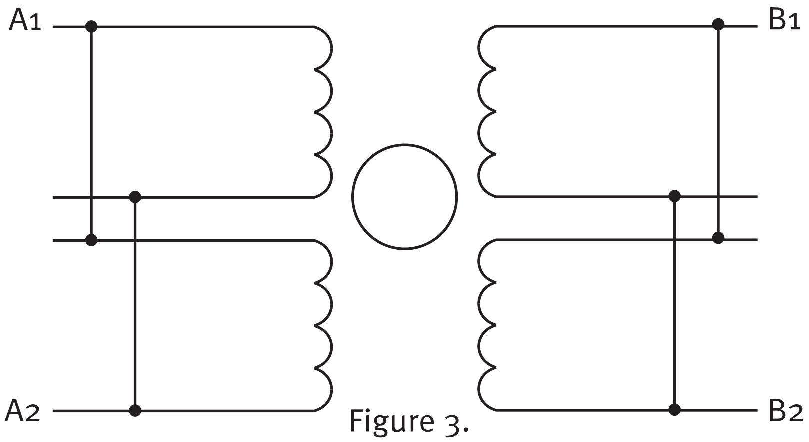

Figure 3.

A four wire (bipolar) stepper motor.

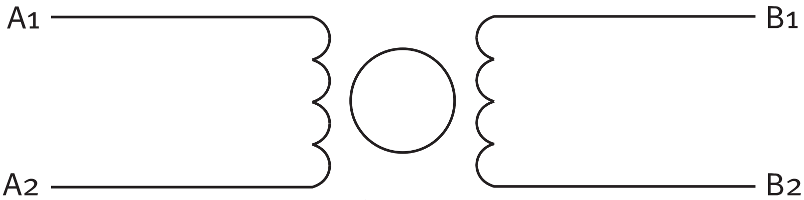

Figure 4.

Note that the stepper motor manufacturer's data is normally given per single phase (for a four phase stepper motor). When wiring a stepper motor in series (to give only two phases) the resulting stepper has twice as much inductance and twice as much resistance per phase. When wiring the stepper in parallel, the result is half the stated inductance and resistance per phase. Thus twice as much current will be required per phase.

The stepper motor performance is thus affected by the wiring configuration. Generally, wiring in series gives a higher zero speed torque, but much lower torque at higher speeds.

STEP ANGLE

The angle a stepper motor rotates through each step is dependent on the stepping mode (see below) and on the physical construction of the of the motor. In a hybrid stepper motor, the rotor consists of a number of magnetic teeth (alternating north and south poles). The stator consists of four teeth in the simplest motors, or more commonly, eight teeth. Coils are wound on the stator teeth. These are the four coils of figures 2 and 3. For an eight teeth stator, the teeth are wired together in pairs.

The number of stator teeth making up each stepper phase (i.e. 1/2 the number of stator teeth) multiplied by the number of rotor teeth gives the number of full motor steps per revolution. Thus a typical 1.8° stepper motor (giving 200 steps per revolution) with eight stator teeth has $200 \div 4 = 50$ rotor teeth.

STEPPING MODES

FULL-STEP, ONE PHASE-ON

The simplest mode of operation of a bipolar stepper motor is to energize one phase at a time. When one pair of windings is energized, the resulting north and south stator poles will attract teeth of the opposite polarity on the rotor. By changing the stator teeth that are energized, a new pair of rotor teeth are attracted, the rotor rotating through the required angle to align the teeth with the newly energized windings. If the phases are energized in the following order, the stepper motor will rotate four steps in one direction:

1) A1 -A2
2) B1 -B2
3) A2 - A1
4) B2 - B1

This is known as Full-step, One phase-on stepping. It takes four steps for the motor to rotate through one torque cycle. In the phases are energized in the reverse order, the stepper will rotate in the opposite direction.

FULL-STEP, TWO PHASES-ON

If the two coils are energized at the same time, the rotor will take up an intermediate position. The is because the rotor is attracted to the two (or four) stator poles equally. Greater torque is produced in this mode because all of the stator poles are holding the rotor in position. The phase sequence to rotate through one torque cycle is:

1)	A1 - A2	B1 - B2
2)	A1 - A2	B2 - B1
3)	A2 - A1	B2 - B1
4)	A2 - A1	B1 - B2

HALF-STEPPING

By alternating between one-phase-on and two-phases-on the rotor will move through only half the normal angle. This is known as half-stepping and gives twice the number of steps per revolution. The phase sequence for one torque cycle is:

1)	A1 - A2	B1 - B2
2)	A1 - A2	
3)	A1 - A2	B2 - B1
4)		B2 - B1
5)	A2 - A1	B2 - B1
6)	A2 - A1	
7)	A2 - A1	B1 - B2
8)		B1 - B2

Half-stepping results in a much smoother rotation (especially at low speeds), twice as much positional accuracy and less overshoot (see glossary) at the end of each step. However it also results in a loss of torque when compared with the full-step, two phases-on mode.

The AIM104-MOTION-1 has a current output shaping capability which compensates for the loss of torque when half-stepping mode is used. When Link 7 is open, the board compensates for the loss of torque when only one-phase is energized by boosting the current output by 40%. This will not exceed a stepper motor's current limits because the current limit per phase as defined by the data sheet refers to when both phases are on in full-step mode. With the current shaping feature, the total dissipated power in the half-stepping mode is the same as that for the full-step mode, and the resulting torque is approximately 95% of the torque of the pure full-step mode.

There are a wide variety of stepper motors suitable for use with the AIM104-MOTION-1. However, because the board requires the use of a rotary encoder (see below), it is recommended that a stepper motor with a rear shaft is selected (or one with a rear mounted encoder already fitted).

ENCODERS

The AIM104-MOTION-1 requires encoder position feedback in order to control a motor's speed and/or position. Only limited open loop positioning is possible with the AIM104-MOTION-1 (see below) even with stepper motors. Position encoders come in a large variety of types. They can be catoregised in a number of ways to define the output they produce, their physical form and the manner in which the encoder position is detected.

INCREMENTAL vs ABSOLUTE

The most fundamental division is between 'incremental' encoders and 'absolute' encoders. The AIM104-MOTION-1 requires the use of an incremental encoder. An incremental encoder provides a pulsed output of some form or other when the encoder is moved. The further the encoder is moved (or rotated) the larger the number of pulses produced.

Absolute encoders produce an output dependent on their absolute position. At all times it is possible to determine the encoder's actual position from the output signal produced. This is true even when the encoder has just been powered up. No initialisation is required. The most common absolute encoder is a rotary encoder providing angular position feedback, with (typically) a 14-bit parallel output defining its position. Absolute encoders are not suitable for use with the AIM104-MOTION-1. Incremental encoders are generally less expensive than absolute encoders.

QUADRATURE OUTPUT

Most incremental encoders output a ‘quadrature’ signal. This means that they have two channels both producing a pulsed output, but the outputs are 90° out of phase. Thus the signal provides directional information as well. The decoding electronics can determine which direction the encoder is moving by detecting which encoder output is leading the other.

Most incremental encoders produce a square wave output although there are some linear incremental encoders (see below) that produce a sinusoidal output instead. The AIM104-MOTION-1 requires an encoder with a square wave output. The AIM104-MOTION-1 will accept either a TTL level signal OR a differential (RS422) line driver output. Another advantage of quadrature encoders is that it is possible to detect four positions for each output pulse (there are four signal edges to detect). Thus a 500 counts/revolution rotary encoder can provide 2000 detectable positions (or quadrature counts) per revolution.

ROTARY and LINEAR ENCODERS

Encoders can be either ‘rotary’ or ‘linear’. Rotary encoders are defined by the number of pulses (or counts) per revolution that they provide (e.g. 500 counts per revolution). A linear encoder is defined by the linear distance between each pulse (e.g. 10mm) and by its total working distance (e.g. 250mm).

The AIM104-MOTION-1 can work with both rotary and linear encoders when controlling DC brushed motors. However, only rotary encoders should be used when controlling stepper motors with the AIM104-MOTION-1. Additionally, the number of quadrature counts per revolution MUST be a whole number multiple of the number of steps per revolution of the stepper motor.

2 AND 3 CHANNEL ENCODERS

Some incremental encoders have a 3rd channel (the index channel). The 3rd channel outputs a pulse once per revolution. The 3rd channel can be connected to the AIM104-MOTION-1 but is only used by the board when controlling stepper motors and is used in conjunction with the ‘phase offset’ feature of the HCTL-1100 (see AIM104-MOTION-1 Technical Manual for more information). The 3rd channel is NOT required by the AIM104-MOTION-1 to control a stepper motor.

Hewlett Packard manufacture a range of suitable rotary encoders (HEDS-55xx and HEDS-56xx series). These are available from RS, Farnell and most HP suppliers.

CLOSED LOOP CONTROL

The AIM104-MOTION-1 has four closed loop control modes: position control, trapezoidal position control, velocity control and integral velocity control. The AIM104-MOTION-1 uses the HCTL-1100 motion control IC which incorporates a 1st order digital filter. The gain (K) of the control loop and the filter's pole and zero positions as well as the sampling time period are programmable. The control loop diagram for the position control mode is shown in figure 5.

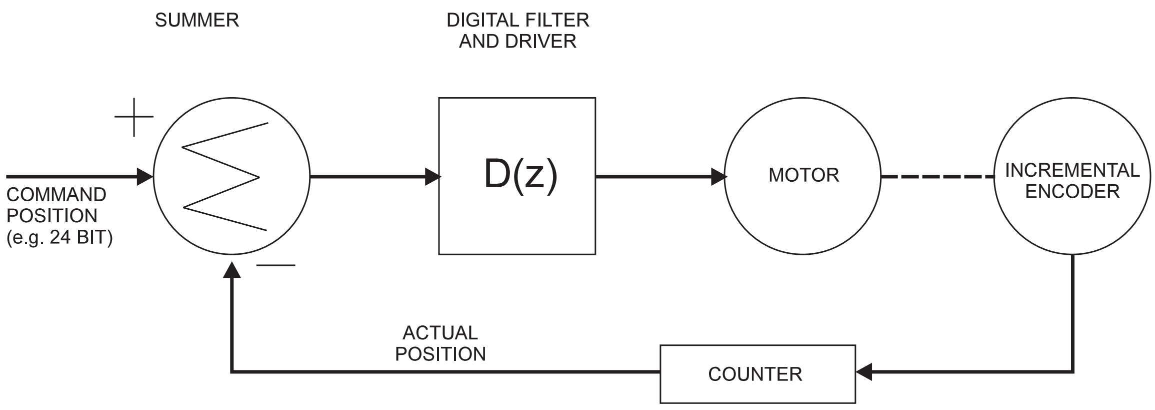

Figure 5.

Each sample period (programmable between 64µs and 2ms) the HCTL-1100 calculates the difference between the actual position and the desired (command) position. The positional error of this sampling period (and of the previous sampling period) as well as the magnitude of the output during the last sampling period are used by the digital filter to produce a new output. More about the operation of the digital filter can be found in the AIM104-MOTION-1 Technical Manual, as well as from Hewlett Packard's Application Notes ABM005 and AN1032.

Details on the operation of the four control modes can be found in the AIM104-MOTION-1 Technical Manual as well as in the HCTL-1100 Data Sheets.

CLOSED-LOOP vs OPEN-LOOP

Stepper motors have traditionally been controlled in open-loop fashion. It is the simplicity with which a stepper motor can be driven open-loop while still achieving good positional accuracy which has lead to its widespread use in industry. However, open-loop control of steppers has several considerable drawbacks including mechanical resonance and intolerance of load changes. In order to compensate for these problems it has become common to use an optical encoder mounted on the stepper shaft - so that any missed steps can be detected.

Using the AIM104-MOTION-1 closed-loop control of a stepper is possible for no additional cost except that of an optical rotary encoder (often used in any case, as mentioned above). A closed-loop system is inherently more stable. With open-loop control, if the speed is increased or the load increased such that the motor is trying to perform outside of its pull-out envelope, the motor will stall. With closed-loop control, the motor will simply slow down until the motor and load torques are matched, thus allowing the motor's full torque capabilities to be utilised.

PRACTICAL EXAMPLES

STEPPER MOTOR

A stepper motor is to be used to accurately position an axis of a plotting machine. The stepper motor shaft is connected to a lead screw (with a 5mm pitch). The stepper motor is a hybrid stepper with 200 steps/rev, 0.6A per phase, and is to be driven in full step mode. A rotary incremental quadrature encoder is mounted on the shaft (on the rear of the stepper motor) and has 500 counts per rev (2000 quadrature counts/rev).

Using the 'register' program (on the AIM104-MOTION-1 utils disk) the controller register values are calculated as follows:

Board Configuration register	= 3
Board Status register	= 2
Ring register	= 40 (i.e. 40 quadrature counts = 1 stepper torque cycle)
X register	= 10
Y register	= 0

The motor will be driven in trapezoidal position mode. Given that there are 200 steps per revolution and the lead screw has a 5mm pitch, the maximum positional accuracy is 25μm. The fastest the axis can travel is to be limited to 200mm/sec. If the sample period is set to the minimum for this mode, i.e. 128ms, then the maximum speed is:

(200mm ¸ 5mm) x 2000	= 80 000 quadrature counts per second
	= 10.24 quadrature counts / sample period
	≈ 10 quadrature counts / sample period

The target time to travel 200mm from rest is 1.1 seconds. With a trapezoidal profile this gives us a desired acceleration of 10 counts/sample period in 0.1 seconds. This gives a minimum acceleration/deceleration of 0.0131 quadrature counts / (sample period)^2 . Thus the command acceleration registers (R27H and R26H, see Technical Manual) should be programmed as follows:

R27H = 0
R26H = 4

This gives an acceleration of 4 ¸ 256 = 0.0156 quadrature counts / (sample period)^2, which gives the time to travel 200mm with a trapezoidal profile of approximately 1.08 secs.

Filter parameters are not too critical, suitable values for a stepper in trapezoidal mode would be K=8, A=0, B=0.

DC SERVO MOTOR

A brushed DC servo motor is to be used to rotate a pair of rollers which are being used to push widgets through a machine. The speed of the rollers must be kept as constant as possible at all times with a varying frictional resistance acting against the rollers. The rollers must push the widgets at a constant 0.5 m/s, or at a constant 0.2m/s if a jam occurs further up the line. The rollers are 92mm in diameter and are mechanically connected by a chain. The motor is mounted on one of the rollers with a 81:1 reduction gearbox. A 24V, 20W DC motor with rear mounted encoder (500 counts per revolution) is chosen.

The circumference of the rollers is 92 x Π = 289mm

When at 0.5 m/s

The rollers must rotate at 500mm ÷ 289mm => 1.73 revolutions / second
The motor needs to rotate at 1.73 x 81 = 140.1 Hz = 8408 rpm.

When at 0.2 m/s

The rollers must rotate at 200mm ÷ 289mm => 0.69 revolutions / second
The motor needs to rotate at 0.69 x 81 = 56.0 Hz = 3360 rpm.

The AIM104-MOTION-1 is programmed to control the motor in integral velocity mode. The sample period is chosen to be 200ms. Thus the command velocity needs to be programmed with:

$$140.1 \text{ (Hz)} \times 2000 \text{ (quadrature counts)} \times 200 \times 10^{-6} \text{ (sample period)}$$
$$= 56.04$$
$$\approx 56 \text{ quadrature counts per sampling period (0.4995 m/s)}$$

[Note: The command velocity resolution = 1 quadrature count / sample period
= 2.5 Hz (motor velocity)
= 0.031 Hz (roller angular velocity)
= 8.9 mm/s
≈ 0.01 m/s roller speed.]

The command velocity at the lower speed (0.2 m/s) needs to be:

$$56 \times 2000 \times 200 \times 10^{-6}$$
$$= 22.4$$
$$\approx 22 \text{ quadrature counts per sampling period (0.196 m/s)}$$

The command acceleration / deceleration is programmed so that it takes approximately 1 second to change speed from 0.5 to 0.2 m/s (or vice-versa).

Thus: Acceleration = 0.3 m/s change
= 0.3 m/s^2

In rpm/sec: $0.3 \div 0.289$
= 1.07 roller revs/s/s
= 86.8 motor revs/s/s
= 5207 motor rpm/sec

Thus in quadrature counts/(sample period)^2 (see Technical Manual, Appendix 1):

$$5207 \times 2000 \times (200 \times 10^{-6})^2 \times 0.01667$$
$$= 6.94 \times 10^{-3} \text{ quadrature counts / (sample period)}^2$$

The command acceleration register needs to be programmed to:

$$6.94 \times 10^{-3} \times 256$$
$$= 1.78$$
$$\approx 2$$

Suitable filter parameters might be K=4, A=229, B=128.

EMC CONCERNS

The AIM104-MOTION-1 has been designed to minimize the emissions of high frequency noise and maximize the immunity of the board to such noise. However when motor and encoder cables are attached to the board consideration should be given to the length, positioning and screening of the cables in order for the whole motor control system to comply with EMC standards.

In order to ensure that the board is protected from external interference and to minimize emissions from the board it is strongly advised that:

- The AIM104-MOTION-1 earth tab is connected by a good earth wire to the chassis of the system.
- Both the encoder cable and the motor drive cable should be fully screened if possible.
- All cables should be kept as short as possible. Where feasible, keep motor and encoder cables less than 1m long.
- Motor and encoder cables should not be routed together.
- The cable screen should NOT be connected to signal ground at any point.
- Use an encoder with a differential line driver (RS422) if possible, especially when used in a noisy environment.

DRIVING LARGER MOTORS

Motors requiring more than 1A per phase can be controlled by the AIM104-MOTION-1 providing a suitable external drive amplifier is used. The AIM104-MOTION-1 provides a TTL level PWM signal and a direction signal on the output connector for connection to a PWM amplifier. This amplifier then replaces the drive electronics on the AIM104-MOTION-1.

A suitable driver circuit for use with a stepper motor which is capable of driving 3A per phase is shown in figure 6 (page 12). The driver ICs should be thermally connected to a heatsink with a rating of 3.3°C/W or better, if the unit is to be capable of driving at 3A at 50°C ambient.

OPEN LOOP CONTROL

The AIM104-MOTION-1 can drive both brushed DC motors and stepper motors in ‘open-loop’, by writing directly to the appropriate output registers by-passing the control loop electronics.

STEPPER MOTORS

Only limited open loop driving is possible even with stepper motors. This is because the HCTL-1100 motion controller IC uses the encoder feedback to determine when to switch the phase output to the stepper. It uses a commutator state machine to implement this. The commutator state machine is set up during initialisation of the HCTL-1100 controller. The counter value is the input to the commutator state machine. However, the state machine can be disabled by setting bit4 of the controller’s flag register (R00H), see manual. The ‘commutator output’ can then be controlled directly by writing to the commutator ‘Phase Offset’ register (R1CH). The PWM register must also be set to a suitable value (typically the maximum value, 100) See the ‘motion.h’ header file and the function ‘open_loop_half_stepper()’ for an example of how to do this.

Driving a stepper motor in this manner is extremely processor intensive as several PC/104 bus read and writes to the AIM104-MOTION-1 board are required for each step.

DC MOTORS

The speed of a brushed DC motor can be controlled in open-loop by by-passing the feedback electronics and writing to the PWM output register directly. The HCTL-1100 should be kept in idle’ mode to avoid the feedback loop updating the PWM register automatically. The PWM register can be set to anything from -100 to +100. The relationship between the magnitude of the output and the speed of the motor will depend upon the characteristics of the motor and the load placed upon it. If the load on the motor is variable, open loop driving will result in poor speed control.

USING THE AIM104-MOTION-1 IN THE ACEpc

The ACEpc baseboard has capacitors connected between ground and each screw terminal input/output for EMC filtering. However, with these connected to the AIM104-MOTION-1 driver outputs, they cause the current limiting circuit of the motion board to unwantedly cut-in. This results in a very low current drive. The V2I1 ACEpc baseboard allows the user to ‘link out’ these filter capacitors on each screw terminal. This should be done for all the motor driver outputs.

GLOSSARY

(Meanings as used in this document)

Absolute - term used to describe an encoder whose output signal depends upon the encoders absolute position.

ACEpc - A CE compliant industrial PC enclosure from Arcom Control Systems Ltd. designed for use with PC/104 modules.

Bipolar - A stepper motor with only two phases, or one with four phases that has been wired to be equivalent to one with two phases. (See 'parallel' and 'series' wiring). Each phase can be energized in either polarity.

Closed-loop control - Control of a motor using a feedback sensor so that actual performance can be compared with desired performance and performance difference used to update the motor drive signal.

Differential - RS422 standard for differential line drivers specifies that there must be a minimum of ±2V when driving a load of 100W. This provides superior noise immunity to single-ended TTL level signals (driving a higher impedance load). The AIM104-MOTION-1 can be directly connected to an encoder with an RS422 differential line driver output.

Digital Filter - A filter using discrete time periods to sample a digital input signal, and producing a digital output signal. A digital filter is defined by the number and position of its 'poles' and 'zeros'. See the AIM104-MOTION-1 Technical Manual, appendix 5 for more details of the AIM104-MOTION-1 digital filter.

Full-step - A stepping motor drive mode, where either only one phase is energized at a time or both phases (of a bipolar motor) are energized all the time.

Half-step - A stepping motor drive mode where the motor phases are energized in a sequence giving twice as many steps per revolution as are obtained when full-step mode is used.

Hybrid - The most common form of stepper motor used in industrial applications. So called because it combines the operating principles of the other two types of stepper motor, the 'permanent magnet' stepper and the 'variable reluctance' stepper.

Incremental - term used to describe position encoders whose output is dependent on the relative distance (or angle) moved, not on the absolute position.

Open-loop control - Control of a motor without using a feedback device.

Overshoot - The single step response of a stepper motor shows that the rotor overshoots the detent position by some margin and oscillates before settling at the detent position. The settling time is typically 5-100ms, the size of the overshoot dependent upon load damping.

Parallel - The wiring of two motor phases together in parallel, so that a four phase stepper motor becomes a two phase bipolar stepper.

Phase - A motor winding or pair of windings (if electrically connected together).

PWM - Pulse Width Modulation

Quadrature - A quadrature signal is a pair of square-wave (or equal amplitude sine-wave) signals 90° out of phase.

Rotor - The rotating inner part of a motor.

Series - The wiring of two motor phases together in series, so that a four phase stepper motor becomes a two phase bipolar stepper.

Stator - The stationary outer section of a motor.

Unipolar - A stepper motor with three or more phases, in which each phase can only be energized in one polarity. Four phase unipolar stepper motors can generally be wired as a two phase bipolar stepper, giving better performance.

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See also Hewlett Packard Application notes:
ABM005 - Sample Timer and Digital Filter
AN1032 - Design of the HCTL-1000's/1100's Digital Filter Parameters by the Combination Method available on Hewlett Packard's web site:http://www.hp.com/HP-COMP/motion/app_index.html

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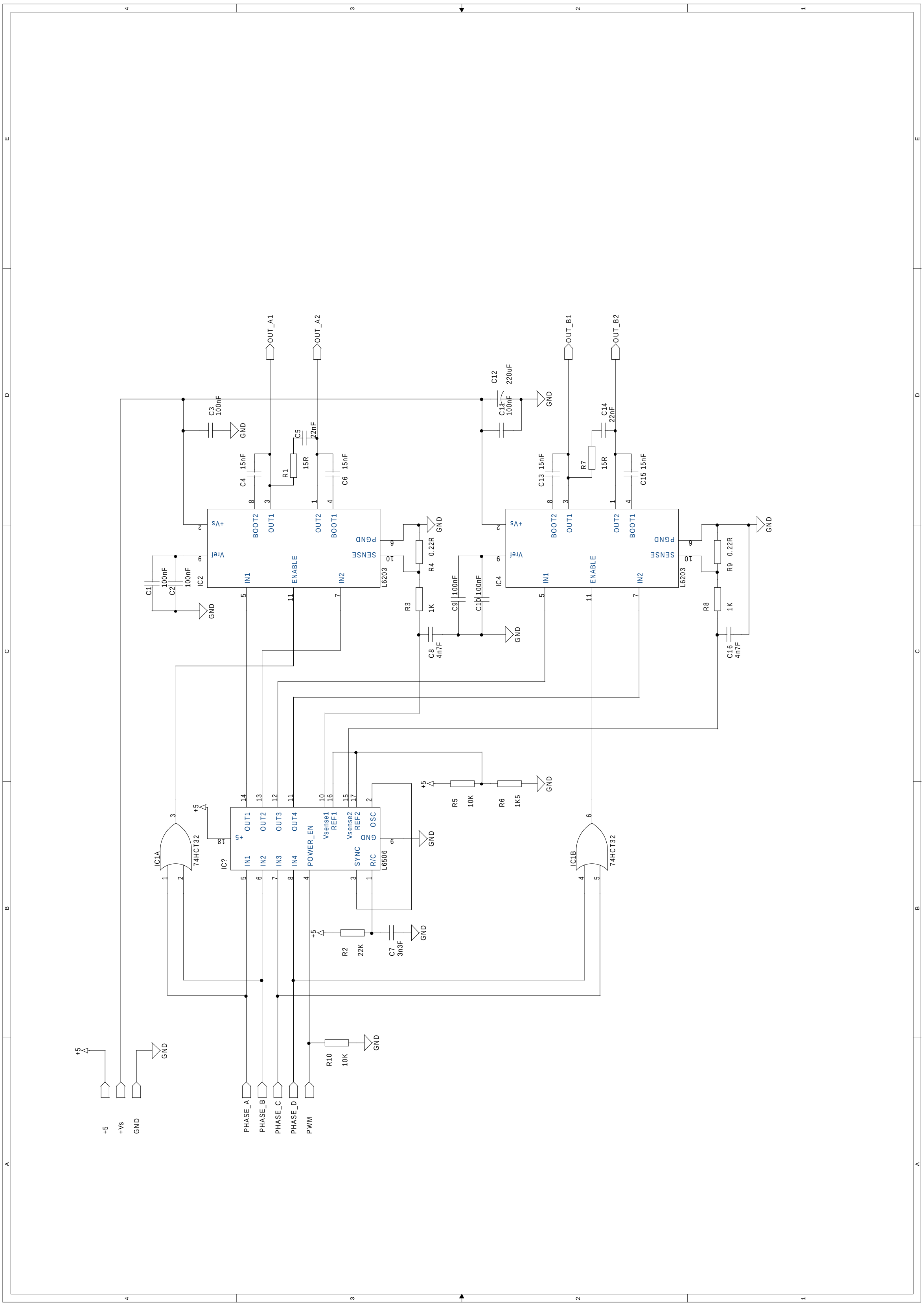
OUT_A1
OUT_A2
OUT_B1
OUT_B2
C12 220uF
C11 100nF
C3 100nF
C4 15nF
C5 22nF
R1 15R
C6 15nF
C13 15nF
C14 22nF
R7 15R
C15 15nF
+Vs
Vref
BOOT2
OUT1
OUT2
BOOT1
PGND
SENSE
IN1
ENABLE
IN2
IC2
IC4
L6203
R4 0.22R
R3 1K
R9 0.22R
R8 1K
C1 100nF
C2 100nF
C8 4n7F
C9 100nF
C10 100nF
C16 4n7F
R5 10K
R6 1K5
IC7
L6506
OUT3
OUT4
IN3
IN4
POWER_EN
Vsense1 REF1
Vsense2 REF2
OSC
SYNC
R/C
R2 22K
C7 3n3F
IC1A 74HCT32
IC1B 74HCT32
R10 10K
GND
+5
PHASE_A
PHASE_B
PHASE_C
PHASE_D
PWM

Figure 6.

AIM104-MOTION-1 CRIB SHEET

MOTORS	CONTROL	NOTES	INTERNAL DRIVE UPTO	INCREMENTAL ENCODER	EXTERNAL DRIVE POSSIBLE?
DC SERVO	CLOSED LOOP		1Amp	LINEAR OR ROTARY	YES (using PWM input amplifier)
DC MOTOR	OPEN LOOP	Board can function as limited DAC, providing variable drive.	1Amp	N/A	YES (using PWM input amplifier)
STEPPER	CLOSED LOOP		1Amp/phase	ROTARY	LIMITED*
STEPPER	OPEN LOOP	Limited open loop stepping possible.	1Amp/phase	N/A	LIMITED*
DC BRUSHLESS	CLOSED LOOP	Motors must have built-in drive electronics. Or suitable external driver required	Drive built in to motor. Board provides PWM and direction signals to motor.	LINEAR OR ROTARY	YES - with PWM input brushless motor amplifiers (see RHB for suitable amplifier.
AC MOTORS	NOT POSSIBLE	NOT POSSIBLE	-	-	-

* STEP and DIRECTION signals for standard stepper driver amplifiers are NOT provided. However, stepper commutator logic for external amplification by fairly simple (customer built) electronics is provided on the 50 way connector.

Table 1

Product Information

Full information about other Arcom products is available via the **Fax-on-Demand System**, (Telephone Numbers are listed below), or by contacting our **WebSite** in the UK at: **www.arcom.co.uk** , or in the US at: **www.arcomcontrols.com**

Useful Contact Information

Customer Support - UK
Tel: +44 (0)1223 412 428
Fax: +44 (0)1223 403 409
E-mail: support@arcom.co.uk

Sales
Tel: +44 (0)1223 411 200
Fax: +44 (0)1223 410 457
E-mail: sales@arcom.co.uk

United Kingdom
Arcom Control Systems Ltd
Clifton Road
Cambridge CB1 7EA, UK
Tel: 01223 411 200
Fax: 01223 410 457
FoD: 01223 240 600

United States
Arcom Control Systems Inc
13510 South Oak Street
Kansas City MO 64145 USA
Tel: 816 941 7025
Fax: 816 941 0343
FoD: 800 747 1097

France
Arcom Control Systems
Centre d'affaires SCALDY
23 rue Colbert
7885 SAINT QUENTIN
Cedex, FRANCE
Tel: 0800 90 84 06
Fax: 0800 90 84 12
FoD: 0800 90 23 80

Germany
Kostenlose Infoline:
Tel: 0130 824 511
Fax: 0130 824 512
FoD: 0130 860 449

Italy
NumeroVerde:
Tel: 1677 90841
Fax: 1677 80841
FoD: 1678 73600

Belgium
Groen Nummer:
Tel: 0800 7 3192
Fax: 0800 7 3191

Netherlands
Gratis 0800 Nummer:
Tel: 0800 022 11 36
Fax: 0800 022 11 48

Whilst Arcom's sales team is always available to assist you in making your decision, the final choice of boards or systems is solely and wholly the responsibility of the buyer. Arcom's entire liability in respect of the boards or systems is as set out in Arcom's standard terms and conditions of sale.

Certificate No. FM 12961

Arcom Control Systems Ltd operate a company-wide quality management system which has been certified by the British Standards institution (BS) as compliant with ISO 9001:1994

If you intend to write your own low level software, you can start with the source code on the disk which is supplied. This is example code only to illustrate use on Arcom's products. It has not been commercially tested. No warranty is made in respect of this code and Arcom shall incur no liability whatsoever or howsoever arising from any use made of the code.

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