DCC Multi Device Function Decoder

DCC Multi Device controller is an Arduino DCC function decoder that can control up to 3 servos, 1 stepper motor, 1 DC motor using PWM and 4 lights with various different lighting effects and directional control. The choice of which of these are controlled is based on the use of function keys; the DCC throttle controls the speed of movement of each of these and the direction of movement is controlled by the normal directional controls.

Configuration variables (CVs) for each servo allow the two end points of travel to be set, the speed at which the servo will move between these two end points, the startup mode of the servo and the function number associated with each servo.

The stepper motor allows the configuration of the number of steps per revolution, the gearbox ratio, the speed at full throttle and the function number associated with the stepper motor. The stepper motor may be used in a free rotational mode or constrained between two end points.

The DC motor control allows the setting of the maximum speed and the function number that activates the motor.

Each of the 4 light outputs supports 12 lighting effects which can be directionally dependent.

There is an additional “soft start” function that can delay the application of power to the servos in order to reduce the initial power requirements of the decoder and remove initial “hunting” of the servos whilst the processor starts up.

The decoder is based on an Arduino Nano, but may also be used on an Uno without modification or on other Arduino boards, such as the mini, with some pin re-allocation.

Arduino Pin Outs

Pin	Description
D2	DCC input to the decoder from the opto-coupler
D3	DCC acknowledge output from the decoder. Pulsed to acknowledge updates of the decoders CVs.
A2	Stepper motor driver
A3	Stepper motor driver
A2	Stepper motor driver
A4	Stepper motor driver
D4	Servo 0 control output
D5	Servo 1 control output
D6	Servo 2 control output
D7	Light 0 output
D8	Light 1 output

Pin	Description
D10	Light 2 output
D11	Light 3 output
N/A	PWM output to DC motor
N/A	PWM output to DC motor
D9	Power control output, driven low to turn on servo power output

Servo Operation

The decoder can control up to 3 servos, each of which is controlled by a set of CV's that define the behavior of the servo. Each servo is assigned a function that will operate it, the servo will only move if the corresponding function is on. Movement of the servo is controlled by use of the speed controller in one of two modes; either the servo will move between the two end stops at a proportion of the maximum defined speed based on the throttle setting.

Alternatively the servo maybe used in absolute mode. The servo will move a percentage of the way between the two defined end stops based on the throttle setting. At 25% throttle setting will result in the throttle moving to the 25% position between the start and end position defined.

When the corresponding function is switched off, or the servo reaches one of the end points, the servo will stop. Multiple servos can be moved at any one time by turning on multiple functions or assigning multiple servos to a single function.

Relative Mode

In relative mode the servo can be moved between the two end points. The direction of movement is controlled by the direction control of the throttle and the speed of movement is controlled by the throttle setting. A throttle setting of 50%, in the forward direction, will cause the servo to move at half the configured speed from it's current position towards the upper limit of travel defined for the servo. Provided the function associated with that servo is currently on. Setting the direction to reverse will cause the servo to move towards the lower limit of travel.

The servo will stop if the function associated with it is switched off, the servo reaches the limit of travel or the throttle is set to the zero position.

Relative mode is set by clearing bit 2 in the configuration flags for the servo, i.e. CV 33, 43 or 53 for each of the servos. These settings may be different for each servo.

Absolute Mode

In absolute mode the throttle is used to determine the position of the servo. Setting the throttle to 50% will cause the servo to move to 50% of the way between the upper and lower limits of travel. A setting of 25% would cause the servo to move to 25% of the way between the lower limit and the upper limit.

In absolute mode the direction setting and the defined maximum speed have no affect on the servo movement.

Absolute mode is enabled by setting bit 2 in the configuration flags for the servo, i.e. CV 33, 43 or 53 for each of the servos. These settings may be different for each servo.

Defining Servo End Points

Each servo has two defined end points that can be used to limit the rotation of the servo, a lower end point and an upper end point. These end points are expressed in degrees, with 0 being the physical most anti-clockwise[1] position the servo can move to. The servo is considered to be moving in a forward direction when it is moving away from the lower limit of travel towards the upper limit of travel.

The limits of travel may be defined differently for each of the servos attached using the CVs appropriate to each particular servo.

Defining Servo Speed

Servo speed is set by defining the desired number of seconds it should take to move from the lower limit of travel to the upper limit of travel with a throttle setting of 100%. Each servo may have its own unique travel time defined in the appropriate CV. If the travel time is set to zero then the servo will move between the end points in a time that is based on the physical limits of the servo.

Servo travel time is only observed if the servo is set to relative mode operation.

Initial Servo Positioning

There are four options available for the initial servo positioning that will take effect when power is applied;

- The servo will move to the defined lower limit of travel
- The servo will move to the defined upper limit of travel
- The servo will move to the mid point between the upper and lower limit of travel
- The servo will remain at the current position

Servo initial position is set by bits 0 and 1 of the servo control flags for each servo, CV 33, 43 or 53.

CV Value	Description
xxxxxx00	The servo will not move when power is applied
xxxxxx01	The servo will move to the lower limit of travel when power is applied
xxxxxx10	The servo will move to the upper limit of travel when power is applied
xxxxxx11	The servo will move to the mid position of travel when power is applied

Servo Bounce

The servo may be made to bounce at either one end of travel or the other end of travel or at both ends of travel. The servo has an initial bounce angle defined in degrees in CV35, 45 or 55. If the bounce is enabled for a particular end of travel then this defines the initial bounce, the servo arm will continue with a decaying bounce angle until it reaches the end position.

To enable servo bounce at a particular end of travel a bit is set in the servo flags configuration variable, CV 33, 43 or 53.

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[1] Clockwise and anti-clockwise are defined as when looking down on the servo horn from above.

CV Value	Description
xxxx1xxx	Servo bounce is enable at the lower limit of travel
xxx1xxxx	Servo bounce is enable at the upper limit of travel

Function Key Mapping

It is possible to define which function has to be active in order to control each of the servos. This is done via the function mapping CV for each servo, CV's 34, 44 and 54. The default is for function 0 to control the first servo, function 1 the second and function 2 the third. By changing the CV for a particular servo a different function key may be used, or a single function key may control multiple servos, the stepper motor and/or the DC motor.

It is not possible to define multiple functions to control a single servo.

Stepper Motor Operation

The decoder can control a single stepper motor, that stepper motor is configured to work with a function control of the decoder and will only move when the corresponding function is on. The speed and direction of the stepper motor are controlled by the throttle and direction control of the DCC throttle. Characteristics of the stepper motor may be configured via configuration variables as may the maximum speed of the stepper motor. The stepper motor may be configured to be free running or to only move between two positions.

Stepper Motor Characteristics

Three configuration variables define the characteristics of the attached motor; the number of steps per revolution of the motor, CV 60 and the gear ratio of the attached gearbox CV 61. The gear ratio is expressed as the number of input revolutions to obtain one revolution of the output. Therefore a ratio of 64 implies 64 rotations of the stepper motor are required to obtain one revolution of the output. Combining this with the number of steps per revolution will give the resolution of the stepper motor arrangement.

The third parameter that controls the stepper motor characteristics in the stepper motor mode CV, CV64. Most of the bits in CV64 are used to control the the operation of the motor, however bit 7 of the mode CV is used to determine if a unipolar or bipolar stepper motor is attached. If bit 7 is set to 1 then the motor is controlled as if it is a bipolar motor, setting the bit to 0 will result in a unipolar motor control, i.e. 4 independent coils within the motor.

Maximum Speed

The maximum speed of the stepper motor is defined as the desired revolutions per minute of the output of the gearbox at the 100% throttle setting.

Stepper Motor Mode

The stepper motor may be used in two modes of operation, as a free running motor that will continually turn when enabled, or as a constrained motor that will only allow the motor to turn between two points. In both modes the speed and direction are controlled by the throttle setting on the DCC handset as with any normal locomotive motor. The corresponding function assigned to the stepper motor must also be on in order for the motor to move.

The stepper motor mode is set via CV64, setting bit zero of this CV to zero configures the stepper motor to be a free running motor. Setting bit zero to one configures the motor to a constrained mode of operation.

It is also possible to reverse the rotation of the stepper motor relative to the forward and reverse setting of the DCC throttle. Setting bit 1 of CV64 to 1 will alter the forward direction of the stepper motor.

When operating in constrained mode bit 2 of the stepper motor mode can be set to make the stepper motor automatically change direction at the end of movement rather than stop. This produces an output suitable for effects such as a radar dish scanning back and forth.

A delay may be added when automatic reverse mode is set. This is set in CV67 as a value in seconds. If no delay is required then write CV67 with a value of 0. Alternatively it is possible to define a random delay by setting bit 3 of CV64, the stepper mode variable, to 1. If this random delay is enabled then the delay on reversal will be a random value between 1 second and the value defined in CV67.

Constrained Mode

The constrained mode allows the motor to move between set points, this is configured by defining an initial, zero point and a number of steps the the motor will be allowed to move away from the zero point. The setting of the zero point is done by placing the motor into the free running mode, by writing a value of 0 to CV64. The motor is then “driven” it to the required position using the DCC throttle and direction functions. Once it is at the position that should become the zero point, the motor should be stopped and the stepper motor mode set to constrained mode by writing a value of 1 to CV64.

The about of movement is set in CV65 and CV66, the value is a 16 bit count of the number of steps allowed. CV65 holds the bottom 8 bits of that value and CV66 the top 8 bits. If you have a motor that requires 8 steps per revolution and a 64 to 1 gearbox, the default CV setting, each step works out to be approximately 0.7 degrees of the output shaft. If the requirement is for 120 degrees of rotation on the output shaft then the calculation of CV65 and CV66 values is as follows:

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allowedSteps = 8 * 64 * 120 / 360 = 170.6 steps (rounded to 171)
CV65 = 171 & 255 = 171
CV66 = 171 / 256 = 0
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The movement is not limited to less than 360, rather the limit is 65535 steps, which in the case of the default gear ratio and steps is more than 46000 degrees or 127 revolutions of the output of the gearbox.

If power is lost when moving in constrained mode the decoder will resume from the same point when power is reapplied without effecting the defined end points. This is done by using the CV68 and CV69 values to store the current step point. The user should never write these CVs with new values, they will be overwritten the next time the stepper motor is active.

Function Key Mapping

It is possible to define which function has to be active in order to control the stepper. This is done via the function mapping CV63. The default is for function 3 to control the stepper motor. Setting a value in CV63 will change this, the same function can be defined to control any or all of the servos, the DC motor and the lights if desired.

DC Motor Operation

The decoder can control a single DC motor using pulse width modulation to control the speed of the motor. The motor is configured to work with a function control of the decoder and will only move when the corresponding function is on. The speed and direction of the stepper motor are controlled by the throttle and direction control of the DCC throttle.

The maximum speed of the motor is controlled by CV 70, a value of 255 will result in full DC voltage being sent at 100% throttle, reducing the value is CV 70 will reduce the maximum speed of the motor.

The function assigned to the DC motor can be controlled by CV 71. Setting a function number here will define which function must be on in order to allow the motor to turn. The same function may be configured to drive one or more servos or the stepper motor.

Light Operation

Four outputs may be used to run lights, each light may have a lighting effect assigned to it, a period for that lighting effect and a function key to assign to the output.

The period (CV76, 81, 86 or 91) is only currently used for flashing effects or in the dimmed mode. It sets the cycle period for flashing effects in units of tenths of a second. For example a value of 40 with the 25% duty cycle effect will cause the output to go high for 1 second and then stay low for 3 seconds. In dimmed mode it sets the brightness of the light, with 128 being 50% brightness and 255 full brightness.

Lighting effects are defined for each light by CV's 75, 80, 85 and 90 using the values defined in the table below.

CV Value	Lighting Effect
0	Constant light, full brightness
1	Dimmer controlled, brightness is set via throttle setting
2	Dimmed light, brightness is set by CV76, 81, 86 or 91
3	Flash with 50% duty cycle. The period of the flashing is defined by CV76, 81, 86 or 91.
4	Flash with 25% duty cycle. The period of the flashing is defined by CV76, 81, 86 or 91.
5	Flash with 75% duty cycle. The period of the flashing is defined by CV76, 81, 86 or 91.
6	Flickering effect
7	Slower flickering effect
8	Random flashing light
9	Fluorescent light with switch on flickering
10	Slow start light, designed to emulate the low energy lightbulbs that get brighter with time
11	Pulsating light, gets brighter and then darker repeatedly. The period of the pulsating is defined by CV76, 81, 86 or 91.

Any lighting effect can be made directional by setting one of the top two bits in the effect CV. If bit 6 is set the light only works in the backward direction whereas if bit 7 is set the light works only in the forwards direction. Setting or clearing both bits allows the light to work in either direction.

Function mapping is also available for each light, with CV's 77, 82, 87 and 92 controlling the function that activates the light.

Configuration Variables

CV Number	Default	Value
1	3	DCC Short address
1, 9	3	DCC Long address, LSB stored in CV 1, MSB stored in CV 9
7	1	Version ID - Read only
8	13 DIY	Manufacturer ID - Read only
29	32	Configuration options
30	0	Lower limit of travel, in degrees, for servo 0
31	180	Upper limit of travel, in degrees, for servo 0
32	20	Time in seconds to move between limits of travel at 100% throttle setting for servo 0
33	1	Servo control flag bit mask for servo 0 0x01 Start at lower limit of travel 0x02 Start at upper limit of travel 0x03 Start at mid travel point 0x04 Set absolute servo position based on throttle setting 0x08 Enable servo bounce at end of travel 0x10 Automatically reverse direction at end of travel 0x80 Reverse meaning of clockwise rotation
34	0	Function associated with servo 0
35	6	Angle of initial bounce
36	Readonly	The current servo angle in degrees
40	0	Lower limit of travel, in degrees, for servo 1
41	180	Upper limit of travel, in degrees, for servo 1
42	20	Time in seconds to move between limits of travel at 100% throttle setting for servo 1

CV Number	Default	Value
43	1	Servo control flag bit mask for servo 1 0x01 Start at lower limit of travel 0x02 Start at upper limit of travel 0x03 Start at mid travel point 0x04 Set absolute servo position based on throttle setting 0x08 Enable servo bounce at end of travel 0x10 Automatically reverse direction at end of travel 0x80 Reverse meaning of clockwise rotation
44	1	Function associated with servo 1
45	6	Angle of initial bounce
46	Readonly	The current servo angle in degrees
50	0	Lower limit of travel, in degrees, for servo 2
51	180	Upper limit of travel, in degrees, for servo 2
52	20	Time in seconds to move between limits of travel at 100% throttle setting for servo 2
53	1	Servo control flag bit mask for servo 2 0x01 Start at lower limit of travel 0x02 Start at upper limit of travel 0x03 Start at mid travel point 0x04 Set absolute servo position based on throttle setting 0x08 Enable servo bounce at end of travel 0x10 Automatically reverse direction at end of travel 0x80 Reverse meaning of clockwise rotation
54	2	Function associated with servo 2
55	6	Angle of initial bounce
56	Readonly	The current servo angle in degrees
60	8	Number of steps for one revolution of the stepper motor
61	64	Reduction ratio of the gearbox on the stepper motor

CV Number	Default	Value
62	60	Revolutions per minute at maximum throttle setting
63	3	Function associated with stepper motor
64	0	Stepper motor mode. Bit 0 controls the mode of operation - 0 gives a free running motor, 1 constrains the rotation to a number of steps. Bit 1 is used to define the forward direction of rotation of the stepper motor. Bit 2 is used to enable automatic reversal of direction at the end of the constrained movement. Setting this bit to 0 will disable automatic reversal of direction. Bit 3 allows for the randomization of the reversal delay. If set a random delay, whose maximum is set by CV67 is applied before the direction of travel is reverse. Bit 4 controls the behavior on deselecting the function associated with the stepper motor. If set then the stepper motor continues at the current speed in the current direction. Changes of speed or direction using the throttle are ignored. If clear the stepper motor will stop. Bit 7 controls unipolar or bipolar output to the motor. Set this bit if you have a bipolar motor attached, clear it if you have a unipolar motor attached.
65	232	Least significant byte of the number of steps allowed in the constrained mode of operation of the stepper motor. Not used in free running mode.
66	3	Most significant byte of the number of steps allowed in the constrained mode of operation of the stepper motor. Not used in free running mode. Combined with CV65 this gives the total number of allowable steps in constrained mode. The default is 1000 steps.
67	10	Delay before reversing direction of travel if automatic reverse mode is enable. If the random delay bit is set then this CV is the maximum delay before reversing direction. Delays are measured in seconds.
68	Read Only	Least significant byte of the current number of steps in constrained mode.

CV Number	Default	Value
69	Read Only	Most significant byte of the current number of steps in constrained mode.
70	255	PWM motor maximum speed, 255 = max speed
71	4	Function associated with the PWM motor
72	50	Delay between reset/power up before the power is applied to the servos.
75	2 (Dimmer)	Light 0 effect in bottom 6 bits, directional control of lighting in the top 2 bits. Bit 7 for forwards only, bit 6 for reverse only.
76	40	Light 0 period
77	5	Light 0 Function
80	1 (Constant)	Light 1 effect in bottom 6 bits, directional control of lighting in the top 2 bits. Bit 7 for forwards only, bit 6 for reverse only.
81	40	Light 1 period
82	6	Light 1 function
85	4 (Flash 50%)	Light 2 effect in bottom 6 bits, directional control of lighting in the top 2 bits. Bit 7 for forwards only, bit 6 for reverse only.
86	40	Light 2 period
87	7	Light 2 function
90	8 (Flash 25%)	Light 3 effect in bottom 6 bits, directional control of lighting in the top 2 bits. Bit 7 for forwards only, bit 6 for reverse only.
91	40	Light 3 period
92	8	Light 3 function