Flash/EE Memory Programming via LIN—Protocol 4
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INTRODUCTION

A key feature of the ADuC7034 is the ability to download code to on-chip Flash/EE memory while in-circuit. This in-circuit code download is performed via the LIN communications bus.

This application note describes the download protocol implemented on the ADuC7034 (Protocol 4) to enable users to develop their own LIN programming tools either for series production programming or for application updates.

The term host refers to the host machine (microcontroller, DSP, or other machine) attempting to download data to the ADuC7034. The term loader refers specifically to serial download firmware resident on the ADuC7034.

Note that this application note describes Protocol 4 only. Protocol 6 is described in the AN-946 Application Note *Programming Flash/EE Memory via LIN—Protocol 6*, available from www.analog.com.

The protocol is shown on the part branding on Line 3 (see Table 1). A40 refers to a released version of Protocol 4 whereas A60 refers to a released version of Protocol 6.

Table 1. Branding Example

Line	LFCSP
Line 1	ADuC7034
Line 2	BCPZ
Line 3	A40 #date code
Line 4	Assembly lot number

This protocol is LIN 2.0 compatible at 19.2 k baud, transmitting 8 bytes of data per packet. It is estimated that this protocol erases and downloads 30,000 bytes to an ADuC7034 device in approximately 35.9 secs.

RUNNING THE ADuC7034 LOADER

To enable an unattended download via LIN, the ADuC7034 enters loader mode only if NTRST is low during reset and the content of Flash/EE memory at Address 0x00080014 is not 0x27011970 or the Page 0 checksum, as illustrated in Figure 1.

Normally, NTRST is kept low and entry to download mode is determined by the content of Flash Address 0x00080014. Typically, in user applications, the value at Flash Address 0x00080014 is not 0xFFFFFFFF; therefore, user code must have a built-in mechanism for corrupting Address 0x00080014 or erasing Page 0 (Flash Address 0x0 to Flash Address 0x200) and for resetting the part. This mechanism allows entry to download mode to reprogram the part. Ideally, the value at Flash Address 0x00080014 should be programmed last to enable re-entry to download mode in case the power fails or another error occurs during reprogramming of the bulk of the program.

The checksum of Page 0 is simply the sum of all the half words in Page 0 excluding the two half words of the word at Address 0x00080014. This sum must be stored at Address 0x00080014.
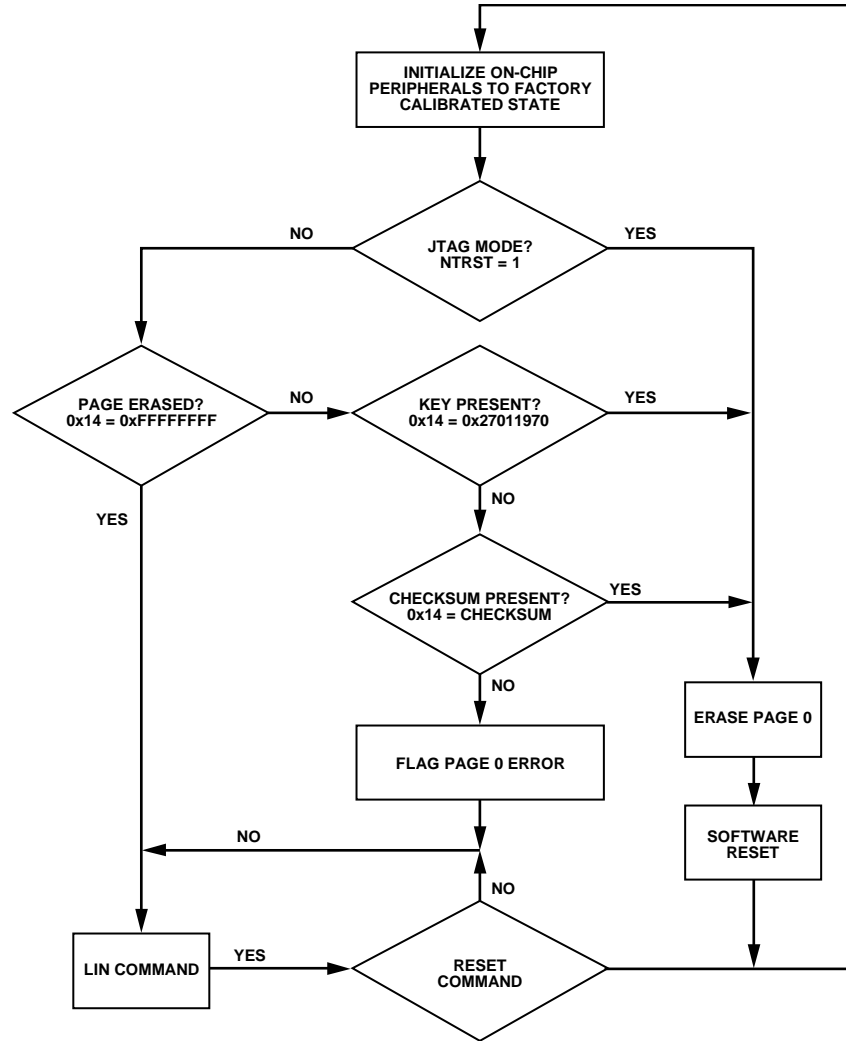
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Figure 1. Entering Download Mode

USER CODE AND SYSTEM CODE REQUIREMENTS

To enter download mode from user code, the user code must change Address 0x00080014 so that it is neither 0x27011970 nor the checksum. A reset must then be generated after which the new code can be downloaded via LIN as per this standard.

In user code, use the following steps to perform a secure entry sequence:

1. Enable Flash/EE erase and write commands (FEExMOD[3]).
2. Remove any protection on pages that are to be reprogrammed, including at least Page 0.
3. Invalidate Address 0x00080014 by writing the value of 0x00000000 to Address 0x00080014.
4. Generate a reset.
5. The loader enters download mode.
6. Set the protected identifiers (PIDs) as described in the Assigning PIDS via LIN section.
7. Send the L command to enable subsequent LIN download commands.
8. Send the download commands and data to reprogram the required pages. At this stage, Address 0x00080014 should be given a value of 0xFFFFFFFF.
9. Verify all programmed pages. If an error is detected, programming can be restarted from Step 4.
10. Program the checksum into Address 0x00080014.
11. Send the R command to cause a software reset.
12. The part enters user code.

In user code, it is important to ensure that this entire sequence is not executed unintentionally.

This mechanism is dependent on the user code controlling Address 0x00080014. If this is not implemented, the user is not able to download via the LIN interface. It is still possible to download via the JTAG interface because, upon reset, NTRST is high (JTAG emulator is connected) and user code is executed regardless of Address 0x00080014.

ASSIGNING PIDs VIA LIN

The ADuC7034 has PIDs assigned by default. To redefine these PIDs the LIN diagnostic frame (0x3C) is used. The ADuC7034 does not reply to LIN diagnostic frames.

Use the following sequence to assign PIDs via LIN:

1. At the start of the download sequence, the loader checks all frames for a PID of 0x3C. If the LIN frame does not contain this diagnostic PID, then the LIN frame is ignored.
2. Once a LIN diagnostic frame with a PID of 0x3C is received, the ADuC7034 device examines the LIN frame from Byte 0 to Byte 4. If they contain the NAD, PCI, SID, and supplier ID as shown in Table 2, the ADuC7034 device assigns the message ID LSB in Byte 5 to the PID specified in Byte 7.

Table 2. LIN Diagnostic Frame

Byte	Description	Value
Byte 0	Node address (NAD)	0x7F
Byte 1	Protocol control information (PCI)	0x06
Byte 2	Service identifier (SID)	0xB1
Byte 3	Analog Devices supplier ID, LSB	0x3A
Byte 4	Analog Devices supplier ID, MSB	0x00
Byte 5	Message ID, LSB	0x00/0x01/0x02/0x03
Byte 6	Message ID, MSB	0x00
Byte 7	User defined PID	User value

3. The LIN master sends one to four of these packets, containing the required user defined PIDs. Each PID is associated with a message ID as shown in Table 3. The secure write PID must be written and must be the last LIN diagnostic frame written.

Table 3. Default PIDs

Message ID	PID	Default	Frame ID
0x0000	Secure write	0xF0	0x30
0x0001	Address write	0xB1	0x31
0x0002	Data write	0x32	0x32
0x0003	Status read	0x73	0x33

4. The loader now recognizes only the L command using the secure write PID.
5. After the L command is received, the R, E, W, and V commands as well as data write and status read frames can be sent using these four PIDs. Commands not using one of these four PIDs are ignored.

The reassignment of the PIDs for address write, data write, and status read is optional. Assigning the secure write frame PID is not optional and must be the last PID assigned by a diagnostic frame.

The diagnostic frame's associated checksum is the classic checksum, that is, the checksum is calculated only over the data. All other packets use the enhanced checksum.

The parity bits constitute part of the PID.

LIN DOWNLOAD PROTOCOL COMMANDS

The ADuC7034 LIN download protocol contains five commands (see Table 4).

Table 4.

Command	Description
L	This command is used to enter LIN download mode. It is only used after the secure write PID is assigned.
E	This command is used to erase Flash/EE pages.
W	This command is used to write data to the Flash/EE.
V	This command is used to generate a 32-bit checksum over a specified range in Flash/EE.
R	This command is used to generate a software reset. For more information on software resets, refer to the ADuC7034 data sheet.

The five commands (shown in Table 4) are split between four PIDs as described in Table 5.

Table 5. LIN Diagnostic Frame

LIN Frame PID	Default PID Value	Valid Command	Result of Command
Secure Write	0xF0	L	Enter LIN download mode
		R	Reset
Flash/EE Address Write	0xB1	E	Erase Flash/EE
		W	Write Flash/EE
		V	Verify
Flash/EE Data Write	0x32	User value	Data for Flash/EE
Status Read	0x73	User value	Status read

For all commands associated with the Flash/EE address write PID, the physical location of the memory, 0x00080000 to 0x000877FF, should be used as opposed to the mapped region, 0x00000000 to 0x000077FF. If the mapped address is used, the command executed is not be successful.

All packets are 8 bytes in length and unused/reserved packets contain 0xFF.

The secure write, Flash/EE address write, data write, and the status read LIN frames have an enhanced checksum, that is, the checksum is calculated over the data and PID.

SECURE WRITE FRAMES

L Command

The LIN enter download mode command puts the loader into LIN download mode. This command is associated with the secure write frame PID, as received in the diagnostic frame.

Syntax: <L[1] 0xFF[1] Key[1] 0xFF[5]>

For example, to enter download mode, use the following command:

<L 0xFF 0x42 0xFF 0xFF 0xFF 0xFF 0xFF>

Key B (0x42) is required for the command to succeed.

Table 6. LIN Enter Download Mode Frame

Byte	Description	Value
Byte 0	Command L	0x4C
Byte 1	Reserved for future use	0xFF
Byte 2	LIN download entry key	0x42
Byte 3	Reserved for future use	0xFF
Byte 4	Reserved for future use	0xFF
Byte 5	Reserved for future use	0xFF
Byte 6	Reserved for future use	0xFF
Byte 7	Reserved for future use	0xFF

R Command

The reset command generates a software reset. For more information on the implications of a software reset, refer to the ADuC7034 data sheet.

Syntax: <R[1] 0xFF[1] Key[1] 0xFF[5]>

For example, to initiate a reset, use the following command:

<R 0xFF 0xBD 0xFF 0xFF 0xFF 0xFF 0xFF>

Table 7. LIN Reset Frame

Byte	Description	Value
Byte 0	Command R	0x52
Byte 1	Reserved for future use	0xFF
Byte 2	LIN download entry key	0xBD
Byte 3	Reserved for future use	0xFF
Byte 4	Reserved for future use	0xFF
Byte 5	Reserved for future use	0xFF
Byte 6	Reserved for future use	0xFF
Byte 7	Reserved for future use	0xFF

ADDRESS WRITE FRAMES

E Command

The erase Flash/EE command erases pages of Flash/EE. For a Flash/EE with 512 byte pages, the number of bytes specified divided by 512 pages are erased. The number of bytes should be a multiple of 512, otherwise the number of pages is rounded down.

The erase command only responds to the PID for Flash/EE address write.

Syntax: <E[1] address[4] number of bytes to erase[2] 0xFF[1]>

For example, to erase Page 0 and Page 1, use the following command:

<E 0x00 0x00 0x08 0x00 0x00 0x04 0xFF>

Table 8. LIN Erase Flash/EE Frame

Byte	Description	Value
Byte 0	Command E	0x45
Byte 1	Start address, LSB	N/A
Byte 2	Start address, second byte	N/A
Byte 3	Start address, third byte	N/A
Byte 4	Start address, MSB	N/A
Byte 5	Number of byte LSB	N/A
Byte 6	Number of byte MSB	N/A
Byte 7	Reserved for future use	0xFF

W Command

The write Flash/EE command prepares writing data to an erased page of Flash/EE. The number of bytes, defined in Byte 5 and Byte 6, is written to Flash/EE, starting at the address specified in Byte 1 to Byte 4.

The write command only responds to the PID for Flash/EE address write.

Syntax: <W[1] Address[4] number of bytes to write[2] 0xFF[1]>

For example, to initiate a write command to the second page of Flash/EE, use the following command:

<W 0x00 0x02 0x08 0x00 0x00 0x02 0xFF>

Table 9. LIN Write Flash/EE Frame

Byte	Description	Value
Byte 0	Command W	0x57
Byte 1	Start address, LSB	User value
Byte 2	Start address, second byte	User value
Byte 3	Start address, third byte	User value
Byte 4	Start address, MSB	User value
Byte 5	Number of byte LSB	User value
Byte 6	Number of byte MSB	User value
Byte 7	Reserved for future use	0xFF

This LIN write Flash/EE frame is then followed by data packets. The data packets are associated with the data write PID for Flash/EE data write.

It is recommended to program Page 0 last, excluding Address 0x00080014.

The number of bytes specified may not be more than 512. Data packets of 8 bytes are transmitted.

After the W packet and all data packets are transmitted, a verify command should be executed over the region written to. The write procedure does not check the data as it is written.

V Command

The verify command causes the 32-bit sum of all the half words of the selected pages to be calculated and put in the status memory, which may be read back by a status read command. If a nonpage-aligned address or number of bytes to verify is selected, this value is rounded down to the nearest page.

The verify command only responds to the PID for Flash/EE address write.

Syntax: <V[1] Address[4] number of bytes to verify[2] 0xFF[1]>

For example, to generate a checksum of the second and third pages (1024 bytes) of Flash/EE, use the following command:

<V 0x00 0x02 0x08 0x00 0x00 0x04 0xFF>

Table 10. LIN Verify Flash/EE Frame

Byte	Description	Value
Byte 0	Command V	0x56
Byte 1	Start address, LSB	User value
Byte 2	Start address, second byte	User value
Byte 3	Start address, third byte	User value
Byte 4	Start address, MSB	User value
Byte 5	Number of byte LSB	User value
Byte 6	Number of byte MSB	User value
Byte 7	Reserved for future use	0xFF

VERIFY COMMAND CHECKSUM CALCULATION

The verify command generates a 32-bit value, which represents the sum of the 16-bit values from the start location, specified in the V frame, over the number of bytes required.

$$Checksum = \sum_{Start\ Location}^{Number\ of\ Bytes} 16 - Bit\ Words$$

For a single 512 byte page, 500 μs are required after the V packet is received by the ADuC7034 device until the start of any subsequent LIN frames.

DATA WRITE FRAME

Data consists of one or more 8-byte LIN packets.

This data is written to Flash/EE as it is received. The number of data packets transmitted is dependent on the number of bytes specified in the preceding address write command. The number of bytes specified is divided by eight to give the number of data packets. Unused data bytes must be padded with 0xFF. These padded bytes do not affect the Flash/EE.

Table 11. LIN Flash/EE Data Frame

Byte	Description	Value
Byte 0	Data 1	0x45
Byte 1	Data 2	User value
Byte 2	Data 3	User value
Byte 3	Data 4	User value
Byte 4	Data 5	User value
Byte 5	Data 6	User value
Byte 6	Data 7	User value
Byte 7	Data 8	0xFF

If any other PID is received before all required data packets are completed, the data stream is terminated and a write error is flagged.

After the data is written, it should be verified using the verify command. This checksum can be read by a status read and compared to the expected checksum by the master.

STATUS READ FRAME

When the master node of the LIN bus requests a read of the slave node, the status frame is read. An 8-byte LIN packet is read by status read.

Table 12. LIN Status Frame

Byte	Description	Values
Byte 0	Last command executed	User value
Byte 1	Device ID byte	0x30/0x34
Byte 2	Status for each command when last executed	User value
Byte 3	Reserved for future use	0xFF
Byte 4	Checksum LSB for V command (reserved otherwise)	User value
Byte 5	Checksum second byte for V command (reserved otherwise)	User value
Byte 6	Checksum third byte for V command (reserved otherwise)	User value
Byte 7	Checksum MSB for V command (reserved otherwise)	User value

The following paragraphs list further information regarding the bytes in Table 11:

- Byte 0 indicates the last command executed, that is, E, L, W, or V.
- Byte 1 indicates the device ID byte from Analog Devices, Inc. 0x34—ADuC7034
- Byte 2 contains good/bad status bit for last command executed.
  The relevant bit is cleared to indicate the command completed successfully and set to indicate a failure. F corresponds to the Flash Page 0 error flag.
  <F 0 0 0 E 0 W V>
- Byte 3 is reserved for future use.
- Bytes 4 to Byte 7 give data depending on the last command executed (verify).

No memory read command is given for user code protection and download protocol efficiency.

Note that all values are transmitted in hexadecimal bytes represented as two nibbles.

ADDITIONAL INFORMATION

Example

Table 13 is an example sequence for downloading 512 bytes to Page 2. The example utilizes the ADuC7034.

Table 13. Example Sequence

PID	Command[1]	Description
0x3C	0x7F 0x06 0xB1 0x3A 0x00 0x01 0x00 AW	AW is the address write PID
0x3C	0x7F 0x06 0xB1 0x3A 0x00 0x02 0x00 DW	DW is the data write PID
0x3C	0x7F 0x06 0xB1 0x3A 0x00 0x03 0x00 SR	SR is the status read PID
0x3C	0x7F 0x06 0xB1 0x3A 0x00 0x00 0x00 SW	SW is the secure write PID
SW	L 0xFF 0x42 0xFF 0xFF 0xFF 0xFF 0xFF	Sequence to enter download protocol Key = B (0x42)
AW	E 0x00 0x02 0x08 0x00 0x00 0x02 0xFF	Erase the content of one page, starting from the second page
SR	E 0x30 0x00 0xFF 0xFF 0xFF 0xFF 0xFF	Good status
AW	W 0x00 0x02 0x08 0x00 0x00 0x02 0xFF	Write 512 bytes at Address 0x80200
DW	Usercode	Download data to Flash 64 packets required
DW	Usercode	
	…	
	…	
DW	Usercode	Last packet to write
AW	V 0x00 0x02 0x08 0x00 0x00 0x02 0xFF	Generate checksum of second page
SR	V 0x30 0x00 0xFF CS	CS is the 4-byte checksum
	…	Program other pages
	…	
SW	R 0xFF 0xBD 0xFF 0xFF 0xFF 0xFF 0xFF	Generate a reset and run user code

[1] The first three diagnostic frames are optional. If not sent, then the default values for AW, DW, and SR are used.

LIN Protocol Download Speed

According to LIN 2.0 protocol, each LIN frame has a slot equal to, or longer than, the maximum frame size. Accordingly,

$$T_{FRAME\ SLOT} = T_{HEADER\ MAXIMUM} + T_{RESPONSE\ MAXIMUM}$$

$$= 1.4 \times (T_{HEADER\ NOMINAL} + T_{RESPONSE\ NOMINAL})$$

$$= 1.4 \times (34 \times T_{BIT} + (10 \times (N_{DATA} + 1) \times T_{BIT}))$$

For more information on LIN frame length refer to the LIN 2.0 specification, LIN Protocol Specification, Section 2.2 Frame Slots.

A single page erase takes 20 ms. To erase the entire 30 kB user space takes 1.2 secs. Using Protocol 4, each frame slot is 9.04 ms. This is the time it takes to download 8 bytes. Therefore, programming the entire user space (30 kB) takes 34.7 ms.

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