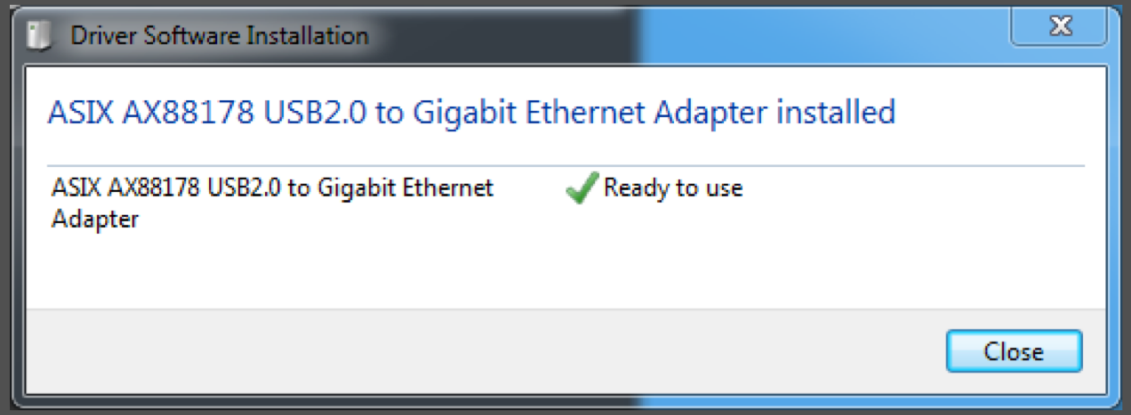
HACKING THE USB WORLD WITH FACEDANCER

ENUMERATION AND THE CONTROL ENDPOINT

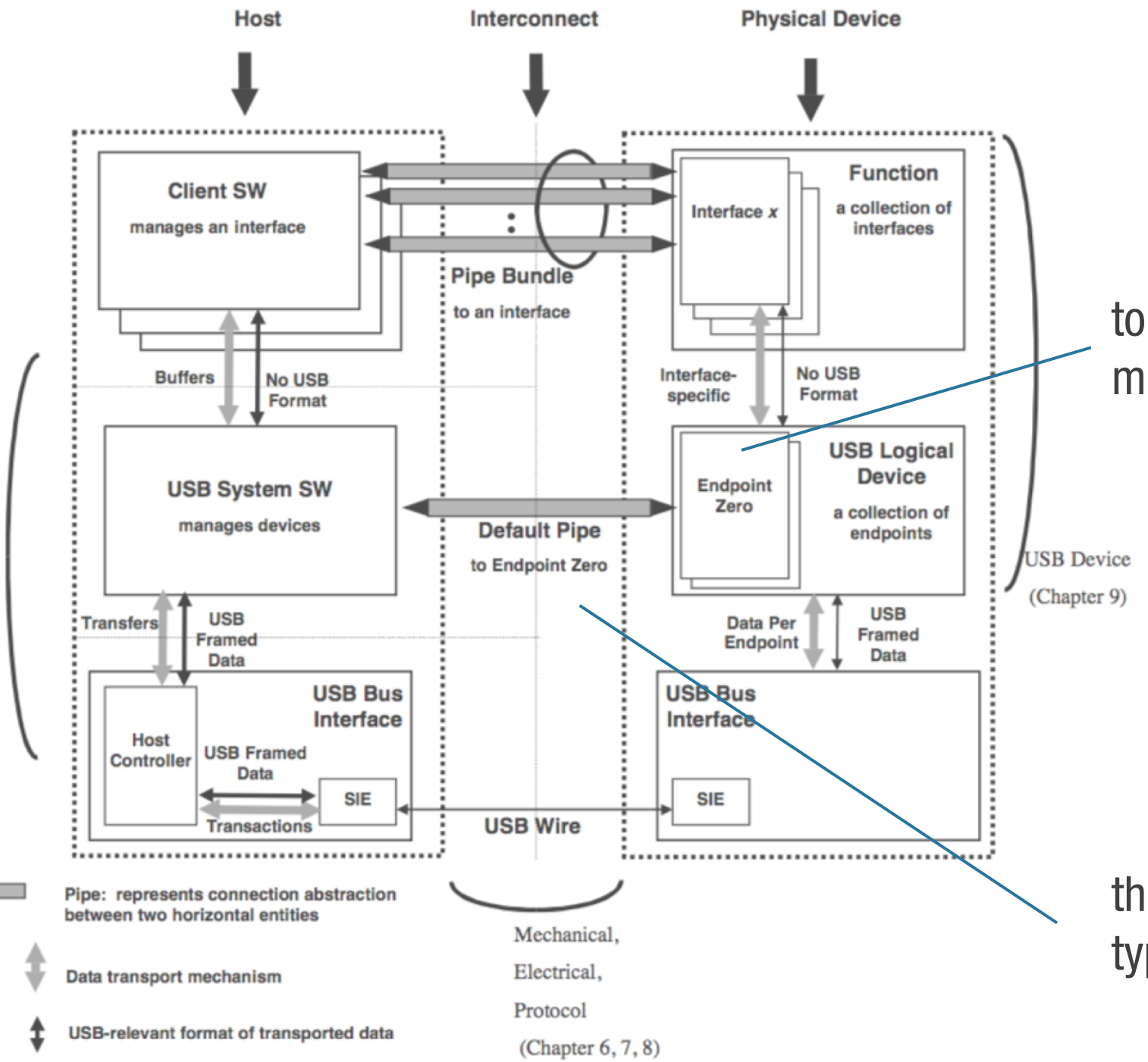
KATE TEMKIN & DOMINIC SPILL

```
ktemkin@mini ~$ lsusb
Bus 020 Device 020: ID 05e3:0612 Genesys Logic, Inc. Hub
Bus 020 Device 009: ID 21a9:1006 21a9 Logic Pro  Serial: SERNUM
Bus 020 Device 004: ID 0451:8140 Texas Instruments Hub
Bus 020 Device 013: ID 17e9:4301 DisplayLink (UK Ltd.) USB3.0 UHD DisplayPort Adapter  Serial: 000100160302793
Bus 020 Device 015: ID 17e9:4301 DisplayLink (UK Ltd.) USB3.0 UHD DisplayPort Adapter  Serial: 000100160280050
Bus 020 Device 017: ID 17e9:4301 DisplayLink (UK Ltd.) USB3.0 UHD HDMI Adapter  Serial: 000100160323886
Bus 020 Device 011: ID 17e9:4301 DisplayLink (UK Ltd.) USB3.0 UHD DisplayPort Adapter  Serial: 000100160285413
Bus 020 Device 021: ID 05e3:0610 Genesys Logic, Inc. USB2.0 Hub
Bus 020 Device 003: ID 0451:8142 Texas Instruments Hub  Serial: 77000879F8CE
Bus 020 Device 007: ID 05ac:8242 Apple Inc. IR Receiver
Bus 020 Device 008: ID 0a5c:4500 Broadcom Corp. BRCM20702 Hub
Bus 020 Device 019: ID 05ac:8289 Apple Inc. Bluetooth USB Host Controller
Bus 020 Device 006: ID 1a40:0201 TERMINUS TECHNOLOGY INC. USB 2.0 Hub [MTT]
Bus 020 Device 022: ID 0403:6001 Future Technology Devices International Limited test  Serial: ftE2G0FR
Bus 020 Device 010: ID 1852:7022 1852 DigiHug USB Audio
Bus 020 Device 018: ID 046d:c52b Logitech Inc. USB Receiver
Bus 020 Device 012: ID 256f:c62f 256f SpaceMouse Wireless Receiver
Bus 020 Device 016: ID 17f6:0905 Unicomp, Inc Endura Pro Keyboard
Bus 000 Device 001: ID 1d6b:ILPT Linux Foundation USB 3.0 Bus
ktemkin@mini ~$
```



enumeration allows devices to be identified and paired with the correct drivers automatically

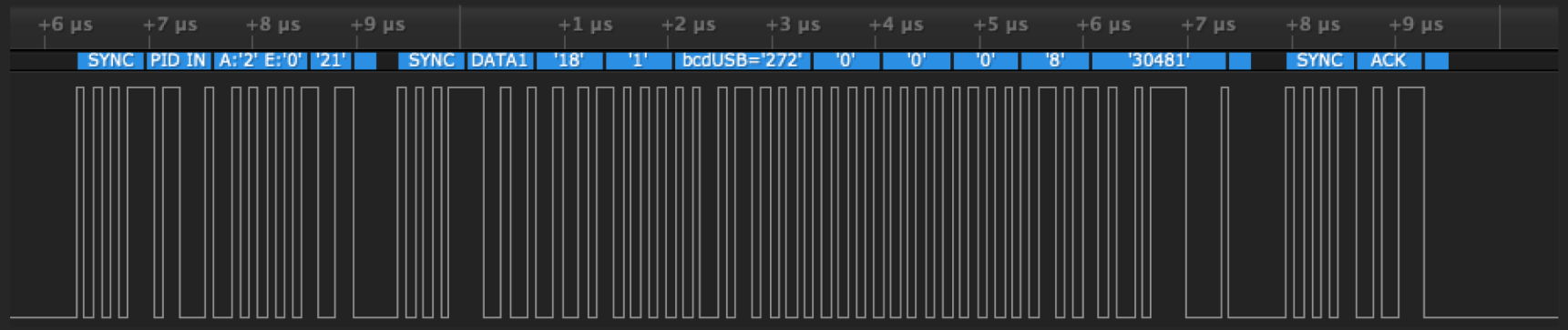
ENUMERATION



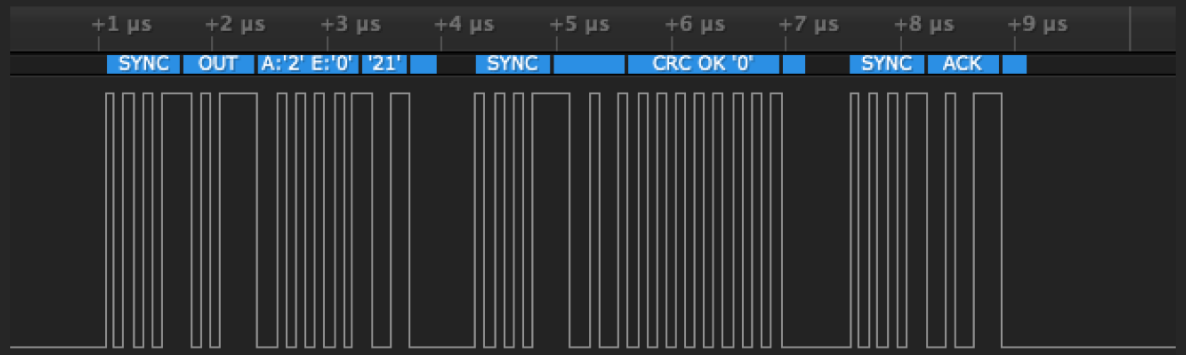
to support enumeration, every USB device must support a standard protocol on EP0

this protocol involves our first formal type of transfer: usb control requests

each control transfer is made up of a number of transactions…



…which form a simple command-and-response protocol.

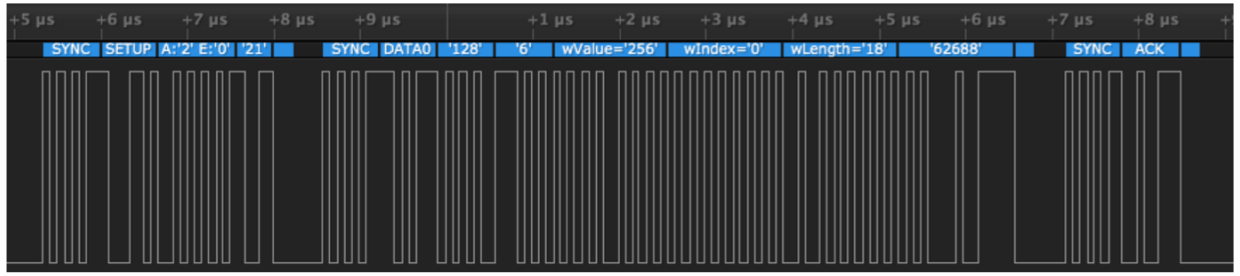


It's often helpful to think of these transactions at a higher level of abstraction…

Get Device Descriptor	Index=0 Length=18
SETUP txn	80 06 00 01 00 00 12 00
IN txn [1 POLL]	12 01 10 01 00 00 00 08
IN txn [4 POLL]	03 04 01 60 00 04 01 02
IN txn [1 POLL]	03 01
OUT txn	

Table 9-2. Format of Setup Data

Offset	Field	Size	Value	Description
0	*bmRequestType*	1	Bitmap	Characteristics of request: D7: Data transfer direction 0 = Host-to-device 1 = Device-to-host D6...5: Type 0 = Standard 1 = Class 2 = Vendor 3 = Reserved D4...0: Recipient 0 = Device 1 = Interface 2 = Endpoint 3 = Other 4...31 = Reserved
1	*bRequest*	1	Value	Specific request (refer to Table 9-3)
2	*wValue*	2	Value	Word-sized field that varies according to request
4	*wIndex*	2	Index or Offset	Word-sized field that varies according to request; typically used to pass an index or offset
6	*wLength*	2	Count	Number of bytes to transfer if there is a Data stage



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OUT txn	

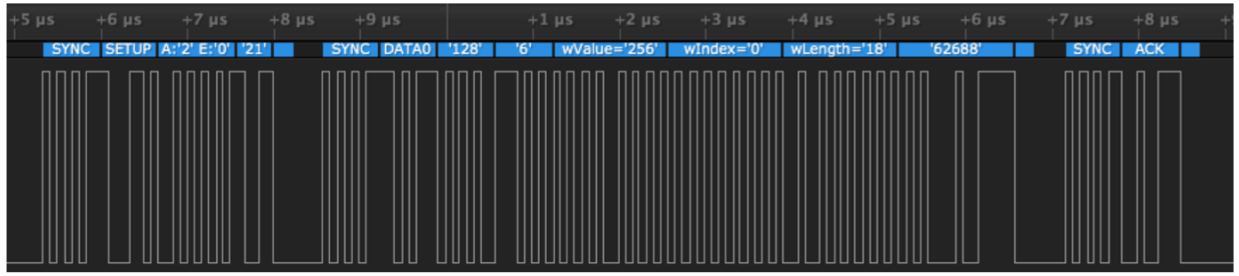
SETUP Data	Radix: auto
bmRequestType.Recipient	Device (0b00000)
bmRequestType.Type	Standard (0b00)
bmRequestType.Direction	Device-to-Host (0b1)
bRequest	Get Descriptor (0x06)
wValue	Device #0 (0x0100)
wIndex	0x0000
wLength	0x0012

SETUP STAGE

Each control transfer begins with a setup stage describing the transactions to be performed.

SETUP STAGE

If a device doesn't support a given request, it can STALL the setup stage by issuing a STALL handshake instead of an ACK.



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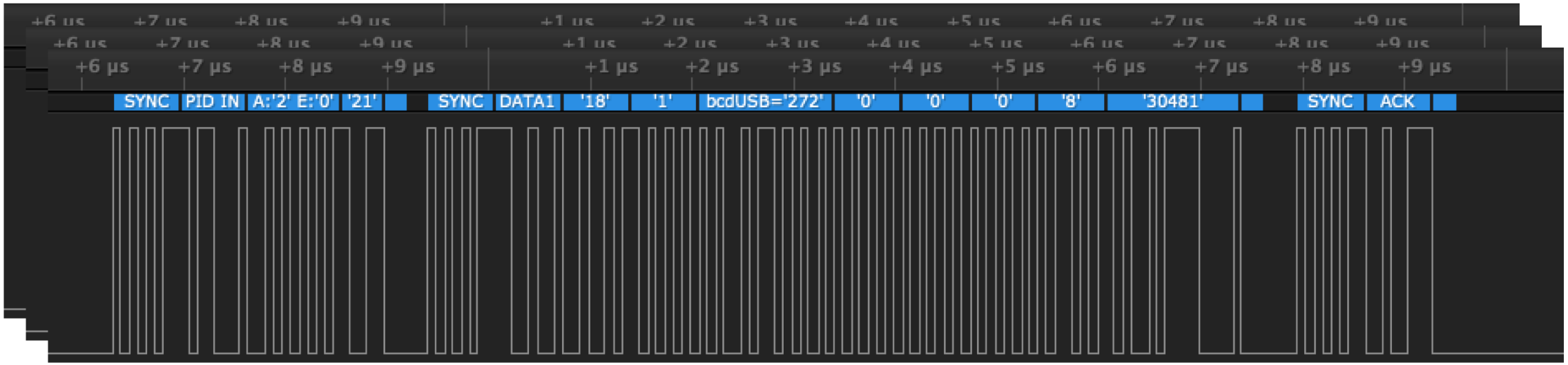

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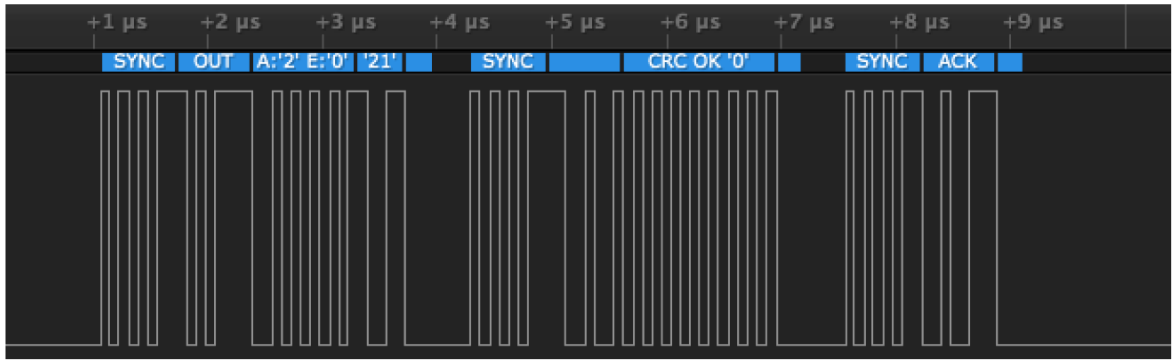
OUT txn	

If the request has a non-zero length, the transfer has a data stage compromised of one or more IN or OUT data transactions.

The data stage ends when a short packet is received– that is, a packet less than the maximum packet size. (i.e. 8 bytes for LS, 64 bytes for FS)

DATA STAGE

If the device isn't ready for the data stage, it can NAK to buy time to become ready.



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IN txn [1 POLL]	12 01 10 01 00 00 00 08
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IN txn [1 POLL]	03 01
OUT txn	

Each control transfer ends with a status stage, which confirms both sides agree that a transaction completed correctly.

The status stage is always in the direction opposite the last transaction, to ensure both sides have a chance to ACK.

STATUS STAGE

CONTROL REQUESTS

Table 9-2. Format of Setup Data

Offset	Field	Size	Value	Description
0	*bmRequestType*	1	Bitmap	Characteristics of request: D7: Data transfer direction 0 = Host-to-device 1 = Device-to-host D6...5: Type 0 = Standard 1 = Class 2 = Vendor 3 = Reserved D4...0: Recipient 0 = Device 1 = Interface 2 = Endpoint 3 = Other 4...31 = Reserved
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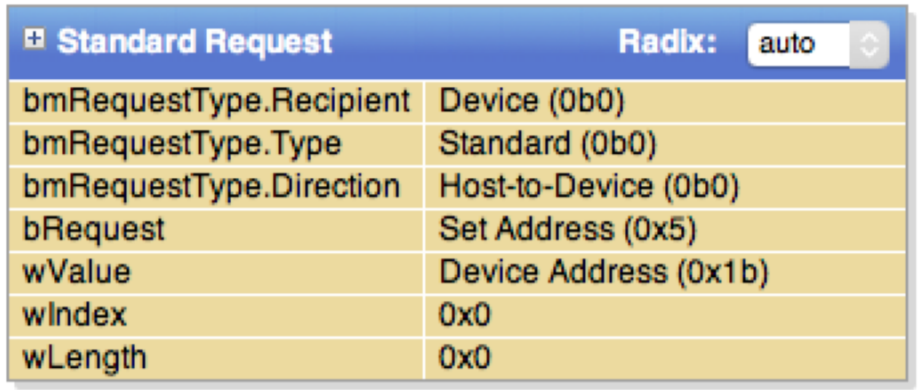
The setup stage of a control transfer describes the type of request, the size and direction of the request's data stage, and provides arguments.

The USB specification requires all devices to support a number of standard control requests, which are used for enumeration and configuration.

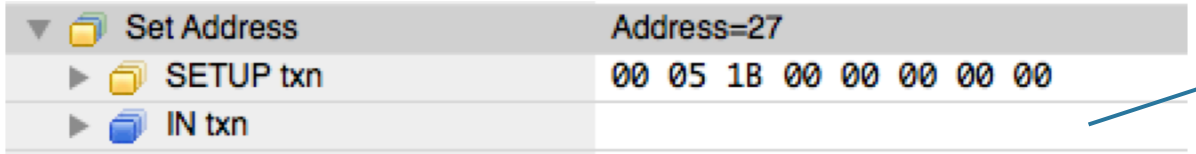
SET_ADDRESS REQUESTS



Standard Request	Radix: auto
bmRequestType.Recipient	Device (0b0)
bmRequestType.Type	Standard (0b0)
bmRequestType.Direction	Host-to-Device (0b0)
bRequest	Set Address (0x5)
wValue	Device Address (0x1b)
wIndex	0x0
wLength	0x0

Every device starts with an address of zero.

A set-address request is one of the first requests commonly issued to a device, and assigns it an address for future communications.



Set Address	Address=27
SETUP txn	00 05 1B 00 00 00 00 00
IN txn	

This request has a length of zero, and thus no data stage. It communicates only via setup arguments:

value = address to be assigned

GET_DESCRIPTOR REQUESTS

A primary goal in enumeration is to allow USB devices to self-describe. Accordingly, devices can provide summaries of themselves and their functions called descriptors.

Device Descriptor	Radix: auto
bLength	18
bDescriptorType	DEVICE (0x01)
bcdUSB	1.10 (0x0110)
bDeviceClass	Defined in Interface (0x00)
bDeviceSubClass	Defined in Interface (0x00)
bDeviceProtocol	Defined in Interface (0x00)
bMaxPacketSize0	8
idVendor	0x0403
idProduct	0x6001
bcdDevice	4.00 (0x0400)
iManufacturer	ftdi (1)
iProduct	test (2)
iSerialNumber	ftE2G0FR (3)
bNumConfigurations	1

There are a multitude of descriptors a device can provide. Some examples:

- device descriptors provide a high-level overview of the device
- string descriptors contain strings that are referenced elsewhere

Get Device Descriptor	Index=0 Length=18
SETUP txn	80 06 00 01 00 00 12 00
IN txn [1 POLL]	12 01 10 01 00 00 00 08
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IN txn [1 POLL]	03 01
OUT txn	

DEVICE DESCRIPTORS

Device Descriptor	Radix: auto
bLength	18
bDescriptorType	DEVICE (0x01)
bcdUSB	1.10 (0x0110)
bDeviceClass	Defined in Interface (0x00)
bDeviceSubClass	Defined in Interface (0x00)
bDeviceProtocol	Defined in Interface (0x00)
bMaxPacketSize0	8
idVendor	0x0403
idProduct	0x6001
bcdDevice	4.00 (0x0400)
iManufacturer	ftdi (1)
iProduct	test (2)
iSerialNumber	ftE2G0FR (3)
bNumConfigurations	1

The device descriptor provides everything a host needs to get an idea of who the device is:

- Vendor ID
- Product ID
- Device ‘class’ in formation
- References to string names.
- Max size of packets on the control endpoint.