Application Note

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Unique Keys for ATSHA204

Features

- Use of the Atmel[®] ATSHA204 unique serial number and a Root Key to create a Unique Key (Diversified Key)
- Configuring the ATSHA204 with Unique Keys
- Authenticating the Unique Key using a Host ATSHA204 containing the Root Key
- Description of the Diversified Key Calculator in ACES (Atmel Crypto Evaluation Studio)
- Demonstration of Host validation using the DeriveKey command
- Demonstration of Host validation using the GenDig command
- Pseudo Code for Host validation for systems that do not have a Host ATSHA204

Description

A unique key can be created for each Client based on its serial number and a Root Key. This is referred to as key diversification. Since each Client device is programmed with a unique secret, the Diversified Key is of less value to an attacker.

This walkthrough will configure the ATSHA204 device with a Diversified Key based on cryptographically combining a Root Key with the ATSHA204 Serial Number which is guaranteed to be unique. After configuring the Diversified Key, this walkthrough will continue with a step by step to writing this Diversified Key to the Client device.

Once the Client is configured, an explanation of how a system can validate the configured key by performing a MAC on the Client Diversified then comparing the resulting digest to the digest generated by an equivalent cryptographic calculation using the Client Serial Number and the Root Key.

A demonstration of how the GenDig command or the DeriveKey command can be used by an ATSHA204 Host device to validate the ATSHA204 Client Diversified Key will also be summarized.

1. Diversified Key Description

As shown in Figure 1-1, the Host authenticates a Client Diversified Key using the Root Key that was used to calculate the Client Diversified Key. The Diversified Key calculation cryptographically combines the Client Serial Number with the Root Key that is stored on the Host. Since Diversified Keys are based on a Root Key, the Host only needs knowledge of the Client Serial Number to validate the Client Diversified Key.



Figure 1-1. Host Authenticates a Client Diversified Key Using the Root Key

Every Client has a Unique Key - Loss of One Does Not Compromise All



2. Walkthrough Steps

The steps in this section describe the process of configuring and authenticating diversified keys.

2.1 Device Configuration

For this walkthrough, start by setting up the Configuration zone within the ATSHA204 device. This configuration will act as both a Host and Client ATSHA204. This configuration uses a single device to demonstrate the concepts; in an actual system the Host device would be separate. Table 2-1 gives both the description and configuration bytes for each slot used.

Slot	Title	Description	Slot Configuration
00	Client Diversified Key	Client Slot: This slot will be diversified using the Serial Number and the Host Root Key.	Read – Is Secret Write – Never Bytes – 8F 8F
01	Host Target	Host Slot: This is the target slot defined for the DeriveKey command.	Read – Is Secret, CheckOnly Write – DeriveKey (parent 2) Bytes – 9F 32
02	Host Root Key	Root used for key diversification: Use the DeriveKey Command to verify the Client Diversified Key. This key is to be programmed on the Host ATSHA204.	Read – Is Secret Write – Never Bytes – 8F 8F
03	Host Root Key	Root used for key diversification : Use the GenDig Command to verify the Client Diversified Key. This key is to be programmed on the Host ATSHA204.	Read – Is Secret, CheckOnly Write – Never Bytes – 9F 8F

Table 2-1. Slot Configurations

- 1. Launch ACES Configuration Environment (CE) with an *unlocked* ATSHA204 device (use an AT88CK101 or an AT88CK454 development kit).
- 2. Select **Configuration Zone** in the **Device Navigator** as shown in Figure 2-1.

Figure 2-1. Select Configuration Zone

Device Navigator	→ ậ 3	× Co	nfigurat	ion Zone			
Zone	Source	Confi	ouration	7 7 one - This 7	one has been read	from the Device	
Configuration Zone	Device						
OTP Zone	Device			00	01	02	03
Slot 00	FactoryData		00	SN	[0:1]	SN	[2:3]
Slot 01	FactoryData		04		Revi	Num	
Slot 02	FactoryData		08		SNI	4:71	
Slot 03	Undetermined						
Slot 04	FactoryData		0C	SN[8]	Reserved13	TWI <u>E</u> nable	Reserved15
Slot 05	Undetermined		10	TWI <u>A</u> ddress	TempOffset	OTPmode	SelectorMode
Slot 06	FactoryData		14	SlotCo	onfig00	SlotC	onfig01
Slot 07	FactoryData	-		C1-10-	-5-02	51-x2	

3. Click on the *SlotConfig00* memory location in the Memory map.



4. The *Write Bytes* dialog box will be displayed as shown in Figure 2-2.

Figure 2-2. Write Bytes Dialog Box — SlotConfig00

SlotConfig00	
8F 8F	ASCII Hex
Bytes To Be Written:	
Write Bytes	

- 5. Type the configuration for Slot 00 in the SlotConfig00 field from Table 2-1 (8F 8F).
 - Repeat for Slot 01 (9F 32).
 - Repeat for Slot 02 (8F 8F).
 - Repeat for Slot 03 (9F 8F).
- 6. Lock the Configuration zone.
 - Select *Tools* > *Lock Zones* from the menu.
 - The *Lock Zone* dialog box will be displayed as shown in Figure 2-3.
 - Select the *Lock Configuration Zone* check box and click on the *Lock Zones* button.
 - The Lock Successful message will be displayed.

Figure 2-3. Lock Zone Dialog Box

10. Lock Zone
✓Lock Configuration Zone
Lock OTP and Data Zones
Save Personalization Filename
:uments\Atmel\CryptoSolutions\ACES\Sha204ZoneData\DiversifiedKey.per
Lock Zones



- 7. Launch Diversified Key Calculation dialog box.
 - Select *Tools* > *Calculate Diversified Keys* from the menu.
 - The *Diversified Key Calculation* dialog box will be displayed as shown in Figure 2-4.
 Note: This dialog box dynamically updates the calculated Diversified Key as inputs are modified.
 - The calculation used for this dialog box is defined by the DeriveKey command.

Figure 2-4. Diversified Key Calculation Dialog Box

iversified	Key Inputs	
Host Targ	et Slot:	1 -
Root Key	Value:	333333333333333333333333333333333333333
Device Se	rial Number:	0123375205975AEEEE
Serial Nu	nber Pad:	777777777777777777777777777777777777777
Input Byt	es:	-
Root Key	3333333333	333333333333333333333333333333333333333
OpCode:	1C	
Param1	04	
Param2	01 00	
	EE	
SN[8]		
SN[8] SN[0:1]	01 23	
SN[8] SN[0:1] Zeros	01 23 0000000000	000000000000000000000000000000000000000
SN[8] SN[0:1] Zeros TempKey	01 23 0000000000 0123375205	00000000000000000000000000000000000000
SN[8] SN[0:1] Zeros TempKey All Input	01 23 0000000000 0123375205	00000000000000000000000000000000000000

- 8. Set the *Diversified Key Inputs* as per the configuration shown in Table 2-1.
 - Set the *Host Target Slot* to **1**.
 - Set the *Root Key Value* to all threes (Use unique secret here if you have one).
 - The *Device Serial Number* will be read from the device and pre-loaded.
 - Set the Serial Number Pad to all sevens (Any pad is ok. Typically all zeros).
- 9. The *Input Bytes* refer to the bytes that will be passed to the Atmel ATSHA256 engine.
 - The bytes and byte order are defined in the GenDig command.
 - The TempKey is the SN + SnPad which can be initialized with the Nonce command.
- The calculated Diversified Key is the result that should be written to the Client Diversified Key (Slot 00).
 Note: This calculation cryptographically combines the Root Key and the Device Serial Number.
 - Leave the *Diversified Key Calculation* dialog box open for later use.

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11. Select Slot 00 in the Device Navigator as shown in Figure 2-5.

Device Navigator		▼ ‡ ×	Slot 0	0					⇒ ×
Zone	Source	*	Slot 00 -	This zor	ne has l	been wi	itten		
Configuration Zone OTP Zone	Device FactoryData	Č.		00	01	02	03		
Slot 00	Written		00	0D	EA	04	27		
Slot 01	FactoryData	8	04	80	89	37	2A		
Slot 02	FactoryData		08	6B	C2	49	зс		
Slot 03 Slot 04	FactoryData		0C	CF	43	33	AB		
Slot 05	FactoryData		10	F6	EC	13	45		
Slot 06	FactoryData		14	E9	EB	58	68		
Slot 07 Slot 08	FactoryData FactoryData		18	CF	43	62	53		
Slot 09	FactoryData		10	45	24	9A	28		
Slot 0A	FactoryData	6							
Slot 0B	FactoryData							-	
Slot 0C	FactoryData		Show	ASCII				Load Key	Save Key

Figure 2-5. Slot 00 Showing Diversified Key Data

- 12. Client Configuration Write the calculated Diversified Key into Slot 00 of the ATSHA204.
 - Triple-click on the calculated Diversified Key data in the **Calculated Diversified Key** dialog box to select all the data.
 - Copy the data into the clipboard.
 - Click on any location in the Memory zone. The *Write Zone* dialog box will be displayed as shown in Figure 2-6.
 - Paste the Diversified Key data into the **Data to Write** field.
 - Click on the *Write To Zone* button.
- 13. Host Configuration Write Root Key into Slot 02 and Slot 03 of the ATSHA204. Follow these steps to write the Root Key (all threes or unique key) that was used to generate the Diversified Key.
 - Click on any location in the Slot 02 Memory zone. The *Write Zone* dialog box will display as shown in Figure 2-6.
 - Paste the Root Key data (all threes or unique key) into the *Data to Write* field.
 - Click on the *Write To Zone* button.
 - Repeat these Write steps for Slot 03.



Figure 2-6. Write Zone Dialog Box — Write Slot 00

ų w	rite	Zor	ne													X
	one Confi OTP Data	9	0	lot I	•	Ac	idre 0	ess C	Offse	et 🤅) 4) 3:	Byte 2 By	es tes			
Da	ta 1		Nri	te	449	100	ARS	249	474	5.25	259	654	S AR	585		ASCII
c	465	656	8A0	DOG	ED 3	6A4	~			0.50					0	Hex
W	rite	Byt	tes													
8E 86	34 5A	D9 5A	DD B5	88 BE	82 CE	57 4E	4A 56	81 5 E	DF 8A	AB	52 00	49 ED	A2 36	A5 A4	3E	2F
St	art A	Addi	ress	0	Cou	unt	32									
W	rite	Co	mm	an	d B	vte	5									
27	12	82	00	00	8E	34	D9	DD	88	82	57	4A	81	DF	AB	52
49 ED	A2 36	A5 A4	3E A1	2F C2	86	5A	5A	85	BE	CE	4E	56	SE	8A	CD	00
							Wri	te T	οZ	one						

- 14. Lock the OTP and Data zones.
 - Select the *Tools* > *Lock Zones* menu.
 - The *Lock Zone* dialog box will be displayed as shown in Figure 2-7.
 - Select the *Lock OTP and Data Zones* check box and click on the *Lock Zones* button.
 - The *Lock Successful* message will be displayed.

Figure 2-7. Diversified Key Calculation Dialog Box



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2.2 Validating the Diversified Key

The Diversified Key has now been configured into the Client (Slot 00).

Note: The Diversified Key uses the Root Key in the cryptographic calculation that generated it — the Client does not need to *have* the RootKey programmed into it.

```
DiversifiedKey = SHA256(RootKey, SerialNumber, ...)
```

In addition to when the Host has knowledge of the RootKey, only the SerialNumber needs to be available to generate the DiversifiedKey. Since the SerialNumber can be read from each ATSHA204 Client, the Host can validate the Diversified Key in one of several different ways:

- Using the DeriveKey command on a ATSHA204 programmed with the Root Key (e.g. Slot 02).
- Using the GenDig command on a ATSHA204 programmed with the Root Key (e.g. Slot 03).
- Using the system code that has access to the Root Key. For most systems, this technique is not recommended.

Each of these validations of the Diversified Key will be demonstrated.

2.2.1 Validation Pseudo Code

The first validation technique that will be examined is the Pseudo Code Host. This technique is *not* recommended since most systems, the Root Key must be used in the clear and cannot be stored securely in firmware. This section is useful for secure microprocessors and to illustrate the calculations that are performed internally in the ATSHA204.

```
Diversified Key Validation Pseudo Code — System Code with RootKey
```

```
// Initialize the communication
sha204p init();
// Set the Client device
sha204p set device id(CLIENT ID);
// Wake up the ATSHA204
sha204c wakeup();
// Function Prototype: resultBuf = sha204m execute(command, param1, param2,
data)
// Read the first 32 bytes from the config zone to get the Client Serial Number
snRead = sha204m execute(SHA204 READ, 0x80, 0x00, 0x00);
// Parse the Client SerialNumber
serialNumber = snRead[0:3] + snRead[8:12];
// Generate a random number on the Host for the 32 byte challenge
randChal = sha204m execute(SHA204 RANDOM, 0x00, 0x0000, null);
// Execute a MAC Command on the ATSHA204 & save the digest
param1Mac = 0x00;
param2Mac = [00, 00];
deviceDigest = sha204m execute(SHA204 MAC, param1Mac, param2Mac, randChal);
```



```
// Calculate the Diversified Key using the DeriveKey calculation & a soft SHA-
256
rootKey = ... // 32 byte secret here
opCodeDk = 0x1C;
param1 = 0x04;
param2 = ... // 2 byte slot ID here (LSB byte order 0x0X 00)
sn8 = \dots // 1 byte SN[8] here
sn01 = ... // 2 bytes SN[0:1] here
zeros = \dots // 25 bytes of 0's here
snPad = ... // 23 bytes of pad here
divKey =
sha256(rootKey+opCode+param1+param2+sn8+sn01+zeros+serialNumber+snPad);
// Execute a MAC on the calculated Diversified Key
// using the calculation of ATSHA204 MAC Command & a soft SHA-256
opCodeMac = 0x08;
zeros
sn23 = [00, 00]; // 2 bytes SN[2:3], use zeros
sn47 = [00, 00, 00, 00]; // 4 bytes SN[4:7], use zeros
macBytes =
divKey+randChal+opCodeMac+param1Mac+param2Mac+otpZeros+sn8+sn47+sn01+sn23;
softDigest = sha256(macBytes);
// Compare the resulting digests from the ATSHA204 & the soft MAC
match = deviceDigest == softDigest;
```

2.2.2 Read Client Serial Number and Execute the MAC Command

The next two methods involve using ACES with Step 1.; read the SerialNumber and Step 2.; execute the MAC Command on the Diversified Key slot.

- 1. Execute Read Read the Serial Number
 - Select the *Tools* > *Command Builder* menu.
 - The *Command Builder* dialog box will be displayed as shown in Figure 2-8.
 - In the **OpCode** drop down list, select the **Read** command.
 - Set the **Zone** to **80** (= 00 and 80) which indicates 32 byte read from the Configuration zone.
 - Set the *Address* to **0000**.
 - Click on the *Execute Command* button.
 - The *Response Packet* field will contain the bytes that were read.
- 2. Isolate the SerialNumber.
 - The nine byte serial number are bytes [0:3] and [8:12].
 - For this example: 0123375205975AEEEE.

							Ser	nd C	oun	t: 0	7	Res	oon	se C	our
Comman	d Packe	et													
OpCode:	Read														
Zone	80														
Address	0000														
Data:															
Send Det	ails														
Send Cou	int:	07													
Send Pac	ket:	02	80 (00	00										
Send Che	cksum:	09	AD												
Response	Detail	s													
Response	Count:		23												
Response	Packet		01 55 9F	23 00 8F	37 FF 94	52 C8 40	00 00 A0	04 55 85	05 00	00 8F	05 8F	97 9F	5A 32	EE 8F	EE 8F
Response	Checks	um:	91	C3											

Figure 2-8. Read SerialNumber — Command Builder



- 3. Execute MAC Obtain the Digest for the Diversified Key slot.
 - Leave the *Command Builder* dialog box open.
 - In the *OpCode* drop down list, select the *MAC* command.
 - Set the *Mode* to 00.
 - Set the *KeyID* to **0000**.
 - Set the *Data* to the input challenge (all ones here).
 - Click on the *Execute Command* button.
 - The *Response Packet* field will contain the digest.

Figure 2-9. MAC — Command Builder

Comman	d Builde	er 📃 🗖
		Send Count: 27 Response Count:
Comman	d Packe	t
OpCode:	MAC	•
Mode	00	
KeyID	0000	
Data:	111111 111111	11111111111111111111111111111111111111
Send Det	ails	
Send Cou	int:	27
Send Pac	ket:	08 00 00 00 11 11 11 11 11 11 11 11 11 11
Send Che	cksum:	40 DB
Response	Details	
Response	Count:	23
Response	Packet:	E2 05 CE CE 79 C2 8A AF 25 E8 49 19 74 50 91 88 B4 CC D0 E6 8F E5 01 5D E9 4D 96 BE 1E 56 21 D5
Response	Checks	um: AC 05
		Execute Command

2.3 Validate Using the GenDig Command

To validate the Client, follow the following steps using the GenDig Command. This sequence represents the Host sequence that will be performed to validate the Client.

- 1. Execute Nonce Initialize TempKey with SerialNumber + SnPad.
 - Select the *Tools* > *Command Builder* menu.
 - The *Command Builder* dialog box will be displayed as shown in Figure 2-10.
 - In the **OpCode** drop down list, select the **Nonce** command.
 - Set the *Mode* to 03 which indicates the pass-through mode.
 - Set the *Data* to SerialNumber + SnPad.
 - Click on the *Execute Command* button.
 - The *Response Packet* field will contain **00**, indicating success.

Figure 2-10. Nonce — Command Builder

		Court Court 27 December Court
		Send Count: 27 Response Count
Comman	d Packe	et
OpCode:	Nonce	
Mode	03	
Zero	0000	
Data:	012337 777777	75205975AEEEE7777777777777777777777777777777
Send Det	ails	
Send Cou	int:	27
Send Pac	ket:	16 03 00 00 01 23 37 52 05 97 5A EE EE 77 7 77 77 77 77 77 77 77 77 77 77 77 7
Send Che	cksum:	08 E9
Response	Details	s
Response	Count:	04
Response	Packet:	: 00
Response	Checks	um: 03 40



- 2. Execute GenDig Initialize TempKey with the Diversified Key.
 - Leave the *Command Builder* dialog box open.
 - In the *OpCode* drop down list, select the *GenDig* command.
 - Set the *MemZone* to **02** which indicates the Data zone.
 - Set the *KeyID* to 0300 (LSB). This is the Host slot configured for GenDig validation of the Diversified Key.
 - Set the *Data* to 1C040100. This is *OtherData* for GenDig that makes the crypto calculation the same as DeriveKey.
 - Click on the *Execute Command* button.
 - The *Response Packet* field will contain **00**, indicating success.

Figure 2-11. GenDig — Command Builder

Command	Builder			
			Send Count: 0B	Response Count: 0
Command	Packet			
OpCode:	GenDig			•
MemZone	02			
KeyID	0300			
Data:	1C040100)		
Send Detai	ls			
Send Count	t: 0B			
Send Packe	et: 15	02 03 00 1C	04 01 00	
Send Check	csum: 8C	6B		
Response I	Details			
Response (Count:	04		
Response P	acket:	00		
Response (Checksum:	03 40		
		Execute Co	ommand	

- 3. Execute CheckMac Compare Client Digest with the MAC of the calculated Diversified Key (now in TempKey).
 - Leave the *Command Builder* dialog box open.
 - In the **OpCode** drop down list, select the **CheckMac** command.
 - Set the *Mode* to 06 (= 04 and 02). Use TempKey and match TempKey source flag.
 - Set the *KeyID* to 0100. This value is ignored by CheckMac when using TempKey.
 - Set the **Data** to Challenge + Response + OtherData.
 - Challenge = All ones.
 - Response = Digest result from the client MAC command.
 - OtherData = 08 (MAC OpCode) + 00 00 00 00 00 00 00 00 00 00 00 00 (12 bytes of 00).
 - Click on the *Execute Command* button.
 - The *Response Packet* field will contain **00**, indicating that the digests match.

Figure 2-12. CheckMac — Command Builder

Comman	d Builder	
		Send Count: 54 Response Count:
Comman	d Packet	
OpCode:	CheckMa	ac 🔹
Mode	06	
KeyID	0100	
Data:	1111111 1111111 D0E6.8F 0000	11111111111111111111111111111111111111
Send Det	ails	
Send Cou	nt:	54
Send Pac	ket:	28 06 01 00 11 11 11 11 11 11 11 11 11 11 11
Send Che	cksum:	12 99
Response	Details	
Response	Count:	04
Response	Packet:	00
Response	Checksu	m: 03 40
		Execute Command



2.4 Validate Using the DeriveKey Command

- 1. Execute Nonce Initialize TempKey with SerialNumber + SnPad.
 - Select the *Tools* > *Command Builder* menu.
 - The *Command Builder* dialog box will be displayed as shown in Figure 2-13.
 - In the *OpCode* drop down list, select the *Nonce* command.
 - Set the *Mode* to **03**, which indicates the pass-through mode.
 - Set the *Data* to SerialNumber + SnPad.
 - Click on the *Execute Command* button.
 - The *Response Packet* field will contain **00**, indicating success.

Figure 2-13. Nonce — Command Builder

Comman	Command Builder					
		Send Count: 27 Response Count: 04				
Comman	d Packe	t				
OpCode:	Nonce	•				
Mode	03					
Zero	0000					
Data:	0123375205975AEEEE7777777777777777777777777777777					
Send Det	ails					
Send Cou	int:	27				
Send Pac	ket:	16 03 00 00 01 23 37 52 05 97 5A EE EE 77 77 77 77 77 77 77 77 77 77 77 77 77				
Send Che	cksum:	08 E9				
Response	Response Details					
Response	Count:	04				
Response	Packet:	00				
Response	Checks	03 40				
		Execute Command				

- 2. Execute DeriveKey Write the Client Diversified Key into a Slot on the Host.
 - In the *OpCode* drop down list, select the *DeriveKey* command.
 - Set the *Random* to **04**. This matches the TempKey source flag of pass-through mode.
 - Set the *TargetKey* to **0100** (LSB). This Host slot is configured for a DeriveKey target.
 - Click on the *Execute Command* button.
 - The *Response Packet* field will contain **00**, indicating success.

Figure 2-14. DeriveKey — Command Builder

Command	Command Builder					
			Send Count: 07	Response Count: 0		
Command	Packet					
OpCode:	DeriveKe	У		•		
Random	04					
TargetKey	0100					
Data:						
Send Detai	ls					
Send Count	t: 07	07				
Send Packe	t: 10	1C 04 01 00				
Send Check	Send Checksum: 80		4F.			
Response [Details					
Response Count:		04				
Response Packet:		00	00			
Response C	hecksum	03 40				
		Execute Co	ommand			



- 3. Execute CheckMac Compare Client Digest with the MAC of the derived Diversified Key (now in Slot 01).
 - Leave the *Command Builder* dialog box open.
 - In the **OpCode** drop down list, select the **CheckMac** command.
 - Set the *Mode* to 06 (= 04 and 02). Use TempKey and match TempKey source flag.
 - Set the *KeyID* to **0100**. This value is ignored by CheckMac when using TempKey.
 - Set the *Data* to Challenge + Response + OtherData.
 - Challenge = All ones.
 - Response = Digest result from the client MAC command.
 - OtherData = 08 (MAC OpCode) + 00 00 00 00 00 00 00 00 00 00 00 00 (12 bytes of 00).
 - Click on the *Execute Command* button.
 - The *Response Packet* field will contain **00**, indicating that the digests match.

Figure 2-15. CheckMac — Command Builder

Command Builder						
			Send Cour	nt: 54 R	esponse C	ount: 0
Comman	d Packet	t				
OpCode:	CheckMa	ac				•
Mode	04					
KeyID	0100					
Data:	1111111 1111111 D0E68F 0000	1111111111111111 111111111E205CEC E5015DE94D96BE1	1111111111 E79C28AAF2 E5621D508(L1111111 25E84919 00000000	11111111 74509188 000000000	1111 84CC 00000
Send Det	ails					
Send Count:		54				
Send Pac	ket:	28 04 01 00 11 11 11 11 11 11 11 11 11 11 11 E8 49 19 74 50 E9 4D 96 BE 1E 00 00 00 00	11 11 11 1 11 11 11 1 11 E2 05 0 91 88 B4 0 56 21 D5 00	11 11 11 11 11 11 CE CE 79 CC DO E0 08 00 00	L 11 11 1 L 11 11 1 9 C2 8A / 5 8F E5 (0 00 00 (L1 11 L1 11 AF 25 D1 5D D0 00
Send Checksum:		00 1A				
Response Details						
Response Count: 04						
Response Packet: 00						
Response Checksum: 03 40						
Execute Command						

3. Revision History

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8841A	04/2013	Initial document release.

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