Universal Serial Bus

Physical Interface Device Class

Version 0.9

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Revision History

Revision	Issue Date	Comments
0.9a	September 17, 1998	Added PID Report Size usage. Changed the DS Device Paused selector to a single bit, dynamic flag usage Device Paused. Changed the DS Actuators Enabled and Disabled selectors to a single bit, dynamic flag usage Actuators Enabled. Removed PID Device State collection, and DS All Effects Stopped, DS Device is Reset and DS Device Running selectors. Updated Report Descriptor.
0.9	August 25, 1998	Added Start Delay usage. Dropped all specific references to units in Usage definitions. And added a recommendation to check Units, Unit Exponent, Physical Minimum and Maximum to determine units. Added Device Operation Report and Device Gain usages.
0.8b	March 31, 1998	Fixed Usage ID assignment problem
0.8a	October 24, 1997	Updated with input from 8.0
0.8	July 24, 1997	Initial Draft

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1. Introduction

1.1 Scope

This Document describes the USB Physical Interface Device or PID Class. The PID Class is intended as an extension of the Human Interface Device (HID) Class for devices that require "real-time" physical feedback. The main focus for the definition is for the use of haptic devices and the implementation of force feedback systems. However there is no requirement that members of this class generate this type of effect. Examples of devices that are member of this class are force feedback joysticks, motion platforms, and force feedback exoskeletons.

1.2 Purpose

This document is intended to supplement to the USB specification and provide manufacturers of PID class devices with the information necessary to build USB compatible devices. Further, this specification specifies how the PID class driver should extract data from USB data streams. Since this device class is an extension of the HID class, the HID class specifications will be required to implement the device functionality.

1.3 Related Documents

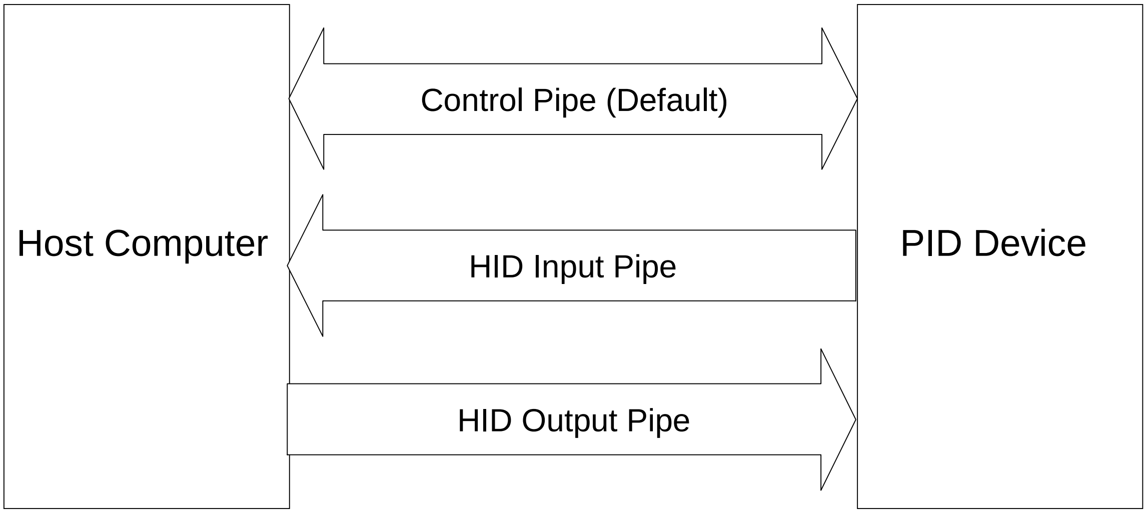
Universal Serial Bus Specification
Device Class Definition for Human Interface Devices (HID)
Universal Serial Bus HID Usage Tables

1.4 Definitions

Set *PB* Report	This term is used to refer to any of the Set-Report commands. Where Set-Reports represents one of the following report types: Set Effect Report, Set Custom Force Report, Set Periodic Report, Set Constant Force Report, Set Ramp Force Report, Set Vendor Report, Set Envelope Report, and Set Condition Report.
INFINITE	Referrers to the maximum value of a range. i.e. if in an 8 bit unsigned field the value of 255 would indicate INFINITE.
Normalized	When a usage is declared as a *Normalized* value, then the device assumes that a range of values between %0 and %100 can be applied by the device where the actual applied value is a percentage p, where p = (Usage Value / (Logical Maximum - Logical Minimum)) * 100.

2. Functional Overview

The Functional connection model for the PID class is below.



The data transfer mechanism for the PID class is based on the HID class Report Descriptors. Communication with a PID device is identical to that of a HID device.

Report Type	Transfer for a GET_REPORT	Transfer for a SET_REPORT
Input	HID Interrupt In pipe	Control pipe
Output	Control pipe	HID Interrupt Out pipe
Feature	Control pipe	Control pipe

3. Configurations

3.1 Configuration and Interface Structure

The PID class has a standard configuration and interface structure defined. The interface structure is designed to be an extension of the HID interface that will allow for the needed low latency output requirement. The first pipe is the default control pipe required for all devices. The second pipe in the interface is an interrupt IN pipe that will process reports as described by the HID specification. The third pipe is an interrupt OUT pipe. The intent of this pipe is to handle all output reports that are sent to the device. This will allow commands to be sent to the device with minimum latency.

3.1.1 Configuration

3.1.2 Interface Definition

Pipe	Type	Description	Required?
0	ctrl	USB control & class SET/GET commands	Y
a	interrupt in	HID data in from device	Y
b	interrupt out	PID command out to the device	N

4. Conventions

4.1 Actuators

An *Actuator* is a mechanism that can exert a force against an object. Typically the force applied by the actuator can defined in some combination of 6 dimensions; X, Y, Z, Rx, Ry and Rz. By definition in the HID specification these dimensions are defined in a coordinate system that is referenced to the direction that the user is facing. For simplicity the usages X, Y, Z, Rx, Ry and Rz from the Generic Desktop page are used by PID class devices to define a NORMALIZED force values. i.e. if the Logical Minimum and Logical Maximum values for an axis are defined to be -100 and +100 respectively, then -100 represents maximum force in the negative direction, 0 no force, and +100 maximum force in the positive direction. If a device requires the assertion of precise absolute force then the Vectors Vx, Vy, Vz, Vbrx, Vbry and Vbrz can be used from the Generic Desktop usage table with Units declaring the actual range of applied force.

In some cases the application of force does not have an easily identifiable set of dimensions that can be applied. An example is the force applied by a pressure suit in a flight simulator. In this document this type of “dimensionless” force will be referred to as a *Normal* force. For simplicity the PID:Normal usage is used to define a Normalized force that can vary between 0 and the maximum force that a device can assert. If the assertion of precise absolute force is required by a device then the vector Vno can be used from the Generic Desktop usage table with Units declaring the actual range of applied force.

Table 1: Actuator Usages

Actuator Type	Normalized Usages	Absolute Usages	Orientation
Dimensionless	PID: Normal	Vno	Perpendicular to the surface of an object.
Translation	Generic Desktop: X	Vx	Force in linear X direction
Translation	Generic Desktop: Y	Vy	Force in linear Y direction
Translation	Generic Desktop: Z	Vx	Force in linear Z direction
Rotation	Generic Desktop: Rx	Vbrx	Torque about X
Rotation	Generic Desktop: Ry	Vbry	Torque about Y
Rotation	Generic Desktop: Rz	Vbrz	Torque about Z

4.2 Joints

A *Joint* is a collection of actuators. PID devices can control multiple joints where each joint can have multiple degrees of freedom (axes). This document refers to *Joint Collections*, which are physical collections wrapped around fields (Main Items), associated with a joint, thus tying the axes together. The usage applied to a Joint collection identifies it in a report. i.e. in a joystick the input axes are contained in a physical collection with the Pointer usage attached. The matching output in a force feedback joystick is found in the Joint (physical) collection that has a Pointer usage attached to it.

Vendor Defined or Ordinal usages can be applied to Joints when more appropriate usages cannot be found. When describing exoskeletons, ordinal usages are attached to the joint physical collections and the Physical Descriptor attached to the joint physical collection can be used to further qualify the specific joint.

4.3 Low Speed Devices

Because the use of the interrupt out pipe type is limited to high-speed devices, all PID class devices must be high-speed devices.

4.4 Units

Usages state specifically whether *Units* are required to define a time base or other reference. A *Units* requirement implies the definition or Units, Physical Maximum, Physical Minimum and Unit Exponent items.

Remember that Units are **global** items that persist from main item to main item. *Units* can be disabled by setting Units to “None”, and Physical Maximum, Physical Minimum and Unit Exponent equal to 0. Applications will typically ignore *Units* when it encounters a Usage that they are not appropriate for, but don’t count on it. Always make sure that the Units are correctly declared for every Usage.

Normalized Usages use Logical Minimum and Logical Maximum to define their range of values. These values are automatically scaled by an application to fit the range of values required for the target operation and do not require *Units*.

5. Physical Input Device Page (0x0F)

Force feedback devices use PID usages to describe their output and Usages from other Usage Pages to describe their input.

A Physical Input Device can use one of two methods to generate sensations to the user: Effects or Custom Effects. A device may support either or both methods. Effects generate force feedback based on the parameters stored in a variety of parameter blocks (structures) that are maintained in the device. The host loads the parameter blocks, then issues a Start Effect Command over an Interrupt Out pipe. Custom Effects are similar to playing an audio file, force information for each axis can be downloaded and “played” locally or sent to the device over an Isochronous Output pipe.

Effects are comprised of parameter blocks. The are 6 types of parameter blocks defined: Effect, Envelope, Condition, Periodic, Constant Force and Ramp Force. All Effects require an Effect Parameter Block. Depending on the effect one or more additional parameter blocks will be required. Parameter blocks are accessed by an handle. The size of a parameter block for a particular device is a function of the size of the associated report.

A default allocation of each type of parameter block is provided by the device, however the host driver can modify the resource allocation to best meet its needs.

Table 2: Physical Input Device Page

Usage ID	Usage Name	Usage ID	Usage Name
00	Undefined	71	Phase
01	**Physical Interface Device**	72	Period
02-1F	Reserved	73	**Set Constant Force Report**
20	Normal	74	**Set Ramp Force Report**
21	**Set Effect Report**	75	Ramp Start
22	Effect Block Index	76	Ramp End
23	Parameter Block Offset	77	**Effect Operation Report**
24	ROM Flag	78	**Operation**
25	**Effect Type**	79	Op Effect Start
26	ET Constant Force	7A	Op Effect Start Solo
27	ET Ramp	7B	Op Effect Stop
28	ET Custom Force Data	7C	Loop Count
29-2F	Reserved	7D	**Device Operation Report**
30	ET Square	7E	Device Gain
31	ET Sine	7F	**PID Pool Report**
32	ET Triangle	80	RAM Pool Size
33	ET Sawtooth Up	81	ROM Pool Size
34	ET Sawtooth Down	82	ROM Effect Block Count
35-3F	Reserved	83	Simultaneous Effects Max
40	ET Spring	84	Pool Alignment
41	ET Damper	85	**PID Pool Move Report**
42	ET Inertia	86	Move Source

Usage ID	Usage Name	Usage ID	Usage Name
43	ET Friction	87	Move Destination
44-4F	Reserved	88	Move Length
50	Duration	89	**PID Block Load Report**
51	Sample Period	8A	Handshake Key
52	Gain	8B	**Block Load Status**
53	Trigger Button	8C	Block Load Success
54	Trigger Repeat Interval	8D	Block Load Full
55	**Axes Enable**	8E	Block Load Error
56	Direction Enable	8F	Block Handle
57	**Direction**	90	**PID Block Free Report**
58	**Type Specific Block Offset**	91	**Type Specific Block Handle**
59	**Block Type**	92	**PID State Report**
5A	**Set Envelope Report**	93	**PID Effect State**
5B	Attack Level	94	ES Playing
5C	Attack Time	95	ES Stopped
5D	Fade Level	96	**PID Device Control**
5E	Fade Time	97	DC Enable Actuators
5F	**Set Condition Report**	98	DC Disable Actuators
60	CP Offset	99	DC Stop All Effects
61	Positive Coefficient	9A	DC Device Reset
62	Negative Coefficient	9B	DC Device Pause
63	Positive Saturation	9C	DC Device Continue
64	Negative Saturation	9D	Reserved
65	Dead Band	9E	Reserved
66	**Download Force Sample**	9F	Device Paused
67	Isoch Custom Force Enable	A0	Actuators Enabled
68	**Custom Force Data Report**	A1	Reserved
69	Custom Force Data	A2	Reserved
6A	Custom Force Vendor Defined Data	A3	Reserved
6B	**Set Custom Force Report**	A4	Safety Switch
6C	Custom Force Data Offset	A5	Actuator Override Switch
6D	Sample Count	A6	Actuator Power
6E	**Set Periodic Report**	A7	Start Delay
6F	Offset	A8	**Parameter Block Size**
70	Magnitude	A9-FFFF	Reserved

The following controls support force feedback devices.

Physical Interface Device	CA - A collection of PID usages.
Normal	DV – A force applied perpendicular to the surface of an object.

5.1 Effect Block Parameters

The minimal Effect parameter block must contain (Effect) Parameter Block Index, Effect Type, Duration, Sample Period, Gain, Trigger Button, Trigger Repeat Interval, Axis Direction, and Type Specific Block Handle values.

Set Effect Report	CL – This usage applies the logical collection that identifies the report associated with setting the effect parameters of a PID.
Effect Block Index	DV - Effect Block Index varies from 0 to the maximum number of effects - 1 stored in the device. See Parameter Block Management for more information.
Parameter Block Offset	DV – The byte offset into the Parameter block pool where the Parameter Block is stored.
ROM Flag	DF – This flag used to distinguish between RAM and ROM based Effect Block Indices and Offsets.

5.1.1 Effect Types

Individual effects are identified by the contents of the Effect Type (ET) field. The declared ET usages enumerate the effects that a device supports. See Table 3 for required Type Specific Block Offsets.

Effect Type	NAry – This collection identifies the Type of Effect this command defines. See Table 3 for list of applicable Effect Type selectors. Vendor defined effect type selectors can also be included in this collection.
ET Constant Force	Sel – The current effect parameters define a Constant waveform.
ET Ramp	Sel - The current effect parameters define a Ramp waveform.
ET Custom Force Data	Sel - The current effect parameters define a downloaded Custom Force waveform.
ET Square	Sel - The current effect parameters define a Square waveform.
ET Sine	Sel - The current effect parameters define a Sine waveform.
ET Triangle	Sel - The current effect parameters define a Triangle waveform.
ET Sawtooth Up	Sel - The current effect parameters define a Sawtooth Up waveform.
ET Sawtooth Down	Sel - The current effect parameters define a Sawtooth Up waveform.
ET Spring	Sel - The current effect parameters creates a compliant restoring force that causes the device to return to a specified point in the device's range of motion.
ET Damper	Sel - The current effect parameters define a Damper effect.
ET Inertia	Sel - The current effect parameters define a Inertia effect
ET Friction	Sel - The current effect parameters define a Friction effect.
Duration	DV - The total duration of the effect. To sustain an effect until explicitly stopped with the **Stop** method, set *Duration* to INFINITE (Null). If an envelope has been applied to the effect, then the attack will be applied, followed by an infinite sustain. Units are used to define the time base.

Sample Period	DV - The period at which the device should play back the effect. A value of zero indicates that the default playback sample rate should be used. Units are used to define the time base. If the device is not capable of playing back the effect at the specified rate, it will choose the supported rate that is closest to the requested value. Setting a custom Sample Period can be used for special effects. For example, playing a sine wave at an artificially large sample period results in a rougher texture.
Gain	DV - The gain to be applied to the effect. The gain is a normalized scaling factor that is applied to all magnitudes and envelopes of an effect.
Trigger Button	DV - The identifier or offset of the button to be used to trigger playback of this effect. A Null Trigger Button value indicates that this Effect is not tied to a button.
Trigger Repeat Interval	DV - The auto-repeat interval, for playback of effects triggered by holding down the trigger button. The interval is the time between the end of the playing effect and start of the next effect. If this effect is a one-time effect (no auto-repeat is desired), this value should be set to INFINITE (Null). Units are used to define the time base.
Axes Enable	US – The *Axes Enable* collection contains joint collections. Each joint collection contains axes or vectors from the Generic Desktop page. This usage changes the type of these Generic Desktop usages to Dynamic Flags (DF) where each usage identifies whether the respective axis or vector is enabled for this effect.
Direction Enable	DF – If the *Direction Enable* flag is set then the Axes Enable flags are ignored, only one Condition Parameter Block is defined and the Direction is applied to the Condition Parameter Block as a polar direction.
Direction	CL – The *Direction* collection contains joint collections. Each joint collection contains axes or vectors from the Generic Desktop page. Each axis usage is treated as a Dynamic Variable (DV). If the values are in Cartesian coordinates then axes usages X, Y or Z or vector usages Vx, Vy or Vz will be declared in this collection as normalized values. If the values are in polar coordinates then axes usages Rx, Ry or Rz or vector usages Vbrx, Vbry or Vbrz will be declared in this collection as normalized values.
Start Delay	DV - The start delay interval, for the playback of effect. The interval is the time between an Op Effect Start or Op Effect Start Solo command and initiation of the effect. If no delay is desired this value should be set to 0. Units are used to define the time base.

5.1.1.1 Type Specific Block Offsets

The number of Type Specific Block Handles declared in an Effect report is determined by the following rules:

1) Custom Downloaded Effects do not use Envelope Blocks.
2) Effects that use Condition Blocks do not use Envelope Blocks.
3) Effects that use Condition Blocks require 1 Condition Block per axis.
4) Effects that do not use Condition Blocks use 1 Parameter Block and an optional Envelope Block.
5) Rules 2 through 4 apply to each declared joint.

The number of Type Specific Block Handles equals the number of joints times the number axes or 2, which ever is greater. The minimum of 2 will support an Envelope and one additional parameter block.

Number of Type Specific Block Offset = joints * (axes or 2, which ever is greater)

The following table lists the type of parameter block that a Type Specific Block Offsets point to for each Effect Type. The table assumes that the device has declared a single joint with two axes, X and Y. If the device had 3 axes then a third Type Specific Block Offset would have been declared. The third Offset would only be used for those Effect Types that require a Condition Block for the axis.

Table 3: Effect Types

Effect Type	Type Specific Block Offset 1	Type Specific Block Offset 2
ET Constant Force	Magnitude	Envelope
ET Ramp	Ramp	Envelope
ET Custom Force Data	Download Custom Force	NA
ET Square	Periodic	Envelope
ET Sine	Periodic	Envelope
ET Triangle	Periodic	Envelope
ET Sawtooth Up	Periodic	Envelope
ET Sawtooth Down	Periodic	Envelope
ET Spring	Condition (X Axis)	Condition (Y Axis)
ET Damper	Condition (X Axis)	Condition (Y Axis)
ET Inertia	Condition (X Axis)	Condition (Y Axis)
ET Friction	Condition (X Axis)	Condition (Y Axis)

Type Specific Block Offset	CL – This collection Ordinal usages to distinguish the individual Type Specific Block Offset fields. Depending on the effect type one or more fields will be valid. See Effect Types for a discussion of the required Offsets. The Parameter Blocks pointed to by these offsets must remain valid throughout the life of the effect.
Block Type	NAry – This collection contains an array item that lists the parameter Block Types supported by the device. The Selectors in this Named Array are the various PID report usages: Set Effect Report, Set Envelope Report, Set Condition Report, Set Periodic Report, Set Constant Report and Set Ramp Force Report. These overloaded usages identify the respective parameter block report.

5.2 Envelope Block Parameters

The Envelope Block describes the envelope to be used by an effect. Note that not all effect types use envelopes. The minimal Envelope parameter block must contain (Envelope) Parameter Block Index, Attack Level, Attack Time, Fade Level and Fade Time values.

Set Envelope Report	CL – This usage applies the logical collection that identifies the report associated with setting the envelope parameters of a PID. This collection must contain the *Attack Level, Attack Time, Fade Level* and *Fade Time* usages.
Attack Level	DV - Normalized amplitude for the start of the envelope, from the baseline.
Attack Time	DV - The transition time to reach the sustain level. Units are used to define the time base.
Fade Level	DV - Normalized amplitude to end the envelope, from baseline.

Fade Time	DV - The fade time to reach the fade level. Units are used to define the time base.

5.3 Condition Block Parameters

The minimal Condition parameter block must contain (Condition) Parameter Block Index, Center Point Offset, Positive Coefficient, Negative Coefficient, Positive Saturation, Negative Saturation and Dead Band values.

Different types of conditions will interpret the parameters differently, but the basic idea is that force resulting from a condition is equal to A(q - q0) where A is a scaling coefficient, q is some metric, and q0 is the neutral value for that metric.

The simplified formula given above must be adjusted if a nonzero dead band is provided. If the metric is less than CP Offset - Dead Band, then the resulting force is given by the following formula:

force = Negative Coefficient * (q - (CP Offset – Dead Band))

Similarly, if the metric is greater than CP Offset + Dead Band, then the resulting force is given by the following formula:

force = Positive Coefficient * (q - (CP Offset + Dead Band))

A spring condition uses axis position as the metric.
A damper condition uses axis velocity as the metric.
An inertia condition uses axis acceleration as the metric.

If the number of Condition report blocks is equal to the number of axes for the effect, then the first report block applies to the first axis, the second applies to the second axis, and so on. For example, a two-axis spring condition with CP Offset set to zero in both Condition report blocks would have the same effect as the joystick self-centering spring. When a condition is defined for each axis in this way, the effect must not be rotated.

If there is a single Condition report block for an effect with more than one axis, then the direction along which the parameters of the Condition report block are in effect is determined by the direction parameters passed in the Direction field of the Effect report block. For example, a friction condition rotated 45 degrees (in polar coordinates) would resist joystick motion in the northeast-southwest direction but would have no effect on joystick motion in the northwest-southeast direction.

Set Condition Report	CL – This usage applies the logical collection that identifies the report associated with setting the effect condition parameters. This collection must contain the *CP Offset*, *Positive Coefficient*, *Negative Coefficient*, *Positive Saturation*, *Negative Saturation* and *Dead Band* usages.
CP Offset	DV – The Normalized Center Point Offset. Offset from axis 0 position.
Positive Coefficient	DV - The Normalized coefficient constant on the positive side of the neutral position.
Negative Coefficient	DV - The Normalized coefficient constant on the negative side of the neutral position.
Positive Saturation	DV - The Normalized maximum positive force output.
Negative Saturation	DV - The Normalized maximum negative force output.

Dead Band	DV - The region around *CP Offset* where the condition is not active. In other words, the condition is not active between *Offset – Dead Band* and *Offset* + *Dead Band*. This value is Normalized.

5.4 Custom Forces

Custom Forces are analogous to audio sound files, they are "played" by the device. The analog continues in that, stereo audio files consist of samples of interleaved right and left channel data. Custom Forces consist of samples of interleaved axis data. Downloaded Custom Forces are stored in the device and then played back in real-time by the device from local memory.

An Effect block is created of type *ET Downloaded Custom Effect*. This effect is similar to a Periodic effect however the waveform, rather than being predefined by ET Sine, ET Sawtooth, etc., is supplied by the host. The waveform is downloaded into the devices Pool. To provide this functionality the Download Custom Force Parameter Block must be declared.

To provide this functionality three reports must be declared:
1) *Download Force Sample* to define the format of the downloaded data.
2) *Custom Force Data Report* to define to the report that moves the data to the device.
3) *Set Custom Force Report* to define the parameter block that is pointed to by the Effect block.

A *Download Force Sample* collection is declared to identify the format of the effect sample that the device is capable of playing from memory. I.e. Two 8-bit samples of X and Y data, three 16-bit samples of X, Y and Z data, etc. The Download Force Sample is defined with it's own Report ID. This report is never actually transferred to the device, it is simply used to declare the format of the downloaded samples.

The *Custom Force Data Report* is used to load the samples into the device. This report consists of 3 parts: *Parameter Block Offset*, *Generic Desktop: Byte Count* and the *Custom Force Data* itself. The *Parameter Block Offset* identifies the byte offset into the pool to start loading the *Custom Force Data*. The *Byte Count* identifies how many bytes of the *Custom Force Data* buffer are to be copied onto the pool.

The *Set Custom Force Report* defines the parameter block that is pointed to by the Type Specific Block Offset in the Effect parameter block. The Set Custom Force parameter block identifies the start offset in the pool and the size of the effect in samples of the data that has been loaded by the Custom Force Data Reports.

5.4.1 Sample Definition

A Sample declares the format of Custom Force data that the device is capable of handling. A sample consists of one or more axes. The size of the sample is a function of the number of axes and the size of their respective bit fields.

A *Force Sample* usage is a collection, which contains joint collections. Each joint collection contains axes from the Generic Desktop page or a *Normal* usage. These usages identify the number and types of axes in a sample. Each axis usage is treated as an Dynamic Variable (DV).

If the values are in Cartesian coordinates then linear axis (X, Y, Z) Axis or vector (Vx, Vy, Vz) usages will be declared in this collection.

If the values are in polar coordinates then a rotational axis (Rx, Ry, Rz) or vector (Vbrx, Vbry, Vbrx) usages will be declared in this collection.

Download Force Sample	CL – The *Download Force Sample* collection contains joint collections. This usage identifies the format of the force data

sample that the host must store in the Pool for later playback by the device.

5.4.2 Data Downloading

Downloading of custom effect data is performed using the *Custom Force Data Report*. This report consists of 3 parts: *Parameter Block Offset*, *Generic Desktop: Byte Count* and the *Custom Force Data* itself.
A Downloaded Custom Force parameter block consumes *Byte Count* bytes in the pool. This allows a Downloaded Custom Force parameter blocks to be loaded sequentially in the Pool, creating a custom force data buffer larger than the Report Count defined for the *Custom Force Data* field.

Custom Force Data Report	CL – This usage applies the logical collection that identifies the report associated with loading Custom Force data. This collection must contain *Parameter Block Offset*, *Generic Desktop: Byte Count* and *Custom Force Data usages.*
Custom Force Data	DV – The *Custom Force Data* usage is attached to a Buffered Bytes item that contains the data to be transferred. Units may be used to define the force value. If no units are declared then assume a normalized value.
Custom Force Vendor Defined Data	DV – The *Custom Force Vendor Defined Data* usage is attached to a Buffered Bytes item that contains the data to be transferred. The format of the data is vendor specific so a *Download Force Sample* is not required.

Samples are packed. A sample might not be an integral number of bytes in length, or the size of the Custom Force Data field may not be an integral number of samples in length, therefore a sample may not end on a byte boundary in the Custom Force Data buffer. If a custom force data buffer required in the device is larger than the Custom Force Data field, then sequential Custom Force Data buffers will have to be loaded into the Pool, and a sample may span Custom Force Data buffers.

For example, assume the following:

1) The Download Force Sample is defined as 3 axes (X, Y, Z) of 8 bit data, resulting in a 24 bit sample.
2) The Custom Force Data Field is 256 bytes in size.
3) The driver wants to load 100 samples (300 bytes).

The driver would send two *Download Custom Data Reports*, one with the *Byte Count* = 256, *Data Offset* = X and another with the *Byte Count* = 44, *Data Offset* = X+256. The first transfer would contain 85.33 samples and the second 14.66. This would form a contiguous 300-byte data buffer in the device's memory.

5.4.3 Custom Force Block Parameters

The minimal Downloaded Custom Force parameter block must contain (Downloaded Custom Force) Parameter Block Offset, Downloaded Custom Force Block Offset and Sample Count values.

Set Custom Force Report	CL – This usage applies the logical collection that identifies the report associated with setting the downloaded custom force effect parameters.
Custom Force Data Offset	DV – Offset into the Pool where the Downloaded Custom Force data starts.
Sample Count	DV – The number of Downloaded Custom Force samples in a single period of the effect.

5.5 Periodic Block Parameters

The minimal Periodic parameter block must contain (Periodic) Parameter Block Index, Magnitude, Offset, Phase and Period values. Once started a periodic effect will loop every *Period* until a Pause or Stop command is received.

Set Periodic Report	CL – This usage applies the logical collection that identifies the report associated with setting the periodic effect parameters. This collection must contain the *Magnitude, Offset, Phase* and *Period* usages.
Offset	DV - Normalized baseline offset. The range of forces generated by the effect will be Offset - Magnitude to Offset + Magnitude. The value of the Offset member is also the baseline for any envelope that is applied to the effect.
Magnitude	DV - The Normalized magnitude of the effect. If an envelope is applied to this effect, then the value represents the magnitude of the envelope. If no envelope is applied, then the value represents the amplitude of the entire effect.
Phase	DV - Determines the position in the wave that playback begins. This is a Normalized value between 0 and 360 degrees. The angular increment is defined by the resolution of the field. A device driver may not provide support for all values of Phase. In this case the value will be rounded off to the nearest supported value.
Period	DV - The period of the effect. Units are used to define the time base.

5.6 Constant Force Block Parameters

The minimal Ramp Force parameter block must contain (Constant Force) Parameter Block Index and Magnitude values.

Set Constant Force Report	CL – This usage applies the logical collection that identifies the report associated with setting the Constant Force effect parameters. This collection must contain the *Magnitude* usages.

5.7 Ramp Force Block Parameters

The minimal Ramp Force parameter block must contain (Ramp Force) Parameter Block Index, Ramp Start and Ramp End values.

Note: The Duration for a ramp force effect cannot be INFINITE.

Set Ramp Force Report	CL – This usage applies the logical collection that identifies the report associated with setting the Ramp Force effect parameters. This collection must contain the *Ramp Start* and *Ramp End* usages.
Ramp Start	DV - The Normalized magnitude at the start of the effect.
Ramp End	DV - The Normalized magnitude at the end of the effect.

5.8 Vendor Defined Parameter Blocks

In a Vendor Defined Parameter Block a vendor can use:

1) Usages defined in the PID spec.; Offset, Magnitude, etc.
2) Vendor define usages from their own usage page.

To be consistent with this document, vendor defined parameter blocks should be defined using a similar format.

1) Using a unique Report ID for each vendor defined report
2) Wrapping the report in a Set xxx Report logical collection, where the Set xxx Report is the vendor defined name on their usage page.
3) Include a Parameter Block Offset or a Block Handle.

5.9 Effect Operations

This report is used to control the operation of effects.

Effect Operation Report	CL – This usage applies the logical collection that identifies the report associated with setting the effect operational parameters. This collection must contain *Effect Block Index, Operation* and *Loop Count* usages.
Operation	NAry - Operation to perform on the effect identified by the Effect ID. This named array that contains Operation (Op) selectors.
Op Effect Start	Sel - Start the effect identified by the Effect Handle.
Op Effect Start Solo	Sel - Start the effect identified by the Effect Handle and stop all other effects.
Op Effect Stop	Sel - Stop the effect identified by the Effect Handle.
Loop Count	DV – The number of times the device will repeat the operation. i.e. a Stop command is not required. A INFINITE value implies “loop for ever”.

5.10 Device Operations

This report is used to control the operation of the overall device.

Device Operation Report	CL – This usage applies the logical collection that identifies the report associated with setting the device operational parameters. This collection can contain a *Device Gain* usage.
Device Gain	DV - The device gain to be applied to all effects on the device. The device gain is a normalized scaling factor applied to all magnitudes and envelopes of an effect, scaling the final output of the device.

5.11 Parameter Block Management

Parameter Blocks are stored in the PID class device. A vendor can choose whether to let the system driver manage the parameter block pool or manage it themselves.

When the driver manages the Parameter Block Pool, the device simply provides a block of memory (the Pool) where the driver loads Parameter Blocks. All decisions as to where to load Parameter Blocks, are made by the driver. The driver maintains a list of all Parameter Blocks that are currently stored in the pool and will perform any garbage collection that is required.

If a device manages it’s own pool then the driver simply passes Parameter Blocks to the device and receives either a negative acknowledgement if there was no room for the block or a positive acknowledgement and a handle for the block if there was room. The handle is used for all future references to the Parameter Block.

5.11.1 Driver Managed

A driver reads the PID Pool Report to identify the size of the RAM and ROM spaces on the device, and the size of the individual parameter blocks (Reports) to be stored there. The RAM Pool size identifies the amount of read/write storage available for parameter blocks. The pool is logically divided into two spaces: the Effect Parameter Block array and the general Pool. The driver manages the space allocation in the Pool and all parameter block types except Effect Parameter Blocks are referenced by their byte offset from the beginning of the Pool.

For efficiency, Effect Parameter Blocks are handled slightly differently. An array of Effect Parameter Blocks always starts at the first location of the Pool. Effect Parameter Blocks are accessed by their index in this array. If a driver determines it wants to store 10 Effects in the device at one time and the Effect Parameter Block is 12 bytes long then the first 120 bytes of the Pool will be occupied by the Effect Parameter Block array. The remainder of the pool will be allocated to the other types of parameter blocks. This approach allows a device with a large Pool (1 MByte) to have a compact Operation field in the PID Operation Output Report.

ROM based effects are also supported. ROM based parameter blocks are accessed the same way that RAM based effects are. The only difference is that they are read-only. A driver can read in the ROM parameter blocks to determine the effects that are stored in the device.

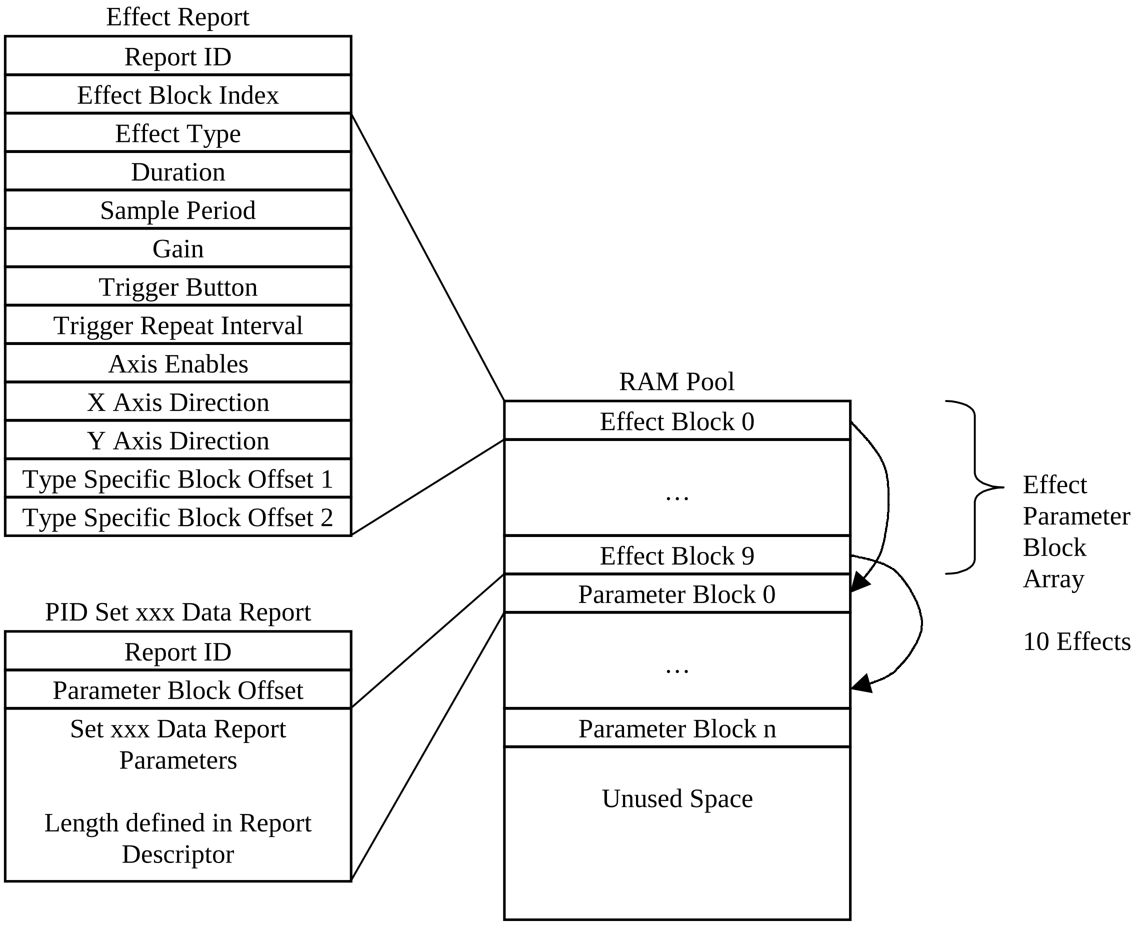
Because pool allocation for parameter blocks is managed by the driver, the driver will know which types of blocks it has loaded and where. The device uses the Effect Type field in the Effect Parameter Block to identify the type(s) of Parameter blocks that the Type Specific Block Offsets point to.

Figure 1 assumes the RAM Pool is initially empty. The Effect Parameter Block Array always starts at the beginning of memory. The Effect Block Index field determines the location in the Effect Parameter Block Array where the Effect Parameter Block will be loaded. In this example space is allocated for 10 Effects.

Note that the space allocated for a single Effect Parameter Block in the RAM Pool is the size of the Effect Report **minus** the size of the Report ID, Effect Block Index and ROM Flag fields if there is one. The same is true for all other types of Parameter Blocks however they can be placed anywhere in the available Pool space. The Report ID identifies the size and type of the Parameter Block while the Effect Block Index and ROM Flag fields identify the offset of the Parameter Block in the Pool. This information is stripped from the Parameter Block before it is stored in memory to save space.

Figure 1 shows the Parameter Blocks immediately following the Effect Parameter Block Area. The arrows on the right show how the Type Specific Block Offset of a Effect Parameter Block will point to any Parameter Blocks associated with that Effects Parameter Block.

Figure 1: Report Allocation in the Pool

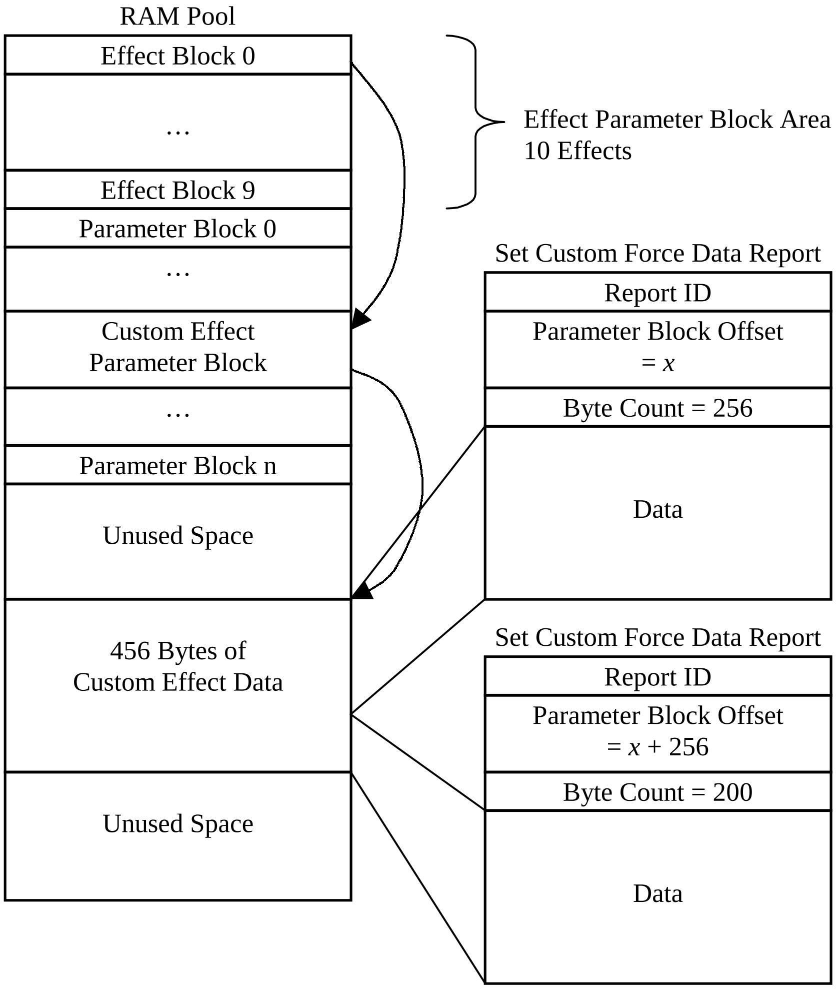


Custom Effect Data is stored in memory as a large contiguous block that is formed by concatenating the Data portion of Set Custom Force Data Reports. In this case the Byte Count is also stripped be for storing the data. Figure 2 shows two Set Custom Force Data Reports, the first containing 256 bytes of data and the second containing 200 bytes. The Data portions of these reports are concatenated starting at the Parameter Block Offset in the Pool. This will generate a 456 byte Custom Force Data Block in the Pool.

The arrows in the center represent how the Type Specific Block Offset of a Effect Parameter Block will point to a Custom Effect Parameter Block which in turn points to the Custom Effect Data. This all assumes that the Type of the Effect is Custom Effect.

Other than the Effect Parameter Blocks the placement of Parameter Blocks and Custom Effect Data in the Pool is determined strictly by the driver. The driver may group blocks of like size or employ other techniques to minimize fragmentation of the Pool.

Figure 2: Custom Effect Allocation in the Pool


RAM Pool
Effect Block 0
…
Effect Block 9
Parameter Block 0
…
Custom Effect Parameter Block
…
Parameter Block n
Unused Space
456 Bytes of Custom Effect Data
Unused Space
Effect Parameter Block Area
10 Effects
Set Custom Force Data Report
Report ID
Parameter Block Offset = x
Byte Count = 256
Data
Set Custom Force Data Report
Report ID
Parameter Block Offset = x + 256
Byte Count = 200
Data

The following usages are only used by devices that let the driver manage their Parameter Block pool.

PID Pool Report	CL – This usage applies the logical collection that identifies the report associated with setting the overall PID control parameters.
RAM Pool Size	DV - The size of the PID RAM parameter pool in bytes.
ROM Pool Size	SV - The size of the PID ROM parameter pool in bytes.
ROM Effect Block Count	SV - The number of ROM Effect Parameter blocks in the ROM parameter pool.
Simultaneous Effects Max	SV – The maximum number of simultaneous effects supported by the device. A device declares this usage to indicate the total number of effects that it can execute at one time.
Pool Alignment	SV – The block start address alignment boundary in bytes. This usage can be defined by a device so that parameter blocks start on 16-bit (Pool Alignment = 2) or 32-bit boundaries (Pool Alignment = 4) etc. If undefined then Pool Alignment = 1 is assumed.
Parameter Block Size	CL – This usage only applies to a Driver Managed pool. It is a logical collection that identifies the size that host should allocate for each fixed size Parameter Block in the Pool. That is, any Report collection that contains an *Parameter Block Index* usage declaration and does not declare a *Generic Desktop:Byte Count*. This collection changes the meaning of the Usages that it contains. The possible included usages are: the *Set Effect Report*, *Set Envelope Report*, *Set Condition Report*, *Set Custom Force Report*, *Set Periodic Report*, *Set Constant Force Report* and *Set Ramp Force Report* Logical Collection (LC) usages. These LC usages each define specific reports that require space in the Pool. When found in a *Parameter Block Size* collection the type of these usages change from a Logical Collection (LC) to a Static Variable (SV), which define the size, in bytes, of the respective report. Note that the *Custom Force Data Report* normally defines a variable sized parameter block that can be loaded in the Pool. A *Generic Desktop: Byte Count* usage is used to define the size of the parameter block dynamically.

When the Pool gets fragmented the driver must perform garbage collection to compact the valid Parameter Blocks and to free the unused ones. The PID Pool Move Report is issued to the device to copy data form one place to another in the Pool. This also allows the device to move any private data that it may have associated with a Parameter Block.

PID Pool Move Report	CL – This usage applies the logical collection that identifies the report associated with moving Parameter Blocks in the Pool for garbage collection. The host must update any effect specific references. Moving a parameter block of an effect that is playing will result in undefined behavior.
Move Source	DV – The source offset of the Parameter Block.
Move Destination	DV – The destination offset of the Parameter Block.
Move Length	DV – The size of the Parameter Block to move in bytes.

Note: The *Data Offset* fields must be declared large enough to access the full extent of the RAM and ROM Pools.

5.11.2 Device Managed

When the device manages Parameter Blocks, the Pool is not visible to the driver. Instead of the *Parameter Block Offset* in Set *PB* Reports, the *Handshake Key* would be used. The *Handshake Key* is a unique identifier generated by the driver. This key is passed back by the device to identify the *PID Block Load Report* that corresponds to the originating Set *PB* Report. The *PID Block Load Report* with the associated *Block Load Status* and *Block Handle* will indicate whether the device was able to load the Parameter Block. If successful, then the driver can use the *Block Handle* to refer to the Parameter Block in the device.

The *Type Specific Block Handle* will be used in the *Set Effect Report* (rather than the *Type Specific Block Offset*) to reference the associated Parameter Block.

When the driver is done with a Parameter Block it will issue a *PID Block Free Report* to inform the device that it could release the parameter block and perform any necessary garbage collection.

This approach allows a device vendor to manage it's own Pool memory, however every Set *PB* Report command will have to wait for a *PID Block Load Report* to be returned before the driver knows whether the command was successful.

The device uses the Effect Type field in the Effect Parameter Block to identify the type(s) of Parameter blocks that the *Type Specific Block Handle*s point to.

The following usages are only used by devices that manage their own Parameter Block pool.

PID Block Load Report	CL – This usage applies the logical collection that identifies the report associated with a device's response to a Set *PB* Report.
Handshake Key	DV – When the parameter block pool is managed by the device this field is found in the Set *PB* Report and the PID Block Load Report. The Handshake Key is used by the driver to match the Set *PB* Reports and the PID Block Load Reports.
Block Load Status	NAry – Identifies the completion status of a Set *PB* Report request. This named array contains Block Load selectors.
Block Load Success	Sel – The Set *PB* Report command successfully completed.
Block Load Full	Sel – The Set *PB* Report command failed to complete because there was no room in the device's parameter block pool.
Block Load Error	Sel – The Set *PB* Report command failed to complete because an error occurred in the device.
Block Handle	SV – A unique identifier that can be used to access a Parameter Block.
PID Block Free Report	CL – This usage applies the logical collection that identifies the report associated with freeing a Parameter Block in a device. This report will contain the *Block* Handle to free.
Type Specific Block Handle	CL – This collection uses Ordinal usages to distinguish the individual Type Specific Block Handle fields. Depending on the effect type one or more fields will be valid. See Effect Types for a discussion of the required Handles.

The Parameter Blocks referenced by these handles must remain valid throughout the life of the effect.

5.12 PID State

PID State Report	CL – This usage applies the logical collection that identifies the report associated with identifying and setting the PID state.
PID Effect State	NAry –The state of the effect identified by the Effect Handle. This is a named array that contains Effect State (PES) selectors.
ES Playing	Sel – The effect identified by the Effect Handle is playing.
ES Stopped	Sel – The effect identified by the Effect Handle is stopped.
PID Device Control	NAry –This usage controls the overall state of the device. This is a named array that contains Device Control (DC) selectors.
DC Enable Actuators	Sel – Enable all device actuators.
DC Disable Actuators	Sel – Disable all the device actuators.
DC Stop All Effects	Sel - Issues a stop on every running effect.
DC Reset	Sel – Clears any device paused condition, enables all actuators and clears all effects from memory.
DC Pause	Sel – The all effects on the device are paused at the current time step.
DC Continue	Sel – The all effects that running when the device was paused are restarted from their last time step.
Device Paused	DF – Indicates that all effects on the device are paused. All effects on the device are paused at the current time step.
Actuators Enabled	DF – Indicates that the device’s actuators are enabled.
Safety Switch	DF – A control indicating the state of the Safety switch on the device. If the *Safety Flag* is set and the device is usable. (Read-only)
Actuator Override Switch	DF – This is an actuator override switch available to the user. The user enables the device’s actuators if this flag is set.
Actuator Power	OOC - When read back this usage indicates the current actuator power status. (Read-only)

6. PID Example

This is an example of a joystick with force feedback capabilities. This device does support Effects, . isochronous and downloaded Custom Force operations. The RAM Pool Size is 256 bytes and the ROM Pool size is 32 K bytes.

In this example the Generic Desktop Pointer is considered a joint and items related to that joint are tied together in Generic: Desktop Pointer physical collections. You will see this demonstrated in the input report axes, Axes Enable fields and the Custom Effect Force axes.

This device supports all Effect Types except Friction.

There are 2 Input Reports: PID Data (stick and button state) and PID State (effect state). 10 output reports: Set Effect, Set Envelope, Set Condition, Set Periodic, Set Constant Force, Set Ramp Force, Set Custom Force, Download Force Sample, Set Custom Force and Effect Operation. And 1 Feature report: Pool

```
USAGE_PAGE (Generic Desktop)                                05 01
REPORT_ID (1)                                               85 01
LOGICAL_MINIMUM (0)                                         15 00
USAGE (Joystick)                                            09 04
COLLECTION (Application)                                    A1 01

        ;Start Joystick input definition

  USAGE_PAGE (Simulation Controls)                          05 02
  USAGE (Throttle)                                          09 BB
  LOGICAL_MINIMUM (-127)                                    15 81
  LOGICAL_MAXIMUM (127)                                     25 7F
  REPORT_SIZE (8)                                           75 08
  REPORT_COUNT (1)                                          95 01
  INPUT (Data,Var,Abs)                                      81 02
  USAGE_PAGE (Generic Desktop)                              05 01

;Define the axes
  USAGE (Pointer)                                           09 01
  COLLECTION (Physical)                                     A1 00
    USAGE (X)                                               09 30
    USAGE (Y)                                               09 31
    REPORT_COUNT (2)                                        95 02
    INPUT (Data,Var,Abs)                                    81 02
  END_COLLECTION                                            C0

:Define the hat switch
  USAGE (Hat switch)                                        09 39
  LOGICAL_MINIMUM (0)                                       15 00
  LOGICAL_MAXIMUM (3)                                       25 03
  PHYSICAL_MINIMUM (0)                                      35 00
  PHYSICAL_MAXIMUM (270)                                    46 0E 01
  UNIT (Eng Rot:Angular Pos)                                66 14 00
  REPORT_SIZE (4)                                           75 04
  REPORT_COUNT (1)                                          95 01
  INPUT (Data,Var,Abs)                                      81 02
  PHYSICAL_MAXIMUM (0)                                      45 00
  UNIT (None)                                               66 00 00
```

:Define the buttons

```
  USAGE_PAGE (Button)                                       05 09
  USAGE_MINIMUM (Button 1)                                  19 01
  USAGE_MAXIMUM (Button 4)                                  29 04
  LOGICAL_MAXIMUM (1)                                       25 01
  REPORT_COUNT (4)                                          95 04
  REPORT_SIZE (1)                                           75 01
  PHYSICAL_MINIMUM (0)                                      35 00
  INPUT (Data,Var,Abs)                                      81 02
```

;End Joystick Input definition

;Start Force Feedback command definitions

```
  USAGE_PAGE (Physical Interface)                           05 0F
```

;Effect Report Definition

```
  USAGE (Set Effect Report)                                 09 21
  COLLECTION (Logical)                                      A1 02
    REPORT_ID (1)                                           85 01
    USAGE (Effect Block Index)                              09 22
    LOGICAL_MAXIMUM (127)                                   25 7F
    REPORT_SIZE (7)                                         75 07
    REPORT_COUNT (1)                                        95 01
    OUTPUT (Data,Var,Abs)                                   91 02

    USAGE (ROM Flag)                                        09 24
    LOGICAL_MAXIMUM (1)                                     25 01
    REPORT_SIZE (1)                                         75 01
    OUTPUT (Data,Var,Abs)                                   91 02
```

;Define the available effect types. Effect Type is a named array that will
; accept any of the ET usages listed.

```
    USAGE (Effect Type)                                     09 25
    COLLECTION (Logical)                                    A1 02
      USAGE (ET Constant Force)                             09 26
      USAGE (ET Ramp)                                       09 27
      USAGE (ET Square)                                     09 30
      USAGE (ET Sine)                                       09 31
      USAGE (ET Triangle)                                   09 32
      USAGE (ET Sawtooth Up)                                09 33
      USAGE (ET Sawtooth Down)                              09 34
      USAGE (ET Spring)                                     09 40
      USAGE (ET Damper)                                     09 41
      USAGE (ET Inertia)                                    09 42
      LOGICAL_MINIMUM (1)                                   15 01
      LOGICAL_MAXIMUM (10)                                  25 0A
      REPORT_SIZE (8)                                       75 08
      OUTPUT (Data,Ary,Abs)                                 91 00
    END_COLLECTION                                          C0

    USAGE (Duration)                                        09 50
    USAGE (Trigger Repeat Interval)                         09 54
    LOGICAL_MINIMUM (0)                                     15 00
    LOGICAL_MAXIMUM (10000)                                 26 10 27
    PHYSICAL_MAXIMUM (10000)                                46 10 27
    REPORT_SIZE (16)                                        75 10
    UNIT (Eng Lin:Time)                                     66 03 10
    UNIT_EXPONENT (-3)                                      55 0D
```

```
REPORT_COUNT (2)                                        95 02
OUTPUT (Data,Var,Abs)                                   91 02

UNIT_EXPONENT (-6)                                      55 0A
USAGE (Sample Period)                                   09 51
REPORT_COUNT (1)                                        95 01
OUTPUT (Data,Var,Abs)                                   91 02
PHYSICAL_MAXIMUM (0)                                    45 00
UNIT_EXPONENT (0)                                       55 00
UNIT (None)                                             65 00

USAGE (Gain)                                            09 52
USAGE (Trigger Button)                                  09 53
LOGICAL_MAXIMUM (127)                                   25 7F
REPORT_SIZE (8)                                         75 08
REPORT_COUNT (2)                                        95 02
OUTPUT (Data,Var,Abs)                                   91 02

USAGE (Axes Enable)    ; Tie these axes to the stick    09 55
COLLECTION (Logical)                                    A1 02
  USAGE_PAGE (Generic Desktop)                          05 01
  USAGE (Pointer)                                       09 01
  COLLECTION (Physical)                                 A1 00
    USAGE (X)                                           09 30
    USAGE (Y)                                           09 31
    LOGICAL_MAXIMUM (1)                                 25 01
    REPORT_SIZE (1)                                     75 01
    REPORT_COUNT (2)                                    95 02
    OUTPUT (Data,Var,Abs)                               91 02
  END_COLLECTION                                        C0

  REPORT_COUNT (6)     ; 6-bit pad                      95 06
  OUTPUT (Cnst,Var,Abs)                                 91 03

  USAGE_PAGE (Physical Interface)                       05 0F
  USAGE (Direction)                                     09 57
  COLLECTION (Logical)                                  A1 02
    USAGE_PAGE (Generic Desktop)                        05 01
    USAGE (Pointer)     ; Tie these axes to the stick   09 01
    COLLECTION (Physical)                               A1 00
      USAGE (X)                                         09 30
      USAGE (Y)                                         09 31
      LOGICAL_MINIMUM (0)                               15 00
      LOGICAL_MAXIMUM (255)                             26 FF 00
      PHYSICAL_MAXIMUM (360)                            46 68 01
      UNIT (Eng Rot:Angular Pos)                        66 14 00
      REPORT_SIZE (8)                                   75 08
      REPORT_COUNT (2)                                  95 02
      OUTPUT (Data,Var,Abs)                             91 02
      UNIT (None)                                       65 00
      PHYSICAL_MAXIMUM (0)                              45 00
    END_COLLECTION                                      C0
  END_COLLECTION                                        C0

  USAGE_PAGE (Physical Interface)                       05 0F
  USAGE (Type Specific Block Offset)                    09 58
  COLLECTION (Logical)                                  A1 02
    USAGE (Ordinals:Instance 1)                         0B 01 00 0A 00
```

```
        USAGE (Ordinals:Instance 2)                         0B 02 00 0A 00
        LOGICAL_MAXIMUM (32765) ; 32K RAM or ROM max.       26 FD 7F
        REPORT_SIZE (16)                                    75 10
        REPORT_COUNT (2)                                    95 02
        OUTPUT (Data,Var,Abs)                               91 02
      END_COLLECTION                                        C0
    END_COLLECTION                                          C0
```

;Envelope Report Definition

```
    USAGE (Set Envelope Report)                             09 5A
    COLLECTION (Logical)                                    A1 02
      REPORT_ID (2)                                         85 02
      USAGE (Parameter Block Offset)                        09 23
      LOGICAL_MAXIMUM (32765) ; 32K RAM or ROM max          26 FD 7F
      REPORT_SIZE (15)                                      75 0F
      REPORT_COUNT (1)                                      95 01
      OUTPUT (Data,Var,Abs)                                 91 02

      USAGE (ROM Flag)                                      09 24
      LOGICAL_MAXIMUM (1)                                   25 01
      REPORT_SIZE (1)                                       75 01
      OUTPUT (Data,Var,Abs)                                 91 02

      USAGE (Attack Level)                                  09 5B
      USAGE (Fade Level)                                    09 5D
      LOGICAL_MAXIMUM (255)                                 26 FF 00
      REPORT_SIZE (8)                                       75 08
      REPORT_COUNT (2)                                      95 02
      OUTPUT (Data,Var,Abs)                                 91 02

      USAGE (Attack Time)                                   09 5C
      USAGE (Fade Time)                                     09 5E
      LOGICAL_MAXIMUM (10000)                               26 10 27
      PHYSICAL_MAXIMUM (10000)                              46 10 27
      UNIT (Eng Lin:Time)                                   66 03 10
      UNIT_EXPONENT (-3)                                    55 0D
      REPORT_SIZE (16)                                      75 10
      OUTPUT (Data,Var,Abs)                                 91 02
      PHYSICAL_MAXIMUM (0)                                  45 00
      UNIT (None)                                           65 00
      UNIT_EXPONENT (0)                                     55 00
    END_COLLECTION                                          C0
```

;Condition Report Definition

```
    USAGE (Set Condition Report)                            09 5F
    COLLECTION (Logical)                                    A1 02
      REPORT_ID (3)                                         85 03
      USAGE (Parameter Block Offset)                        09 23
      LOGICAL_MAXIMUM (32765)                               26 FD 7F
      REPORT_SIZE (15)                                      75 0F
      REPORT_COUNT (1)                                      95 01
      OUTPUT (Data,Var,Abs)                                 91 02

      USAGE (ROM Flag)                                      09 24
      LOGICAL_MAXIMUM (1)                                   25 01
      REPORT_SIZE (1)                                       75 01
      OUTPUT (Data,Var,Abs)                                 91 02
      USAGE (CP Offset)                                     09 60
      USAGE (Positive Coefficient)                          09 61
      USAGE (Negative Coefficient)                          09 62
      USAGE (Positive Saturation)                           09 63
      USAGE (Negative Saturation)                           09 64
      USAGE (Dead Band)                                     09 65
      LOGICAL_MAXIMUM (255)                                 26 FF 00
      REPORT_SIZE (8)                                       75 08
      REPORT_COUNT (6)                                      95 06
      OUTPUT (Data,Var,Abs)                                 91 02
    END_COLLECTION                                          C0

;Periodic Report Definition
    USAGE (Set Periodic Report)                             09 6E
    COLLECTION (Logical)                                    A1 02
      REPORT_ID (4)                                         85 04
      USAGE (Parameter Block Offset)                        09 23
      LOGICAL_MAXIMUM (32765)                               26 FD 7F
      REPORT_SIZE (15)                                      75 0F
      REPORT_COUNT (1)                                      95 01
      OUTPUT (Data,Var,Abs)                                 91 02

      USAGE (ROM Flag)                                      09 24
      LOGICAL_MAXIMUM (1)                                   25 01
      REPORT_SIZE (1)                                       75 01
      OUTPUT (Data,Var,Abs)                                 91 02

      USAGE (Magnitude)                                     09 70
      USAGE (Offset)                                        09 6F
      USAGE (Phase)                                         09 71
      LOGICAL_MAXIMUM (255)                                 26 FF 00
      REPORT_SIZE (8)                                       75 08
      REPORT_COUNT (3)                                      95 03
      OUTPUT (Data,Var,Abs)                                 91 02

      USAGE (Period)                                        09 72
      LOGICAL_MAXIMUM (10000)                               26 10 27
      PHYSICAL_MAXIMUM (10000)                              46 10 27
      UNIT (Eng Lin:Time)                                   66 03 10
      UNIT_EXPONENT (-3)                                    55 0D
      REPORT_SIZE (16)                                      75 10
      REPORT_COUNT (1)                                      95 01
      OUTPUT (Data,Var,Abs)                                 91 02
      PHYSICAL_MAXIMUM (0)                                  45 00
      UNIT (None)                                           65 00
      UNIT_EXPONENT (0)                                     55 00
    END_COLLECTION                                          C0

;Constant Force Report Definition
    USAGE (Set Constant Force Report)                       09 73
    COLLECTION (Logical)                                    A1 02
      REPORT_ID (5)                                         85 05
      USAGE (Parameter Block Offset)                        09 23
      LOGICAL_MAXIMUM (32765)                               26 FD 7F
      REPORT_SIZE (15)                                      75 0F
      REPORT_COUNT (1)                                      95 01
      OUTPUT (Data,Var,Abs)                                 91 02
      USAGE (ROM Flag)                                      09 24
      LOGICAL_MAXIMUM (1)                                   25 01
      REPORT_SIZE (1)                                       75 01
      OUTPUT (Data,Var,Abs)                                 91 02

      USAGE (Magnitude)                                     09 70
      LOGICAL_MAXIMUM (255)                                 26 FF 00
      REPORT_SIZE (8)                                       75 08
      OUTPUT (Data,Var,Abs)                                 91 02
    END_COLLECTION                                          C0
  END_COLLECTION                                            C0
```

;Ramp Force Report Definition

```
  USAGE (Set Ramp Force Report)                             09 74
  COLLECTION (Logical)                                      A1 02
    REPORT_ID (6)                                           85 06
    USAGE (Parameter Block Offset)                          09 23
    LOGICAL_MAXIMUM (32765)                                 26 FD 7F
    REPORT_SIZE (15)                                        75 0F
    REPORT_COUNT (1)                                        95 01
    OUTPUT (Data,Var,Abs)                                   91 02

    USAGE (ROM Flag)                                        09 24
    LOGICAL_MAXIMUM (1)                                     25 01
    REPORT_SIZE (1)                                         75 01
    OUTPUT (Data,Var,Abs)                                   91 02

    USAGE (Ramp Start)                                      09 75
    USAGE (Ramp End)                                        09 76
    LOGICAL_MAXIMUM (255)                                   26 FF 00
    REPORT_SIZE (8)                                         75 08
    REPORT_COUNT (2)                                        95 02
    OUTPUT (Data,Var,Abs)                                   91 02
  END_COLLECTION                                            C0
```

;Custom Force Data Report Definition
; Downloads are always into RAM space so the ROM usage is not declared.

```
  USAGE (Custom Force Data Report)                          09 68
  COLLECTION (Logical)                                      A1 02
    REPORT_ID (7)                                           85 07
    USAGE (Parameter Block Offset)                          09 23
    LOGICAL_MAXIMUM (32765)                                 26 FD 7F
    REPORT_SIZE (15)                                        75 0F
    REPORT_COUNT (1)                                        95 01
    OUTPUT (Data,Var,Abs)                                   91 02

    USAGE (Generic Desktop:Byte Count)                      0B 3B 00 01 00
    LOGICAL_MAXIMUM (256)                                   26 00 01
    REPORT_SIZE (9)                                         75 09
    OUTPUT (Data,Var,Abs)                                   91 02

    USAGE (Custom Force Data)                               09 69
    LOGICAL_MAXIMUM (255)                                   26 FF 00
    REPORT_SIZE (8)                                         75 08
    REPORT_COUNT (256)                                      96 00 01
    OUTPUT (Data,Var,Abs,Buf)                               92 02 01
  END_COLLECTION                                            C0
```

;Download Force Sample Definition

```
  USAGE (Download Force Sample)                             09 66
  COLLECTION (Logical)                                      A1 02
    REPORT_ID (8)                                           85 08
    USAGE_PAGE (Generic Desktop)                            05 01
    USAGE (Pointer)                                         09 01
    COLLECTION (Logical)                                    A1 02
      USAGE (X)                                             09 30
      USAGE (Y)                                             09 31
      LOGICAL_MINIMUM (-127)                                15 81
      LOGICAL_MAXIMUM (127)                                 25 7F
      REPORT_SIZE (8)                                       75 08
      REPORT_COUNT (2)                                      95 02
      OUTPUT (Data,Var,Abs)                                 91 02
    END_COLLECTION                                          C0
  END_COLLECTION                                            C0
  USAGE_PAGE (Physical Interface)                           05 0F
```

;Define the Custom Force parameter block
; Custom Effects are always RAM based
; so ROM flags are not declared.

```
  USAGE (Set Custom Force Report)                           09 6B
  COLLECTION (Logical)                                      A1 02
    REPORT_ID (9)                                           85 09
    ; Parameter block offset in pool
    ; Custom Force data offset in pool
    USAGE (Parameter Block Offset)                          09 23
    USAGE (Custom Force Data Offset)                        09 6C
    USAGE (Sample Count)                                    09 6D
    LOGICAL_MINIMUM (0)                                     15 00
    LOGICAL_MAXIMUM (32765) ; 32K of RAM or ROM max.        26 FD 7F
    REPORT_COUNT (3)                                        95 03
    REPORT_SIZE (16)                                        75 10
    OUTPUT (Data,Var,Abs)                                   91 02
  END_COLLECTION                                            C0
```

;Effect Operation Report Definition

```
  USAGE (Effect Operation Report)                           09 77
  COLLECTION (Logical)                                      A1 02
    REPORT_ID (10)                                          85 0A
    USAGE (Effect Block Index)                              09 22
    LOGICAL_MAXIMUM (127)                                   25 7F
    REPORT_SIZE (7)                                         75 07
    REPORT_COUNT (1)                                        95 01
    OUTPUT (Data,Var,Abs)                                   91 02

    USAGE (ROM Flag)                                        09 24
    LOGICAL_MAXIMUM (1)                                     25 01
    REPORT_SIZE (1)                                         75 01
    OUTPUT (Data,Var,Abs)                                   91 02

    USAGE (Operation)                                       09 78
    COLLECTION (Logical)                                    A1 02
      USAGE (Op Effect Start)                               09 79
      USAGE (Op Effect Start Solo)                          09 7A
      USAGE (Op Effect Stop)                                09 7B
      LOGICAL_MINIMUM (1)                                   15 01
      LOGICAL_MAXIMUM (3)                                   25 03
      REPORT_SIZE (8)                                       75 08
      OUTPUT (Data,Ary,Abs)                                 91 00
    END_COLLECTION                                          C0

    USAGE (Loop Count)                                      09 7C
    LOGICAL_MINIMUM (0)                                     15 00
    LOGICAL_MAXIMUM (255)                                   26 FF 00
    OUTPUT (Data,Ary,Abs)                                   91 00
  END_COLLECTION                                            C0

;PID Pool Report Definition
  USAGE (PID Pool Report)                                   09 7F
  COLLECTION (Logical)                                      A1 02
    REPORT_ID (1)                                           85 01
    USAGE (PID Pool Report)                                 09 7F
    USAGE (RAM Pool Size)                                   09 80
    USAGE (ROM Pool Size)                                   09 81
    LOGICAL_MAXIMUM (32765)                                 26 FD 7F
    REPORT_COUNT (3)                                        95 03
    REPORT_SIZE (16)                                        75 10
    FEATURE (Data,Var,Abs)                                  B1 02

    USAGE (Parameter Block Size)                            09 A8
    COLLECTION (Logical)                                    A1 02
      USAGE (Set Effect Report)                             09 21
      USAGE (Set Envelope Report)                           09 5A
      USAGE (Set Condition Report)                          09 5F
      USAGE (Set Periodic Report)                           09 6E
      USAGE (Set Constant Force Report)                     09 73
      USAGE (Set Ramp Force Report)                         09 74
      USAGE (Set Custom Force Report)                       09 6B
      LOGICAL_MAXIMUM (255)                                 26 FF 00
      REPORT_SIZE (8)                                       75 08
      REPORT_COUNT (7)                                      95 07
      FEATURE (Data,Var,Abs)                                B1 02
    END_COLLECTION                                          C0

    LOGICAL_MAXIMUM (1)                                     25 01
    REPORT_SIZE (7)                                         75 07
    REPORT_COUNT (1)                                        95 01
    FEATURE (Cnst,Var,Abs) ; 7-bit pad                      B1 03
    USAGE (Isoch Custom Force Enable)                       09 67
    REPORT_SIZE (1)                                         75 01
    FEATURE (Data,Var,Abs)                                  B1 02
  END_COLLECTION                                            C0

;PID State Report Definition
  USAGE (PID State Report)                                  09 92
  COLLECTION (Logical)                                      A1 02
    REPORT_ID (2)                                           85 02
    USAGE (Effect Block Index)                              09 22
    LOGICAL_MAXIMUM (127)                                   25 7F
    REPORT_SIZE (7)                                         75 07
    FEATURE (Data,Var,Abs)                                  B1 02

    USAGE (ROM Flag)                                        09 24
    LOGICAL_MAXIMUM (1)                                     25 01
    REPORT_SIZE (1)                                         75 01
    REPORT_COUNT (1)                                        95 01
    INPUT (Data,Var,Abs)                                    81 02

    USAGE (PID Effect State)                                09 93
    COLLECTION (Logical)                                    A1 02
      USAGE (ES Playing)                                    09 94
      USAGE (ES Stopped)                                    09 95
      LOGICAL_MINIMUM (1)                                   15 01
      LOGICAL_MAXIMUM (2)                                   25 02
      REPORT_SIZE (2)                                       75 02
      FEATURE (Data,Ary,Abs)                                B1 00
    END_COLLECTION                                          C0

    USAGE (Actuators Enabled)                               09 A0
    USAGE (Safety Switch)                                   09 A4
    USAGE (Actuator Power)                                  09 A6
    LOGICAL_MINIMUM (0)                                     15 00
    LOGICAL_MAXIMUM (1)                                     25 01
    REPORT_SIZE (1)                                         75 01
    REPORT_COUNT (3)                                        95 03
    FEATURE (Data,Var,Abs)                                  B1 02

    FEATURE (Cnst,Var,Abs)  ; 3-bit pad                     B1 03
  END_COLLECTION                                            C0

;PID Pool Move Report Definition
  USAGE (PID Pool Move Report)                              09 85
  COLLECTION (Logical)                                      A1 02
    REPORT_ID (11)                                          85 0B
    USAGE (Move Source)                                     09 86
    USAGE (Move Destination)                                09 87
    USAGE (Move Length)                                     09 88
    LOGICAL_MAXIMUM (32767)                                 26 FF 7F
    REPORT_SIZE (16)                                        75 10
    REPORT_COUNT (3)                                        95 03
    OUTPUT (Data,Var,Abs,Buf)                               92 02 01
  END_COLLECTION                                            C0
END_COLLECTION                                              C0
```

7. Example Reports

Figure 3: Example PID Data Input Report

	Bit							
Byte	7	6	5	4	3	2	1	0
0	Report ID = 1							
1	Throttle							
2	X-axis							
3	Y-axis							
4	Button 4	Button 3	Button 2	Button 1	Hat Switch			

Figure 4: Example PID Set Effect Output Report

	Bit							
Byte	7	6	5	4	3	2	1	0
0	Report ID = 1							
1	ROM Flag	Effect Block Index						
2	Effect Type							
3	Duration							
5	Sample Period							
6	Gain							
7	Trigger Button							
8	Trigger Repeat Interval							
9	Pad						Y Axis Enable	X Axis Enable
10	X Axis Direction							
11	Y Axis Direction							
12 - 13	Type Specific Block Offset 1							
14 - 15	Type Specific Block Offset 2							

Figure 5: Example PID Set Envelope Output Report

	Bit							
Byte	7	6	5	4	3	2	1	0
0	Report ID = 2							
1	Parameter Block Offset (bits 7 – 0)							
2	ROM Flag	Parameter Block Offset (bits 14 – 8)						
3	Attack Level							
4	Attack Time							
5	Fade Level							
6	Fade Time							

Figure 6: Example PID Set Condition Output Report

	Bit							
Byte	7	6	5	4	3	2	1	0
0	Report ID = 3							
1	Parameter Block Offset (bits 7 – 0)							
2	ROM Flag	Parameter Block Offset (bits 14 – 8)						
3	CP Offset							
4	Positive Coefficient							
5	Negative Coefficient							
6	Positive Saturation							
7	Negative Saturation							
8	Dead Band							

Figure 7: Example PID Set Periodic Output Report

	Bit							
Byte	7	6	5	4	3	2	1	0
0	Report ID = 4							
1	Parameter Block Offset (bits 7 – 0)							
2	ROM Flag	Parameter Block Offset (bits 14 – 8)						
3	Magnitude							
4	Offset							
5	Phase							
6	Period							

Figure 8: Example PID Set Constant Force Output Report

	Bit							
Byte	7	6	5	4	3	2	1	0
0	Report ID = 5							
1	Parameter Block Offset (bits 7 – 0)							
2	ROM Flag	Parameter Block Offset (bits 14 – 8)						
3	Magnitude							

Figure 9: Example PID Set Ramp Force Output Report

	Bit							
Byte	7	6	5	4	3	2	1	0
0	Report ID = 6							
1	Parameter Block Offset (bits 7 – 0)							
2	ROM Flag	Parameter Block Offset (bits 14 – 8)						
3	Ramp Start							
4	Ramp End							

Figure 10: Example PID Set Custom Force Data Output Report

	Bit							
Byte	7	6	5	4	3	2	1	0
0	Report ID =7							
1	Parameter Block Offset (bits 7 – 0)							
2	Byte Count (bit 0)	Parameter Block Offset (bits 14 – 8)						
3	Byte Count (bits 8-1)							
4-259	Custom Force Data (256 bytes)							

Figure 11: Example PID Download Force Sample Output Report

	Bit							
Byte	7	6	5	4	3	2	1	0
0	Report ID =8							
1	X Axis							
2	Y Axis							

Note: This report is never actually transferred.

Figure 12: Example PID Set Custom Force Output Report

	Bit							
Byte	7	6	5	4	3	2	1	0
0	Report ID = 9							
1-2	Parameter Block Offset							
3-4	Custom Force Data Offset							
5-6	Sample Count							

Figure 13: Example PID Effect Operation Output Report

	Bit							
Byte	7	6	5	4	3	2	1	0
0	Report ID = 10							
1	ROM Flag	Effect Block Index						
2	Operation							
3	Loop Count							

Figure 14: Example PID Pool Feature Report

Bit

Byte	7	6	5	4	3	2	1	0
0	Report ID = 1							
1	RAM Pool Size							
3	ROM Pool Size							
5	ROM Effect Block Count							
7	Parameter Block Size (Set Effect Report)							
8	Parameter Block Size (Set Envelope Report)							
9	Parameter Block Size (Set Condition Report)							
10	Parameter Block Size (Set Periodic Report)							
11	Parameter Block Size (Set Constant Force Report)							
12	Parameter Block Size (Set Ramp force Report)							
13	Parameter Block Size (Set Custom Force Report)							
14	Custom Force Enable	Pad						

Figure 15: Example PID State Feature Report

Bit

Byte	7	6	5	4	3	2	1	0
0	Report ID = 2							
1	ROM Flag	Effect Block Index						
2	Pad			Actuator Power	Safety Switch	Enable Actuators	PID State	

Figure 16: Example PID Custom Force Streaming Output Report

Bit

Byte	7	6	5	4	3	2	1	0
0	X Axis							
1	Y Axis							

Figure 17: Example PID Pool Move Output Report

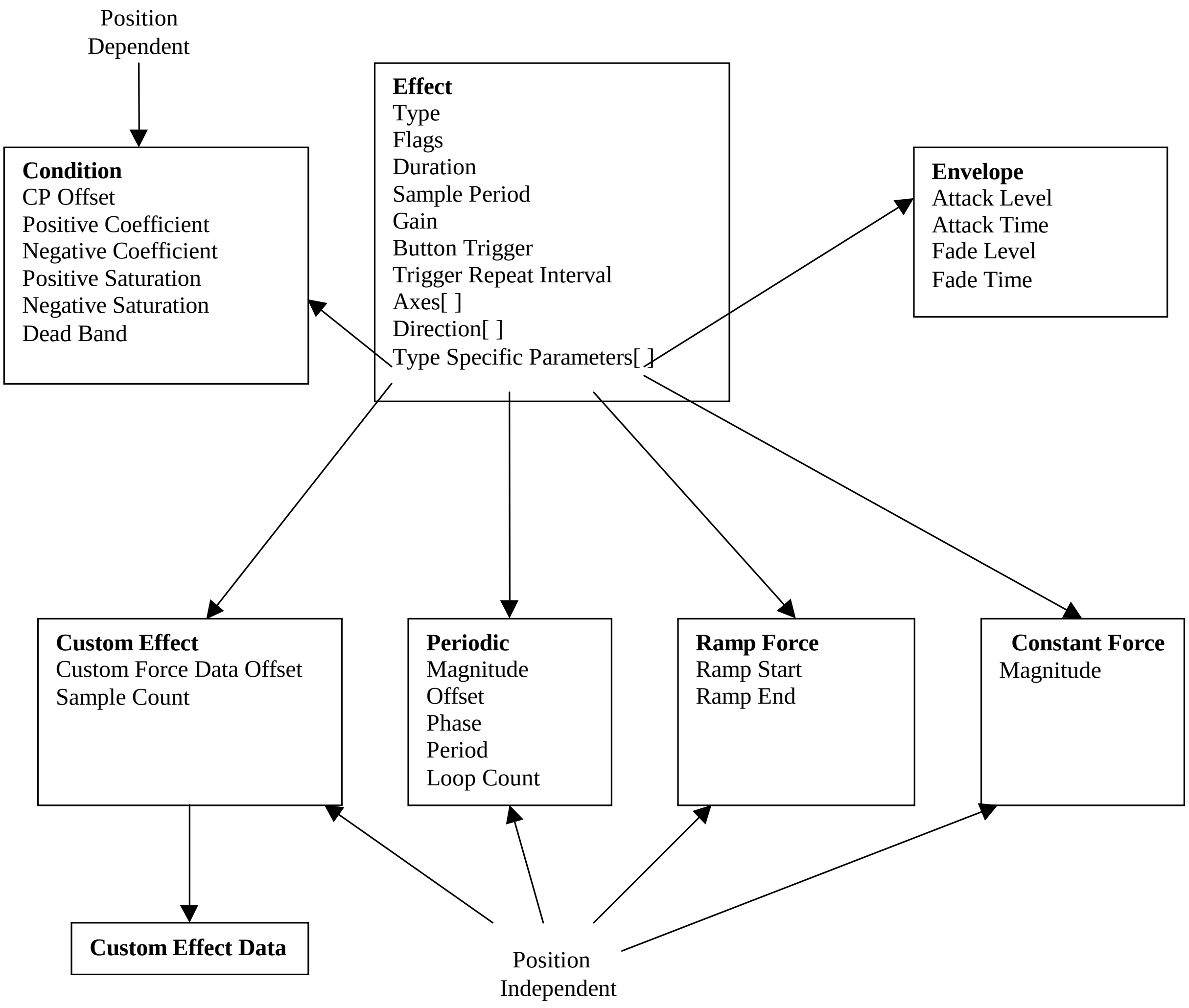
	Bit							
Byte	7	6	5	4	3	2	1	0
0	Report ID = 11							
1	Move Source							
3	Move Destination							
5	Move Length							

8. Parameter Blocks

Depending on the Effect Type the Type Specific Parameters of the Effect Parameter Block will point to or provide a Handle for other Parameter Block types.

Position Dependence and Position Independence is related to the position of the actuator not the position in the Pool.

Figure 18: Parameter Blocks


Position Dependent
Effect
Type
Flags
Duration
Sample Period
Gain
Button Trigger
Trigger Repeat Interval
Axes[ ]
Direction[ ]
Type Specific Parameters[ ]
Condition
CP Offset
Positive Coefficient
Negative Coefficient
Positive Saturation
Negative Saturation
Dead Band
Envelope
Attack Level
Attack Time
Fade Level
Fade Time
Custom Effect
Custom Force Data Offset
Sample Count
Periodic
Magnitude
Offset
Phase
Period
Loop Count
Ramp Force
Ramp Start
Ramp End
Constant Force
Magnitude
Custom Effect Data
Position Independent