TEF668X User Manual

Device version /V102

Rev. 1.6 — 17 February 2015 **User Manual**

Document information

Info	Content
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Abstract	Overview of TEF668X series device control

Revision history

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		'Lithio' TEF6686, TEF6687, TEF6688 and TEF6689, device version V102, user manual Description of the TEF668X/V102 control interface (API) and related information
1.6	20150217	Change bars indicate changes from V102 user manual Rev. 1.5 3.33, 3.37, 4.6 corrected example and table content 3.40 changed 55.4667 to 55.46667 MHz reference frequency for consistency with other documentation (no control change required) 6.2.1, 6.2.2, 6.2.3 updated with V102 required initialization p2.22
1.5	20141219	3.9, 3.10, 3.11, 3.12 added extended API noise blanker control (p2.21) 6.2.1, 6.2.2, 6.2.3 updated with V102 required initialization p2.21
1.4	20141124	6.2.1, 6.2.2, 6.2.3 updated with V102 required initialization p2.19
1.2	20140415	3.3 improved description of min_bandwidth parameter 6.2.1, 6.2.2, 6.2.3 updated with V102 required initialization p2.15
1.1	20140324	6.2.1, 6.2.2, 6.2.3 updated with V102 required initialization p2.14
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0.8	20140129	4.2.3 increased allowed times using RDS data buffer 6.2.1, 6.2.2, 6.2.3 updated with V102 required initialization p2.12
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0.5	20131106	3.6 added AM co-channel detection control command (p2.09) 4.1 added AM noise detector and AM co-channel detector quality read (p2.09) 6.2.1, 6.2.2, 6.2.3 updated with V102 required initialization p2.09 7 updated command tables

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Revision history

Rev	Date	Description
0.4	20131018	Generic changes from the device version V101 user manual: - changed version identification and references to V102 (= firmware version 2.00) - added TEF6687 and TEF6689 variants with FMSI system Changes from V101 user manual Rev 1.8 (V101 p01.24): 3.15 added FMSI enable command 3.19 removed attention note regarding FM_Highcut_Options special control (resolved) 3.20 added note regarding stereo control ‘off’ as suggested for FMSI use 3.20 FM_Set_Stereo_Max corrected table head (parameters) 3.26 FM/AM_Set_DR_Options corrected table head (parameters) 3.29 added FMSI control commands 3.40 APPL_Set_ReferenceClock renamed parameters to frequency_msb, frequency_lsb 4.5 added FMSI processing status read 6.2.1, 6.2.2, 6.2.3 updated with V102 required initialization (p2.06) 7 Table 1 consistency corrections on listed commands and parameters Template update

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1. Introduction

TEF668X ('Lithio') is a series of novel single-chip car radio devices with an upper mainstream to high-end performance and feature set.
The Lithio series consists of four variants; TEF6686, TEF6687, TEF6688 and TEF6689. All Lithio variants offer worldwide FM band reception as well as full AM band reception up to 27 MHz. In addition to the TEF6686 feature set the variants TEF6687 and TEF6689 (Lithio FMSI and Lithio FMSI DR) offer the added performance of extended FM stereo reception and the variants TEF6688 and TEF6689 (Lithio DR and Lithio FMSI DR) offer connectivity and support for digital radio reception in the AM and FM bands.

This user manual describes the TEF668X series control interface or API (Application Programming Interface). The document describes the available write and read commands with parameter and data definitions.

This document version contains limited background information regarding the feature functionality and the offered control options so some general knowledge of car radio functions is required.

This user manual describes the functionality and control of the TEF668X device version V102 specifically (TEF668X/V102).

2. Control interface

2.1 Overview

The TEF668X devices are equipped with an I²C bus interface for control of the device. Full control of the device functions and features is available using this single interface.

The I²C bus supports bit rates of up to 400 kbit/s in accordance with the 'fast mode' I²C bus specification.

The control interface is described in this document on an abstract 'application' level as well as on I²C protocol level.

The TEF668X interface definition is compatible with the TEF665X (Atomic-2) and TEF701X (Sabre) series of devices, although differing in available commands reflecting the available functionality. The interface is compatible with the TEA685X (Tiger-2) series as well.

Future NXP car radio devices will employ the same interface allowing compatible control between device types, versions and variants.

Via the I²C bus commands and parameters can be written to the device and information can be read from the device.

TEF668X control is organized in modules. Modules are independent functional blocks that can be regarded sub-devices within the device.

The TEF668X consists of four modules:

- module 32 : FM = FM radio reception
- module 33 : AM = LW, MW and SW radio reception
- module 48 : AUDIO = Audio processing
- module 64 : APPL = System and application control

Different modules can be controlled independently even when the addressed module itself is inactive at the time of control. This means modules can be prepared and initialized before use.

Compatible command definitions have been used for the modules of FM and AM radio where applicable. Defaults and range definitions may differ in some cases to fit the different band properties.

Module commands have one or more parameters for control of the module behavior and option selections.

The control is organized in such a way that future devices may support writing of a single parameter up to writing of all parameters available for a given command.
Device version V102 however does not offer this flexibility and requires all command parameters described in this document to be transmitted. This behavior is equal to device version V101.

Fig 1 represents the TEF668X control interface as seen from the host controller.

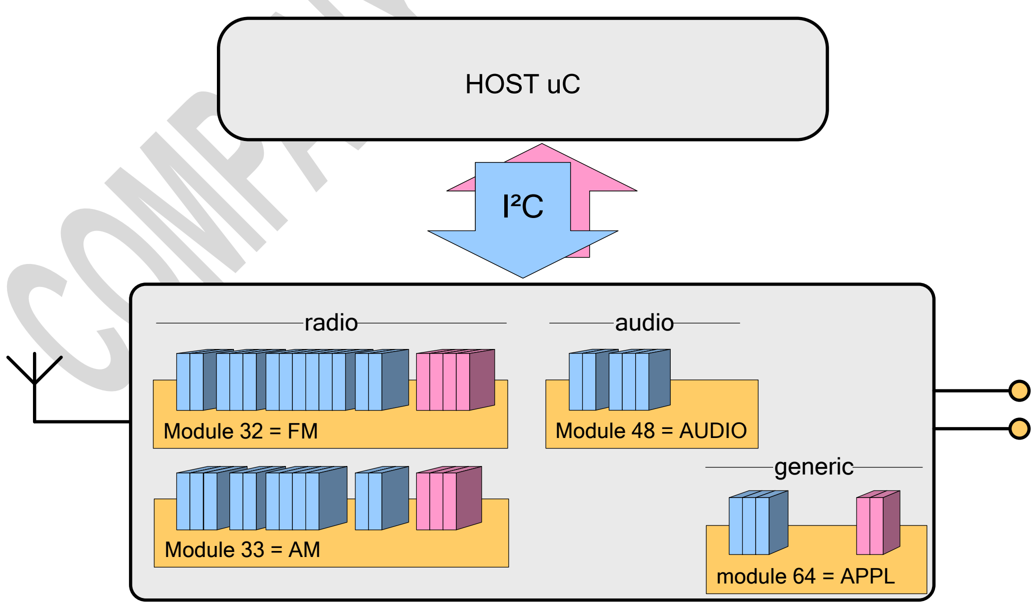


Fig 1. I²C control –TEF668X

TEF668X device variants are fully control compatible, although differing in available features. Future derivatives of these devices will remain compatible also but possibly with a different variation and extension in supported functions and features.

The API template of TEF668X and compatible devices will be used in future NXP car-radio developments also, offering compatible control with additional variation in supported functions and features.

The parameter ranges as depicted in this document are the guaranteed ranges for operation. Control outside of these ranges is not allowed for application.

The command parameters in general allow for a higher range and granularity than what is available from TEF668X. Parameters can be set to any value within the documented range even where the actual number of available settings is less than offered by the parameter. In these cases the TEF668X will realize the nearest available setting.

Information regarding the actual available granularity is limited in this document but will be extended in future user manual updates.

2.2 History

The control interface of the TEF668X has been improved over previous product generations in order to ensure and offer:

- Extendibility: Extension of modules, commands and parameters allowing addition and extension of control options, features and functionality for future car radio devices from low-end to high-end.
- Granularity and range: The parameter definition allows for extremely detailed parameter setting and range extension where needed in the future.
- Reduced control effort: Although not supported for device version V102 the interface definition allows for single parameter manipulation simplifying user control software.

Although no direct compatibility is present it should be noted that the TEF668X command interface shares most of its API functionality with previous products. A translation from previous generation style control to the TEF668X control can therefore be made with little effort. Description semantics and description units have been maintained between generations to support easy transfer of settings.

3. Write commands

Write commands allow control or setting of specific features. Writing consists of a module, a command and an index value generally followed by one or more parameter values.

The module value defines the processing part that is addressed. Modules are integral functional parts of the device that can be regarded sub-devices. Available modules in the TEF668X are 32 'FM' for FM radio', 33 'AM' for AM radio, 48 'AUDIO' for audio processing and I/O selection and 64 'APPL' for application and system settings.

The command value defines a control function, a feature setting or a set of feature settings.

The index value is present for future use to allow writing of certain specific parameter parts out of the available command parameters.
Device version V102 requires index = 1 to be used and requires all command parameters described in this user manual to be transmitted. This behavior is equal to device version V101.

The first parameter starts from index = 1.

Write commands are only available in the device 'active state' operation modes with the exception of certain APPL commands available during 'idle state'.

Independent from the selected 'active state' operation mode ('radio standby', 'FM' or 'AM') the write commands of every module are available for writing so full device initialization is possible in any of the 'active state' operation modes.

Note: FM radio and AM radio are never available together. Enabling of one radio module (by a tuning action command on that module) will disable the other radio module but control to the disabled radio module remains available for initialization purposes.

For detailed information on the I²C protocol for write commands see 5.2 Write control.

3.1 FM / AM cmd 1 Tune_To

Tuning within the active radio band or tuning to a different radio band with selection of FM / AM operation.

module	32 / 33	FM / AM			
cmd	**1**	**Tune_To**	mode, frequency		
index	1	mode [15:0]	tuning actions		
			0 = no action (reserved)		
			1 = Preset		Tune to new program with short mute time Enable radio and FM/AM change where applicable
			2 = Search		Tune to new program and stay muted Enable radio and FM/AM change where applicable
			FM 3 = AF-Update		Tune to alternative frequency, store quality and tune back with inaudible mute
			4 = Jump		Tune to alternative frequency with inaudible mute
			5 = Check		Tune to alternative frequency and stay muted
			AM 3 … 5 = reserved		
			6 = reserved		
			7 = End		Release the mute of a Search or Check action (frequency is not required and ignored)
	2	frequency [15:0]	tuning frequency		
			FM	6500 … 10800	65.00 … 108.00 MHz / 10 kHz step size
			AM LW	144 … 288	144 … 288 kHz / 1 kHz step size
			MW	522 … 1710	522 … 1710 kHz / 1 kHz step size
			SW	2300 … 27000	2.3 … 27 MHz / 1 kHz step

Application example	FM_Tune_To (1, 1, 8930)	Preset tuning to FM 89.3 MHz
	AM_Tune_To (1, 2, 990)	Search tuning (from FM) to AM 990 kHz
	AM_Tune_To (1, 7)	End (release mute of AM Search action)
I²C example (hex)	[w 20 **01** 01 0001 22E2]	Preset tuning to FM 89.3 MHz
	[w 21 **01** 01 0002 03DE]	Search tuning (from FM) to AM 990 kHz
	[w 21 **01** 01 0007]	End (release mute of Search action)

3.1.1 radio tuning actions with setting of band and frequency

The mode control parameter allows for execution of different radio tuning actions.

The tuning actions take care of every detail of radio tuning; next to the obvious tuner functions of band switching and frequency adjustment additional control is active for inaudible audio mute, reset of quality detectors, reset or hold of weak signal processing control and suppression of pop noise. All this functionality is an integrated part of

TEF668X tuning. The set of tuning actions offered by TEF668X is an NXP standard and found in car radio devices for many generations.

The set of tuning actions frees the controlling μC from all non-essential timing and control complexity, however control flexibility is not limited in any way because the full ‘decision intelligence’ remains at the μC side. The tuning actions can be regarded building blocks for creating the desired radio tuning control. Tuning actions can be chained together to build complete tuning routines or realize a single basic routine by themselves.

A total of six mode tuning actions are defined for different types of tuning.

mode = 1 ; Preset

mode = 1 performs a complete ‘Preset-change’ tuning for tuning to a new program or possibly to a new band. For a Preset-change it is desired to start the new program immediately with the best quality possible, therefore time constants of the weak signal handling and AM demodulator AGC are controlled for fast settling to the new signal conditions within a small preset mute time of approx. 32 ms for FM and 60 ms for AM bands.

mode = 2 ; Search:

mode = 2 performs a tuning action to create a search to a new program (previous / next search) or searching for several programs (auto-store).

Search is equal in function to a Preset action however the mute is not released automatically. This allows signal conditions to be checked while muted and when insufficient reception quality is found a new Search action can be activated again and again for a new frequency until a valid search stop condition is found.
Mute can then be released by an End action (mode = 7).

Also a Preset may be used as the last ‘search’ tuning action to release mute.

Preset and Search employ a 10 ms mute and de-mute slope timing for gentle program switching, so actual tuning is delayed by 10 ms. In case mute is already active (like from a previous Search action) no mute delay is present and tuning is started instantly.

A Preset and Search tuning action also allows for band switching between FM and AM. An AM Preset or AM Search will disable ‘radio standby’ or ‘FM’ operation and enable AM module operation. Equally an FM Preset or FM Search will enable FM module operation.

Note the 10 ms mute delay time should also be taken into account when switching between FM and AM module operation.

mode = 3 ; AF_Update:

mode = 3 performs a complete ‘alternative frequency update’ tuning cycle for inaudible testing of the quality of alternative frequencies in the background. AF_Update tunes to an alternative frequency, gathers signal quality information and returns to the original frequency within a very short time.

Inaudible mute is employed and the measured AF quality information is stored for easy read-out by I²C. Time constants of the weak signal handling and DC decoupling are controlled so they are not disturbed by the AF signal conditions.

A default AF_Update cycle finishes within 6 ms for the complete action including mute enabling and disabling.

For AF_Update options like the bandwidth used during AF_Update tuning see 3.2 FM cmd 2 Set_Tune_Options.

mode = 4 ; Jump:

mode = 4 performs a complete tuning action for switching to a 'known' alternative frequency. Jump performs a tuning with a minimum mute time, only intended to suppress PLL tuning disturbances. Starting from the control setting of the previous frequency the weak signal handling will change gradually to the new signal conditions using the standard weak signal timings, as desired for an inaudible switching to an alternative frequency with the same program.

Since Jump releases mute automatically it must be assumed that the new frequency indeed contains the same program. Should it later be found this is not the case (e.g. by reading the RDS PI code) a new Jump is the designated tuning action for a fast return to the original frequency.

mode = 5 ; Check:

mode = 5 performs a tuning action for switching to an 'unknown' alternative frequency. Check is equal in function to a Jump action however the mute is not released automatically. During the Check mute an RDS PI code can be searched for and verified and if a valid program is found mute can be released by an End action (mode = 7). During mute the weak signal handling is not disturbed by the new signal conditions and after mute release the weak signal handling will gradually change to the new conditions using the standard weak signal timings. In case an invalid program is found a Jump is the designated tuning action for a fast return to the original frequency.

It is possible to string several Check transmissions together to create an AF_Update like routine for checking several AF signal conditions in a row. Such a string of Check transmissions may be finished by mode = End or Jump or, alternatively, by mode = AF_Update in which case a 'standard' AF_Update is executed with quality data hold while returning to the original frequency as present before the string of Check tunings.

Note: AF_Update, Jump and Check employ a 1 ms mute and de-mute slope timing for fast inaudible switching, so actual tuning is delayed by 1 ms. In case mute is already active (presumably by a previous Check action) no mute delay is present and tuning is started instantly.

mode = 7 ; End:

mode = 7 ends a currently active tuning action. End releases the sustained mute of a Search (mode = 2) or Check (mode = 5) tuning action.

An End action does not require any additional data, so only the mode parameter needs to be transmitted. In case the frequency is included it is ignored. End is only effective for the currently active radio band (module setting).

3.2 FM cmd 2 Set_Tune_Options

Settings used during a tuning action (FM AF_Update).

module	32	FM	
cmd	**2**	**Set_Tune_Options**	afu_bw_mode, afu_bandwidth, afu_mute_time, afu_sample_time
index	1	afu_bw_mode [15:0]	IF bandwidth control mode during AF_Update
			0 = fixed (default)
			1 = automatic bandwidth
	2	afu_bandwidth [15:0]	fixed IF bandwidth during AF_Update
			560 … 3110 [*0.1 kHz] = IF bandwidth 56 … 311 kHz; narrow … wide 2360 = 236 kHz (default)
	3	afu_mute_time [15:0]	AF_update inaudible mute slope time
			250 … 1000 [* 1 us] = 0.25 … 1 ms 1000 = 1 ms (default)
	4	afu_sample_time [15:0]	AF_update sampling time
			1000 … 20000 [* 1 us] = 1 … 20 ms 2000 = 2 ms (default)

Application example	FM_Set_Tune_Options (1, 0, 1680, 1000, 2000)	168 kHz bandwidth during AFU
I²C example (hex)	`[ w 20 02 01 0000 0690 03E8 07D0 ]`	168 kHz bandwidth during AFU

Note: afu_sample_time is accurate to 1 ms intervals and a minimum of 2 ms is advised for sufficient settling of all quality detectors.

3.3 FM / AM cmd 10 Set_Bandwidth

Fixed bandwidth selection of the radio selectivity filter.

For FM automatic bandwidth control can be selected with control sensitivity options.

module	32 / 33	FM / AM		
cmd	**10**	**Set_Bandwidth**	FM : mode, bandwidth, control_sensitivity, low_level_sensitivity, (min_bandwidth, nominal_bandwidth, control_attack.) AM : mode, bandwidth	
index	1	mode [15:0]	IF bandwidth control mode	
			FM	0 = fixed
				1 = automatic (default)
			AM	0 = fixed (default)
	2	bandwidth [15:0]	fixed IF bandwidth	
			FM	560 … 3110 [*0.1 kHz] = IF bandwidth 56 … 311 kHz; narrow … wide 2360 = 236 kHz (default)
			AM	30 … 80 [*0.1 kHz] = IF bandwidth 3 … 8 kHz; narrow … wide 40 = 4.0 kHz (default)
	3	control_sensitivity [15:0]	FM automatic IF bandwidth control sensitivity	
			500 … 1500 [*0.1 %] = 50 … 150 % relative adjacent channel sensitivity 1000 = 100 % (default)	
	4	low_level_sensitivity [15:0]	FM automatic IF bandwidth control sensitivity for low level conditions	
			500 … 1500 [*0.1 %] = 50 … 150 % relative adjacent channel sensitivity 1000 = 100 % (default)	
	5	min_bandwidth [15:0]	extended API: FM minimum IF bandwidth	
			560 … 1140 [*0.1 kHz] = IF bandwidth 56 … 114 kHz; narrow … wide 560 = 56 kHz (default)	
	6	nominal_bandwidth [15:0]	extended API: FM automatic IF bandwidth control nominal bandwidth	
			1510 … 2360 [*0.1 kHz] = IF bandwidth 151 … 236 kHz; narrow … wide bandwidth in use during no disturbance and low modulation condition 2360 = 236 kHz (default)	
	7	control_attack [15:0]	extended API: FM automatic IF bandwidth control attack timing	
			150 … 450 [*1 us] = 150 … 450 us attack time attack time (from wide to narrow bandwidth) 300 = 300 us (default)	

Application example

FM_Set_Bandwidth (1, 1, 2360, 1000, 1000)	standard parameters with FM default
AM_Set_Bandwidth (1, 0, 40)	All parameters with AM default value
FM_Set_Bandwidth (1, 0, 2360, 1000, 1000)	bandwidth = fixed 236 kHz
FM_Set_Bandwidth (1, 1, 2360, 800, 1000)	control_sensitivity = 80 %
FM_Set_Bandwidth (1, 1, 2360, 1000, 800)	control+low_level sensitivity = 80 %

I²C example (hex)

[w 20 **0A** 01 0001 0938 03E8 03E8]	All parameters with FM default value
[w 21 **0A** 01 0000 0028]	All parameters with AM default value
[w 20 **0A** 01 0000 0938 03E8 03E8]	FM bandwidth = fixed 236 kHz

```
[ w  20 0A 01  0001 0938 0320 03E8 ]
[ w  20 0A 01  0001 0938 03E8 0320 ]
```

control_sensitivity = 80 %
control+low_level sensitivity = 80 %

Note: For FM the following sixteen bandwidth settings are supported: 56 / 64 / 72 / 84 / 97 / 114 / 133 / 151 / 168 / 184 / 200 / 217 / 236 / 254 / 287 / 311 kHz.

For AM the following four bandwidth settings are supported: 3 / 4 / 6 / 8 kHz.
Other bandwidth parameter values are rounded to the nearest supported bandwidth.

Note: Extended API control parameters 5, 6 and 7 are available for additional performance tuning. Adaptation of these default values is not advised in general but allows for performance fine-tuning on specific conditions. Feature innovation may cause extended API defaults and control to change with firmware release.

Min_bandwidth allows for limitation of the minimum bandwidth. Adaptation of the minimum bandwidth default value reduces the achievable adjacent channel suppression but might be considered for areas with 200 kHz FM grid. Please note that also the fixed IF bandwidth control is limited by the min_bandwidth setting.
Transmission of the minimum bandwidth parameter 5 is optional and not required.

The minimum bandwidth option requires initialization version p2.13 or higher.

Nominal_bandwidth allows for selection of the bandwidth in use for the equilibrium state of the system, i.e. for a condition with no adjacent channel disturbance and low modulation index. Adaptation of the nominal_bandwidth default value should be used with care and may impair modulation handling and stereo channel separation performance.

Control_attack allows for selection of the bandwidth control attack time. Control_attack defines control sensitivity in addition to the control_sensitivity parameter which primarily controls the decay time. A smaller control_attack setting (i.e. shorter time) will show a higher sensitivity, a longer time will show a decrease in sensitivity.

The nominal_bandwidth and control_attack option require initialization version p2.17 or higher.

Use of the special control parameters 5, 6 and 7 is optional and transmission is not required. Parameters that are not transmitted are set to their default value.

Modulation boost control is available from 3.28 FM cmd 86 Set_Bandwidth_Options.

3.4 FM / AM cmd 11 Set_RFAGC

Start level of the tuner front-end AGC.

Performance balancing of desensitization (high start level) against inter-modulation (low start level).

Optional extension of the FM RF AGC range with one step by external application use.

module	32 / 33	FM / AM		
cmd	**11**	**Set_RFAGC**	FM: start, extension AM: start	
index	1	start [15:0]	RF AGC start	
			FM	840 … 920 [*0.1 dBμV) = 84 … 92 dBμV 920 = 92 dBμV (default)
			AM	940 … 1020 (*0.1 dBμV) = 94 … 102 dBμV 1000 = 100 dBμV (default)
	2	extension [15:0]	RF AGC step extension	
			FM	0 = integrated steps only (default)
				1 = AGC step extension from control output (GPIO feature 'AGC')
			AM	reserved

Application example	FM_Set_RFAGC (1, 890, 0) AM_Set_RFAGC (1, 970)	FM RF AGC start at 89 dBμV, no ext. AM RF AGC start at 97 dBμV
I²C example (hex)	`[ w 20 0B 01 037A 0000 ]` `[ w 21 0B 01 03CA ]`	FM RF AGC start at 89 dBμV, no ext. AM RF AGC start at 97 dBμV

Note: FM RF AGC step extension requires GPIO pin assignment; see 3.39 Set_GPIO APPL cmd = 3.

3.5 AM cmd 12 Set_Antenna

AM antenna attenuation control (RF AGC attenuation limit).

In case of an AM active antenna application part of the required level correction can be located in the front-end.

module	33	AM	
cmd	**12**	**Set_Antenna**	attenuation
	1	attenuation [15:0]	LNA gain reduction
			0 / 60 / 120 / 180 / 240 / 300 / 360 (*0.1 dB) = 0 … 36 dB antenna attenuation (6 dB step size) 0 = no attenuation (default)

Application example	AM_Set_Antenna (1, 180)	AM 18 dB antenna attenuation
I²C example (hex)	[w 21 **0C** 01 00B4]	AM 18 dB antenna attenuation

3.6 AM cmd 14 Set_CoChannelDet

Control of the AM co-channel detector.

The AM co-channel detector searches for sub-sonic audio content as may be found during conditions where the AM channel is disturbed by the signal from a different station transmitting on the same channel but with a slightly different carrier frequency.

module	33	AM	
cmd	**14**	**Set_CoChannelDet**	mode, restart, sensitivity, count
index	1	mode [15:0]	co-channel detector operation
			1 = on (default)
	2	restart [15:0]	co-channel detector restart
			1 = manual restart; reset detector result and start looking for co-channel (note: returns to restart = 2; automatic restart after tuning remains enabled)
			2 = automatic restart after tuning (default); start looking for new co-channel after Preset and Search tuning action (see AM cmd = 1 TuneTo)
	3	sensitivity [15:0]	co-channel detection sensitivity
			500 … 1500 [*0.1 %] = 50 … 150 % relative detection sensitivity 1000 = 100 % (default)
	4	count [15:0]	co-channel detection count threshold
			1 … 15 = 1 … 15 detection counts until signaling of co-channel detected 3 = (default)

Application example	AM_Set_CoChannelDet (1, 1, 2, 1200, 3)	Set sensitivity to 120 %
	AM_Set_CoChannelDet (1, 1, 2, 1000, 5)	Set count = 5 for higher reliability
I²C example (hex)	[w 21 **0E** 01 0001 0002 04B0 0003]	Set sensitivity to 120 %
	[w 21 **0E** 01 0001 0002 03E8 0005]	Set count = 5 for higher reliability

See 4.1 FM / AM cmd 128 / 129 Get_Quality for co-channel detection read.

Note: AM co-channel detection and control requires initialization version p2.09 or higher.

3.7 FM cmd 20 Set_MphSuppression

Optional use of the 'iMS' FM multipath suppression system.

module	32	FM	
cmd	**20**	**Set_MphSuppression**	mode
index	1	mode [15:0]	FM multipath suppression
			0 = off (default)
			1 = on

Application example	FM_Set_MphSuppression (1, 1)	Enable the multipath suppression
	FM_Set_MphSuppression (1, 0)	Disable the multipath suppression
I²C example (hex)	[w 20 **14** 01 0001]	Enable the multipath suppression
	[w 20 **14** 01 0000]	Disable the multipath suppression

Note: The advised setting is 'on' for improved field performance.

3.8 FM cmd 22 Set_ChannelEqualizer

Optional use of the FM channel equalizer.

module	32	FM	
cmd	**22**	**Set_ChannelEqualizer**	mode
index	1	mode [15:0]	FM channel equalizer
			0 = off (default)
			1 = on

Application example	FM_Set_ChannelEqualizer (1, 1)	Enable the channel equalizer
	FM_Set_ChannelEqualizer (1, 0)	Disable the channel equalizer
I²C example (hex)	[w 20 **16** 01 0001]	Enable the channel equalizer
	[w 20 **16** 01 0000]	Disable the channel equalizer

Note: The advised setting is 'on' for improved field performance

3.9 FM cmd 23 Set_NoiseBlanker

Noise blanker options and sensitivity setting.

module	32	FM	
cmd	**23**	**Set_NoiseBlanker**	mode, sensitivity (, -, modulation, offset, attack, decay)
index	1	mode [15:0]	noise blanker
			0 = off
			1 = on (default)
	2	sensitivity [15:0]	trigger sensitivity
			500 … 1500 [*0.1 %] = 50 … 150 % relative trigger sensitivity 1000 = 100 % (default)
	3	- [15:0]	reserved
			0 = don't care
	4	modulation [15:0]	extended API: modulation dependency on trigger sensitivity
			160 … 1660 [*0.1 %] = 16 … 166 % modulation (= 12 … 125 kHz FM dev.) Modulation index where minimum pulse detection sensitivity is reached; trigger sensitivity is controlled between maximum sensitivity for no modulation and minimum sensitivity at set modulation index. 900 = 90 % (default)
	5	offset [15:0]	extended API: sensitivity offset
			0 … 250 [*0.1 %] = 0 … 25 % fixed sensitivity threshold Pulse detection offset; prevent false triggering in good signal conditions 1 = 0.1 % (default)
	6	attack [15:0]	extended API: trigger reference attack time
			15 … 1200 [*1 µs] = 15 … 1200 µs Attack time of noise average filter used as reference for pulse detection 140 = 140 µs (default)
	7	decay [15:0]	extended API: trigger reference decay time
			300 … 6000 [*1 µs] = 300 µs … 6 ms Decay time of noise average filter used as reference for pulse detection 2800 = 2.8 ms (default)

Application example	FM_Set_NoiseBlanker (1, 1, 1000)	FM default values
	FM_Set_NoiseBlanker (1, 1, 1000, 0, 900, 1, 140, 2800)	FM defaults extended API
I²C example (hex)	[w 20 **17** 01 0001 03E8]	FM default values
	[w 20 **17** 01 0001 03E8 0000 0384 0001 008C 0AF0]	FM defaults extended API

Note: Extended API control parameters 4 to 7 are available for additional performance tuning. Changing default values is not advised in general but allows for performance fine-tuning on specific conditions. Defaults and control may change over firmware releases.

Use of the special control parameters 4 to 7 is optional and transmission is not required. In case of a standard transmission (parameters 1 and 2) extended API changes remain.

For AM cmd 23 Set_NoiseBlanker see chapter 3.11.

3.10 FM cmd 24 Set_NoiseBlanker_Options

Extended API control options of the FM noise blanker.

module	32	FM	
cmd	**24**	**Set_NoiseBlanker_Options**	blank_time, blank_time2, blank_modulation
index	1	blank_time [15:0]	FM noise blanker blank time on low modulation
			75 … 300 [*1 us] = 75 … 300 us pulse stretch time Blank time for low modulation; compared to parameter ‘blank_time2’ an equal or longer value is suggested optimized for noise pulse suppression. 210 = 210 us (default)
	2	blank_time2 [15:0]	FM noise blanker blank time on high modulation
			75 … 300 [*1 us] = 75 … 300 us pulse stretch time Blank time for high modulation; compared to parameter ‘blank time’ an equal or smaller value is suggested optimized for modulation fidelity. 210 = 210 us (default)
	3	blank_modulation [15:0]	FM modulation dependent blank time
			160 … 1660 [*0.1 %] = 16 … 166 % modulation (= 12 … 125 kHz FM dev.) Modulation index threshold for which the blank time is adapted; the ‘blank_time’ setting is used below the set modulation index and the ‘blank_time2’ setting is used above the set modulation index. 250 = 25 % (default)

Application example FM_Set_NoiseBlanker_Options (1, 210, 210, 250) Extended API default values

I²C example (hex) `[ w 20 18 01 00D2 00D2 00FA ]` Extended API default values

Note: Extended API control is available for additional performance tuning. Adaptation of these default values is not advised in general but allows for performance fine-tuning on specific conditions. Feature innovation may cause extended API defaults and control to change with firmware release.

Note: Noise blanker extended API control requires initialization version p2.21 or higher.

3.11 AM cmd 23 Set_NoiseBlanker

Noise blanker options and sensitivity setting.

module	33	AM	
cmd	**23**	**Set_NoiseBlanker**	mode, sensitivity (, gain, blank_time)
index	1	mode [15:0]	noise blanker
			0 = off
			1 = on (default)
	2	sensitivity [15:0]	trigger sensitivity
			500 … 1500 [*0.1 %] = 50 … 150 % relative trigger sensitivity 1000 = 100 % (default)
	3	gain [15:0]	extended API: AM trigger sensitivity for noise conditions
			600 … 1600 [*0.1 %] = 60 … 160 % relative trigger sensitivity Pulse detection gain; allows balancing of lower RF level trigger sensitivity with the parameter 2 trigger sensitivity for higher RF level. 1000 = 100 % (default)
	4	blank_time [15:0]	extended API: AM noise blanker blank time
			25 … 250 [*1 µs] = 25 … 250 us pulse stretch time Blanker pulse extension time 56 = 56 µs (default)

Application example	AM_Set_NoiseBlanker (1, 1, 1000)	AM default values
	AM_Set_NoiseBlanker (1, 1, 1000, 1000, 56)	AM defaults extended API
	AM_Set_NoiseBlanker (1, 1, 1200)	sensitivity 120% for more suppression
I²C example (hex)	[w 21 **17** 01 0001 03E8]	AM default values
	[w 21 **17** 01 0001 03E8 03E8 0038]	AM defaults extended API
	[w 21 **17** 01 0001 04B0]	sensitivity 120% for more suppression

Note: Extended API control parameters 3 and 4 are available for additional performance tuning. Changing default values is not advised in general but allows for performance fine-tuning on specific conditions. Defaults and control may change over firmware releases.

Use of the special control parameters 3 to 4 is optional and transmission is not required. In case of a standard transmission (parameters 1 and 2) extended API changes remain.

Note: Noise blanker extended API control requires initialization version p2.21 or higher.

For FM cmd 23 Set_NoiseBlanker see chapter 3.9.

3.12 AM cmd 24 Set_NoiseBlanker_Audio

AM Audio noise blanker options and sensitivity setting.

module	33	AM	
cmd	**24**	**Set_NoiseBlanker_Audio**	mode, sensitivity (, -, blank_time)
index	1	mode [15:0]	AM audio noise blanker (audio frequency detection) 0 = off 1 = on (default)
	2	sensitivity [15:0]	AM audio noise blanker trigger sensitivity 500 … 1500 [*0.1 %] = 50 … 150 % relative trigger sensitivity 1000 = 100 % (default)
	3	- [15:0]	reserved 0 = don’t care
	4	blank_time [15:0]	extended API: AM noise blanker blank time 400 … 1200 [*1 µs] = 400 … 1200 us pulse stretch time Blanker pulse extension time 800 = 800 µs (default)

Application example	AM_Set_NoiseBlanker_Audio (1, 1, 1000)	AM default values
	AM_Set_NoiseBlanker_Audio (1, 1, 1000, 0, 800)	AM defaults extended API
	AM_Set_NoiseBlanker_Audio (1, 1, 1200)	sensitivity 120%; more suppression
I²C example (hex)	[w 21 **18** 01 0001 03E8]	AM default values
	[w 21 **18** 01 0001 03E8 0000 0320]	AM defaults extended API
	[w 21 **18** 01 0001 04B0]	sensitivity 120%; more suppression

Note: Extended API control is available for additional performance tuning. Adaptation of these default values is not advised in general but allows for performance fine-tuning on specific conditions. Feature innovation may cause extended API defaults and control to change with firmware release.

Use of the special control parameter 4 is optional and transmission is not required. In case of a standard transmission (parameters 1 and 2) extended API changes remain.

Note: Noise blanker extended API control requires initialization version p2.21 or higher.

3.13 FM / AM cmd 30 Set_DigitalRadio

Available for TEF6688 and TEF6689 only.

Enabling of I/O signal lines for external digital radio processor; DR I²S output and DR Blend input (enabling DR audio input from IIS_SD_0).

Note: See 3.26 FM / AM cmd 84 Set_DR_Options for additional digital radio options.

module	32 / 33	FM / AM	
cmd	**30**	**Set_DigitalRadio**	mode
index	1	mode [15:0]	digital radio
			0 = off (default)
			1 = on

Application example	FM_Set_DigitalRadio (1, 1)	Enable digital radio for FM use
	AM_Set_DigitalRadio (1, 1)	Enable digital radio for AM use
I²C example (hex)	[w 20 **1E** 01 0001]	Enable digital radio for FM use
	[w 21 **1E** 01 0001]	Enable digital radio for AM use

3.14 FM cmd 31 Set_Deemphasis

Selection of FM deemphasis time constant

module	32	FM	
cmd	**31**	**Set_Deemphasis**	timeconstant
index	1	timeconstant [15:0]	deemphasis time constant
			0 = off; for evaluation purposes only
			500 = 50 μs deemphasis (default)
			750 = 75 μs deemphasis

Application example	FM_Set_Deemphasis (1, 750)	75 μs deemphasis
I²C example (hex)	[w 20 **1F** 01 02EE]	75 μs deemphasis

3.15 FM cmd 32 Set_StereoImprovement

Available for TEF6687 and TEF6689 only.

Selection of extended stereo weak signal handling; stereo high blend (default operation) or special FMSI (FM stereo improvement) blend system for improved sound quality.

module	32	FM	
cmd	**32**	**Set_StereoImprovement**	mode
index	1	mode [15:0]	FM stereo extended weak signal handling
			0 = stereo high blend (default)
			1 = FMSI stereo band blend system

Application example FM_Set_StereoImprovement (1, 1) enable FMSI stereo improvement

I²C example (hex) `[ w 20 20 01 0001 ]` enable FMSI stereo improvement

Note: The default stereo high blend is controlled from FM cmd 70 … 76 Set_StHiBlend, settings from this command range are in use during active stereo high blend processing. FMSI stereo improvement is controlled from FM cmd 90 … 92 Set_StereoBandBlend, settings from this command range are in use during active FMSI signal processing.

Note: With FMSI enabled the stereo high blend function is disabled but the standard stereo weak signal handling remains. FM cmd 60 … 66 Set_Stereo should be defined with disabled settings (or reduced sensitivity settings) to demonstrate the full FMSI stereo performance.

Note: The advised setting is ‘FMSI’ for improved field performance

3.16 FM / AM cmd 38 Set_LevelStep

Selection of level correction as a function of the tuner front-end AGC.

The level step offset is included in the weak signal handling and the level read value of Get_Quality (4.1 FM / AM cmd 128 / 129 Get_Quality).

A setting of 0 dB will show no level change by full compensation of the actual -6 dB AGC attenuation step. Instead a setting of -6 dB will show the actual AGC attenuation step.

module	32 / 33	FM / AM	
cmd	**38**	**Set_LevelStep**	step1, step2, step3, step4, step5, step6, step7
index	1	step1 [15:0]	level offset for an AGC step from 0 to 1 -60 … 0 (*0.1 dB) = -6 … 0 dB -20 = -2 dB (FM default) / -10 = -1 dB (AM default)
	2	step2 [15:0]	level offset for an AGC step from 1 to 2 -60 … 0 (*0.1 dB) = -6 … 0 dB -30 = -3 dB (FM default) / -20 = -2 dB (AM default)
	3	step3 [15:0]	level offset for an AGC step from 2 to 3 -60 … 0 (*0.1 dB) = -6 … 0 dB -40 = -4 dB (FM default) / -30 = -3 dB (AM default)
	4	step4 [15:0]	level offset for an AGC step from 3 to 4 -60 … 0 (*0.1 dB) = -6 … 0 dB -50 = -5 dB (FM default) / -40 = -4 dB (AM default)
	5	step5 [15:0]	level offset for an AGC step from 4 to 5 -60 … 0 (*0.1 dB) = -6 … 0 dB -60 = -6 dB (FM default) / -50 = -5 dB (AM default)
	6	step6 [15:0]	level offset for an AGC step from 5 to 6 -60 … 0 (*0.1 dB) = -6 … 0 dB -60 = -6 dB (default)
	7	step7 [15:0]	level offset for an AGC step from 6 to 7 (or higher) -60 … 0 (*0.1 dB) = -6 … 0 dB -60 = -6 dB (default)

Application example	AM_Set_LevelStep(1, 0, -10, -20, -30, -40, -50, -60)	AM increased level extension
	AM_Set_LevelStep(1, -20, -30, -40, -50, -60, -60, -60)	AM decreased level extension
I²C example (hex)	[w 21 **26** 01 0000 FFF6 FFEC FFE2 FFD8 FFCE FFC4]	AM increased level extension
	[w 21 **26** 01 FFEC FFE2 FFD8 FFCE FFC4 FFC4 FFC4]	AM decreased level extension

Note: Adaptation of the LevelStep default values is not advised in general but allows for a specific fine-tuning of the weak signal handling in high signal conditions.

Note: The indicated steps are the added values of feedback and input AGC steps.

Note: AGC steps higher than step 7 will employ the step 7 setting.

3.17 FM / AM cmd 39 Set_LevelOffset

Selection of level correction.

The level offset can be used as an overall correction for antenna noise level and is included in the weak signal handling and the level read value of Get_Quality (4.1 FM / AM cmd 128 / 129 Get_Quality). A standard use case is the compensation for AM active antenna circuits (typical offset setting = -30 dB).

module	32 / 33	FM / AM	
cmd	**39**	**Set_LevelOffset**	offset
index	1	offset [15:0] signed	level offset
			-480 … +150 (*0.1 dB) = -48 … +15 dB
			0 = 0 dB (default)

Application example	AM_Set_LevelOffset (1, -300)	-30 dB level correction
I²C example (hex)	[w 21 **27** 01 FED4]	-30 dB level correction

3.18 FM / AM cmd 40 … 45 Set_Softmute

Timing and quality sensitivity settings for the Softmute weak signal handling.

‘Set_Softmute_Time’ defines the weak signal handling response times active for the level detector and FM noise and multipath detectors. Fast and slow response times are available for dual timer functionality, with enable options at the level, noise and mph commands.’

‘Set_Softmute_Mod’ enables modulation dependency and sets sensitivity (AM only).

‘Set_Softmute_Level’ sets the level sensitivity and enables slow and fast timing.

‘Set_Softmute_Noise’ and ‘Set_Softmute_Mph’ set the noise and multipath sensitivity and enables slow and fast timing (FM only)

‘Set_Softmute_Max’ enables and defines the maximum amount of softmute attenuation (as realized for poor signal conditions).

module	32 / 33	FM / AM	
cmd	**40**	**Set_Softmute_Time**	slow_attack, slow_decay, fast_attack, fast_decay
index	1	slow_attack [15:0]	slow attack time of weak signal handling
			60 … 2000 (ms) = 60 ms … 2 s slow attack time
			120 = 120 ms (default)
	2	slow_decay [15:0]	slow decay time of weak signal handling
			120 … 12500 (ms) = 120 ms … 12.5 s slow attack time
			500 = 500 ms (default)
	3	fast_attack [15:0]	fast attack time of weak signal handling
			10 … 1200 (*0.1 ms) = 1 ms … 120 ms fast attack time
			20 = 2 ms (FM default) / 120 = 12 ms (AM default)
	4	fast_decay [15:0]	fast decay time of weak signal handling
			20 … 5000 (*0.1 ms) = 2 ms … 500 ms fast attack time
			20 = 2 ms (FM default) / 500 = 50 ms (AM default)

Application example	FM_Set_Softmute_Time (1, 120, 500, 10, 20)	Slow 120 / 500 ms, fast 1 / 2 ms
	AM_Set_Softmute_Time (1, 500, 4000, 100, 500)	Slow 500 / 4000 ms, fast 10 / 50 ms
I²C example (hex)	`[ w 20 28 01 0078 01F4 000A 0014 ]`	Slow 120 / 500 ms, fast 1 / 2 ms
	`[ w 21 28 01 01F4 0FA0 0064 01F4 ]`	Slow 500 / 4000 ms, fast 10 / 50 ms

Note: Suggested FM setting is 1 ms fast_attack for improved field performance.

module	33	AM	
cmd	**41**	**Set_Softmute_ Mod**	mode, start, slope, shift
index	1	mode [15:0]	modulation dependent weak signal handling
			0 = off (default)

			1 = on
	2	start [15:0]	weak signal handling modulation start
			100 … 1000 [*0.1 %] = control when modulation falls below 10% … 100% 210 = 21% (default)
	3	slope [15:0]	weak signal handling modulation range
			30 … 1000 (*0.1 %) = control over modulation range of 3% … 100% 120 = 12% (default)
	4	shift [15:0]	weak signal handling control shift
			50 … 1000 (*0.1 %) = maximum weak signal control shift of 5% … 100% 260 = 26% (default) (percentage of the linear control range from 0 dB to _Max limit)

module	32 / 33	FM / AM	
cmd	**42**	**Set_Softmute_Level**	mode, start, slope
index	1	mode [15:0]	timer selection
			0 = off (only for evaluation)
			1 = fast timer control
			2 = slow timer control (default)
			3 = dual timer control; combined fast and slow timer control
	2	start [15:0]	weak signal handling level start
			0 … 500 [*0.1 dBµV] = control when level falls below 0 dBµV … 50 dBµV 150 = 15 dBµV (FM default) / 280 = 28 dBµV (AM default)
	3	slope [15:0]	weak signal handling level range
			60 … 300 [*0.1 dB] = control over level range of 6 dB … 30 dB 220 = 22 dB (FM default) / 250 = 25 dB (AM default)

Note: Suggested AM setting for LW band is 34 dBµV start and 30 dB slope for improved field performance.

module	32	FM	
cmd	**43**	**Set_Softmute_Noise**	mode, start, slope
index	1	mode [15:0]	timer selection
			0 = off (default)
			1 = fast timer control
			2 = slow timer control
			3 = dual timer control; combined fast and slow timer control
	2	start [15:0]	FM weak signal handling noise start
			0 … 800 [*0.1 %] = control when noise above 0… 80% of USN detector 500 = 50% (default)
	3	slope	FM weak signal handling noise range

		[15:0]	100 … 1000 [*0.1 %] = control over range of 10… 100% of USN detector 1000 = 100% (default)

module	32	FM	
cmd	**44**	**Set_Softmute_Mph**	mode, start, slope
index	1	mode [15:0]	timer selection
			0 = off (default)
			1 = fast timer control
			2 = slow timer control
			3 = dual timer control; combined fast and slow timer control
	2	start [15:0]	FM weak signal handling multipath start
			0 … 800 [*0.1 %] = control when mph above 0… 80% of WAM detector 500 = 50% (default)
	3	slope [15:0]	FM weak signal handling multipath range
			100 … 1000 [*0.1 %] = control over range of 10… 100% of WAM detector 1000 = 100% (default)

module	32 / 33	FM / AM	
cmd	**45**	**Set_Softmute_Max**	mode, limit
index	1	mode [15:0]	weak signal handling (dynamic control)
			0 = off (for evaluation only)
			1 = on; maximum dynamic control defined by limit parameter (default)
	2	limit [15:0]	softmute dynamic attenuation limit
			0 … 400 [*0.1 dB] = 0 … 40 dB softmute maximum attenuation 200 = 20 dB (FM default) / 250 = 25 dB (AM default)

Application example	FM_Set_Softmute_Max (1, 1, 240)	FM 24 dB max. softmute attenuation
	AM_Set_Softmute_Max (1, 1, 300)	AM 30 dB max. softmute attenuation
I²C example (hex)	[w 20 **2D** 01 0001 00F0]	FM 24 dB max. softmute attenuation
	[w 21 **2D** 01 0001 012C]	AM 30 dB max. softmute attenuation

Suggested AM setting for LW band is 33 dB limit.

3.19 FM / AM cmd 50 … 59 Set_Highcut

Timing and quality sensitivity settings for the Highcut weak signal handling.

'Set_Highcut_Time' defines the weak signal handling response times active for the level detector and FM noise and multipath detectors. Fast and slow response times are available for dual timer functionality, with enable options at the level, noise and mph commands.'

'Set_Highcut_Mod' enables modulation dependency and sets sensitivity

'Set_Highcut_Level' sets the level sensitivity and enables slow and fast timing.

'Set_Highcut_Noise' and 'Set_Highcut_Mph' set the noise and multipath sensitivity and enables slow and fast timing (FM only)

'Set_Highcut_Max' enables and defines the maximum amount of Highcut attenuation (as realized for poor signal conditions).

'Set_Highcut_Min' optionally defines a minimum amount of Highcut attenuation (as realized for good signal conditions).

'Set_Lowcut_Max' enables and defines the maximum dynamic Lowcut attenuation and 'Set_Lowcut_Min' optionally defines a minimum attenuation for low signal frequencies.

Dynamic 'Lowcut' (as set by Set_Lowcut_Max) is part of the 'Highcut' control and shares the HighCut time and sensitivity settings.

'Set_Highcut_Options' allows selection between three different Highcut control characteristics (FM only).

module	32 / 33	FM / AM	
cmd	**50**	**Set_Highcut_Time**	slow_attack, slow_decay, fast_attack, fast_decay
index	1	slow_attack [15:0]	slow attack time of weak signal handling
			60 … 2000 (ms) = 60 ms … 2 s slow attack time 500 = 500 ms (default)
	2	slow_decay [15:0]	slow decay time of weak signal handling
			120 … 12500 (ms) = 120 ms … 12.5 s slow attack time 2000 = 2 s (default)
	3	fast_attack [15:0]	fast attack time of weak signal handling
			10 … 1200 (*0.1 ms) = 1 ms … 120 ms fast attack time 20 = 2 ms (FM default) / 120 = 12 ms (AM default)
	4	fast_decay [15:0]	fast decay time of weak signal handling
			20 … 5000 (*0.1 ms) = 2 ms … 500 ms fast attack time 20 = 2 ms (FM default) / 500 = 50 ms (AM default)

Application example	FM_Set_Highcut_Time (1, 200, 500, 10, 80)	Slow 200 / 500 ms, fast 1 / 8 ms
	AM_Set_Highcut_Time (1, 500, 4000, 100, 500)	Slow 500 / 4000 ms, fast 10 / 50 ms
I²C example (hex)	`[ w 20 32 01 00C8 01F4 000A 0050 ]`	Slow 200 / 500 ms, fast 1 / 8 ms
	`[ w 21 32 01 01F4 0FA0 0064 01F4 ]`	Slow 500 / 4000 ms, fast 10 / 50 ms

Note: Suggested FM settings are 200 ms slow_attack, 1 ms fast_attack and 8 ms fast_ decay for improved field performance.

module	32 / 33	FM / AM	
cmd	**51**	**Set_Highcut_ Mod**	mode, start, slope, shift
index	1	mode [15:0]	modulation dependent weak signal handling
			0 = off (default)
			1 = on (independent modulation timer)
	2	start [15:0]	weak signal handling modulation start
			100 … 1000 [*0.1 %] = control when modulation falls below 10% … 100% 250 = 25% (default) (note: for FM band 100% modulation equals 75 kHz deviation)
	3	slope [15:0]	weak signal handling modulation range
			30 … 1000 (*0.1 %) = control over modulation range of 3% … 100% 130 = 13% (default)
	4	shift [15:0]	weak signal handling control shift
			50 … 1000 (*0.1 %) = maximum weak signal control shift of 5% … 100% 500 = 50% (default) (percentage of the linear control range from _Min limit to _Max limit)

module	32 / 33	FM / AM	
cmd	**52**	**Set_Highcut_Level**	mode, start, slope
index	1	mode [15:0]	timer selection
			0 = off (only for evaluation)
			1 = fast timer control
			2 = slow timer control (AM default)
			3 = dual timer control; combined fast and slow timer control (FM default)
	2	start [15:0]	weak signal handling level start
			200 … 600 [*0.1 dBμV] = control when level is below 20 dBμV … 60 dBμV 360 = 36 dBμV (FM default) / 400 = 40 dBμV (AM default)
	3	slope [15:0]	weak signal handling level range
			60 … 300 [*0.1 dB] = control over level range of 6 dB … 30 dB 300 = 30 dB (FM default) / 200 = 20 dB (AM default)

Note: Suggested AM setting for MW and SW band is 47 dBμV start for improved field performance. Suggested for AM LW band is 52 dBμV start.

module	32	FM	
cmd	**53**	**Set_Highcut_Noise**	mode, start, slope

index	1	mode [15:0]	timer selection
			0 = off
			1 = fast timer control
			2 = slow timer control (default)
			3 = dual timer control; combined fast and slow timer control
	2	start [15:0]	FM weak signal handling noise start
			0 … 800 [*0.1 %] = control when noise above 0… 80% of USN detector 360 = 36% (default)
	3	slope [15:0]	FM weak signal handling noise range
			100 … 1000 [*0.1 %] = control over range of 10… 100% of USN detector 300 = 30% (default)

Note: Suggested is 'dual timer' mode, 15% start and 20% slope for improved field performance.

module	32	FM	
cmd	**54**	**Set_Highcut_Mph**	mode, start, slope
index	1	mode [15:0]	timer selection
			0 = off (only for evaluation)
			1 = fast timer control
			2 = slow timer control (default)
			3 = dual timer control; combined fast and slow timer control
	2	start [15:0]	FM weak signal handling multipath start
			0 … 800 [*0.1 %] = control when mph above 0… 80% of WAM detector 360 = 36% (default)
	3	slope [15:0]	FM weak signal handling multipath range
			100 … 1000 [*0.1 %] = control over range of 10… 100% of WAM detector 300 = 30% (default)

Note: Suggested is 'dual timer' mode, 12% start and 16% slope for improved field performance.

module	32 / 33	FM / AM	
cmd	**55**	**Set_Highcut_Max**	mode, limit
index	1	mode [15:0]	weak signal handling (dynamic control)
			0 = off; for evaluation only
			1 = on; maximum dynamic control set by limit parameter (default)
	2	limit [15:0]	Highcut attenuation limit
			FM Highcut corner frequency for maximum -3 dB attenuation 4000 = 4 kHz (default)
			1500 … 7000 [*1 Hz] = 1.5 … 7 kHz 'IIR' filter (Options '1' (default))

		700 … 3000 [*1 Hz] = 0.7 … 3 kHz ‘deemphasis’ mode (Options ‘2’)
		2700 … 7000 [*1 Hz] = 2.7 … 7 kHz ‘FIR’ highcut filter (Options ‘3’)
	AM	1350 … 7000 [*1 Hz] = 1.35 … 7 kHz Highcut maximum -3 dB att. 1800 = 1.8 kHz (default)

Application example

FM_Set_Highcut_Max (1, 1, 2400) — FM 2.4 kHz max. Highcut attenuation
AM_Set_Highcut_Max (1, 1, 1500) — AM 1.5 kHz max. Highcut attenuation

I²C example (hex)

```
[ w 20 37 01 0001 0960 ]
[ w 21 37 01 0001 05DC ]
```

FM 2.4 kHz max. Highcut attenuation
AM 1.5 kHz max. Highcut attenuation

Note: For FM different limit ranges apply for the different Highcut control characteristics as available from FM Set_Highcut_Options (cmd = 59).

Note: Suggested FM setting is 2.4 kHz limit for improved ‘IIR’ filter field performance.

module	32 / 33	FM / AM		
cmd	**56**	**Set_Highcut_Min**	mode, limit	
index	1	mode [15:0]	strong signal handling	
			0 = off; high audio frequency bandwidth is not limited (FM default)	
			1 = on; minimum control limit set by limit parameter (AM default)	
	2	limit [15:0]	Highcut fixed attenuation limit	
			FM	Highcut corner frequency for minimum -3 dB attenuation 10000 = 10 kHz (default)
				2700 … 15000 [*1 Hz] = 2.7 … 15 kHz ‘IIR’ filter (Options ‘1’ (default))
				1500 … 3183 [*1 Hz] = 1.5 … 3.18 kHz ‘deemphasis’ (Options ‘2’) 2122 = 75 µs deemphasis / 3183 = 50 µs deemphasis
				2700 … 15000 [*1 Hz] = 2.7 … 15 kHz ‘FIR’ highcut filter (Options ‘3’)
			AM	2700 … 15000 [*1 Hz] = 2.7 … 15 kHz -3 dB att. for min. Highcut 6000 = 6 kHz (default)

Application example

FM_Set_Highcut_Min (1, 1, 10000) — FM 10 kHz min. Highcut attenuation
AM_Set_Highcut_Min (1, 1, 3000) — AM 3 kHz min. Highcut attenuation

I²C example (hex)

```
[ w 20 38 01 0001 2710 ]
[ w 21 38 01 0001 0BB8 ]
```

FM 10 kHz min. Highcut attenuation
AM 3 kHz min. Highcut attenuation

Note: In case of characteristic ‘deemphasis’ from FM cmd 59 Set_Highcut_Options mode = 2, the FM cmd 31 Set_Deemphasis setting is ignored and 50 µs or 75 µs deemphasis is defined by FM_Set_Highcut_Min parameters mode = 1, and limit instead.

Note: For a normal control behavior Set_Highcut_Min always should set a weaker signal handling limit (i.e. a higher frequency) than Set_Highcut_Max.

module	32 / 33	FM / AM	
cmd	**57**	**Set_Lowcut_ Max**	mode, limit
index	1	mode [15:0]	weak signal handling (dynamic control)
			0 = off
			1 = on; maximum dynamic control defined by limit parameter (default)
	2	limit [15:0]	Lowcut dynamic attenuation limit
			30 … 500 [Hz] = 30 … 500 Hz -3 dB attenuation for maximum Lowcut 120 = 120 Hz (default)

Application example

FM_Set_Lowcut_Max (1, 1, 100) FM 100 Hz max. Lowcut attenuation
AM_Set_Lowcut_Max (1, 1, 300) AM 300 Hz max. Lowcut attenuation

I²C example (hex)

```
[ w  20 39 01  0001 0064 ]
[ w  21 39 01  0001 012C ]
```

FM 100 Hz max. Lowcut attenuation
AM 300 Hz max. Lowcut attenuation

Note: Suggested FM setting is 100 Hz limit for improved field performance.

module	32 / 33	FM / AM	
cmd	**58**	**Set_Lowcut_Min**	mode, limit
index	1	mode [15:0]	strong signal handling
			0 = off; low audio frequency bandwidth is not limited (FM default)
			1 = on; minimum control limit set by limit parameter (AM default)
	2	limit [15:0]	Lowcut fixed attenuation limit
			10 … 200 [Hz] = 10 … 200 Hz Lowcut minimum -3 dB attenuation 20 = 20 Hz (default)

Application example

FM_Set_Lowcut_Min (1, 1, 10) FM 10 Hz min. Lowcut attenuation
AM_Set_Lowcut_Min (1, 1, 30) AM 30 Hz min. Lowcut attenuation

I²C example (hex)

```
[ w  20 3A 01  0001 000A ]
[ w  21 3A 01  0001 001E ]
```

FM 10 Hz min. Lowcut attenuation
AM 30 Hz min. Lowcut attenuation

Note: For a normal control behavior Set_Lowcut_Min always should set a weaker signal handling limitation (i.e. a lower frequency) than Set_Lowcut_Max.

module	32	FM	
cmd	**59**	**Set_Highcut_Options**	mode
index	1	mode [15:0]	FM Highcut control characteristics
			1 = IIR; ‘analog’ first order lowpass filter with controlled frequency (default)
			2 = deemphasis; controlled frequency of the 50 / 75 μs deemphasis filter
			3 = FIR; ‘digital’ high order lowpass filter with controlled frequency

Application example	FM_Set_Highcut_Options (1, 2)	FM ‘deemphasis’ type Highcut control
I²C example (hex)	[w 20 **3B** 01 0002]	FM ‘deemphasis’ type Highcut control

Note: Different FM Highcut control characteristics are available for selection of sound taste.

Note: In addition to the _Options selection of the Highcut filter type appropriate values should be written to FM_Set_Highcut_Min and FM_Set_Highcut_Max.

Note: In case of ‘deemphasis’ characteristics the FM_Set_Deemphasis setting is ignored and selection of 50 μs or 75 μs deemphasis is defined by FM_Set_Highcut_Min instead.

3.20 FM cmd 60 … 66 Set_Stereo

Timing and quality sensitivity settings for the FM Stereo weak signal handling.

‘Set_Stereo_Time’ defines the weak signal handling response times active for the level detector and noise and multipath detectors. Fast and slow response times are available for dual timer functionality, with enable options at the level, noise and mph commands.’

‘Set_Stereo_Mod’ enables modulation dependency and sets sensitivity

‘Set_Stereo_Level’ sets the level sensitivity and enables slow and fast timing.

‘Set_Stereo_Noise’ and ‘Set_Stereo_Mph’ set the noise and multipath sensitivity and enables slow and fast timing.

‘Set_Stereo_Max’ allows disabling the dynamic stereo control for evaluation purposes.

‘Set_Stereo_Min’ optionally defines a minimum amount of Stereo attenuation (as realized for good signal conditions).

module	32	FM	
cmd	**60**	**Set_Stereo_Time**	slow_attack, slow_decay, fast_attack, fast_decay
index	1	slow_attack [15:0]	slow attack time of weak signal handling
			60 … 2000 (ms) = 60 ms … 2 s slow attack time 1000 = 1 s (default)
	2	slow_decay [15:0]	slow decay time of weak signal handling
			120 … 12500 (ms) = 120 ms … 12.5 s slow attack time 4000 = 4 s (default)
	3	fast_attack [15:0]	fast attack time of weak signal handling
			10 … 1200 (*0.1 ms) = 1 ms … 120 ms fast attack time 80 = 8 ms
	4	fast_decay [15:0]	fast decay time of weak signal handling
			20 … 5000 (*0.1 ms) = 2 ms … 500 ms fast attack time 80 = 8 ms

Application example	FM_Set_Stereo_Time (1, 200, 4000, 20, 80)	Slow 200 / 4000 ms, fast 2 / 8 ms
I²C example (hex)	[w 20 3C 01 00C8 0FA0 0014 0050]	Slow 200 / 4000 ms, fast 2 / 8 ms

Note: Suggested is 200 ms slow_attack and 2 ms fast_attack for improved field performance.

module	32	FM	
cmd	**61**	**Set_Stereo_ Mod**	mode, start, slope, shift
index	1	mode [15:0]	modulation dependent weak signal handling
			0 = off (default)
			1 = on (independent modulation timer)

	2	start [15:0]	weak signal handling modulation start
			100 … 1000 [*0.1 %] = control when modulation falls below 10% … 100% 210 = 21% (default) (note: for FM band 100% modulation equals 75 kHz deviation)
	3	slope [15:0]	weak signal handling modulation range
			30 … 1000 (*0.1 %) = control over modulation range of 3% … 100% 90 = 9% (default)
	4	shift [15:0]	weak signal handling control shift
			50 … 1000 (*0.1 %) = maximum weak signal control shift of 5% … 100% 500 = 50% (default) (percentage of the linear control range from _Min limit to ‘mono’)

module	32	FM	
cmd	**62**	**Set_Stereo_Level**	mode, start, slope
index	1	mode [15:0]	timer selection
			0 = off (only for evaluation)
			1 = fast timer control
			2 = slow timer control
			3 = dual timer control; combined fast and slow timer control (default)
	2	start [15:0]	weak signal handling level start
			300 … 600 [*0.1 dBμV] = control when level below 30 dBμV … 60 dBμV 460 = 46 dBμV (default)
	3	slope [15:0]	weak signal handling level range
			60 … 300 [*0.1 dB] = control over level range of 6 dB … 30 dB 240 = 24 dB (default)

module	32	FM	
cmd	**63**	**Set_Stereo_Noise**	mode, start, slope
index	1	mode [15:0]	timer selection
			0 = off
			1 = fast timer control
			2 = slow timer control
			3 = dual timer control; combined fast and slow timer control (default)
	2	start [15:0]	FM weak signal handling noise start
			0 … 800 [*0.1 %] = control when noise above 0… 80% of USN detector 240 = 24% (default)
	3	slope [15:0]	FM weak signal handling noise range
			100 … 1000 [*0.1 %] = control over range of 10… 100% of USN detector 200 = 20% (default)

Note: Suggested is 12% start and 16% slope for improved field performance.

module	32	FM	
cmd	**64**	**Set_Stereo_Mph**	mode, start, slope
index	1	mode [15:0]	timer selection
			0 = off
			1 = fast timer control
			2 = slow timer control
			3 = dual timer control; combined fast and slow timer control (default)
	2	start [15:0]	FM weak signal handling multipath start
			0 … 800 [*0.1 %] = control when mph above 0… 80% of WAM detector 240 = 24% (default)
	3	slope [15:0]	FM weak signal handling multipath range
			100 … 1000 [*0.1 %] = control over range of 10… 100% of WAM detector 200 = 20% (default)

Note: Suggested is 10% start and 15% slope for improved field performance.

module	32	FM	
cmd	**65**	**Set_Stereo_Max**	mode
index	1	mode [15:0]	weak signal handling (dynamic control)
			0 = off (for evaluation only)
			1 = on; maximum dynamic control is 0 dB channel sep, i.e. mono (default)

Note: _Max mode 'off' is not suitable to disable Stereo handling as may be desired for FMSI operation. Setting 'off' on _Mod, _Level, _Usn and _Mph should be used instead.

module	32	FM	
cmd	**66**	**Set_Stereo_Min**	mode, limit
index	1	mode [15:0]	strong signal handling
			0 = off; channel separation is not limited (default)
			1 = on; minimum control limit set by limit parameter
			2 = forced mono
	2	limit [15:0]	Stereo fixed attenuation limit
			60 … 400 [0.1* dB] = 6 … 40 dB Stereo minimum channel separation 400 = 40 dB (default)

Application example	FM_Set_Stereo_Min (1, 1, 200)	FM 20 dB min. Stereo channel sep.
	FM_Set_Stereo_Min (1, 2, 200)	FM forced mono
I²C example (hex)	[w 20 **42** 01 0001 00C8]	FM 20 dB min. Stereo channel sep.
	[w 20 **42** 01 0002 00C8]	FM forced mono

3.21 FM cmd 70 … 76 Set_StHiBlend

Timing and quality sensitivity settings for the FM StHiBlend weak signal handling.

'Set_StHiBlend_Time' defines the weak signal handling response times active for the level detector and noise and multipath detectors. Fast and slow response times are available for dual timer functionality, with enable options at the level, noise and mph commands.'

'Set_StHiBlend_Mod' enables modulation dependency and sets sensitivity

'Set_StHiBlend_Level' sets the level sensitivity and enables slow and fast timing.

'Set_StHiBlend_Noise' and 'Set_StHiBlend_Mph' set the noise and multipath sensitivity and enables slow and fast timing.

'Set_StHiBlend_Max' enables and defines the maximum amount of StHiBlend attenuation (as realized for very poor signal conditions).

'Set_StHiBlend_Min' optionally defines a minimum amount of StHiBlend attenuation (as realized for good signal conditions).

module	32	FM	
cmd	**70**	**Set_StHiBlend_Time**	slow_attack, slow_decay, fast_attack, fast_decay
index	1	slow_attack [15:0]	slow attack time of weak signal handling
			60 … 2000 (ms) = 60 ms … 2 s slow attack time 500 = 500 ms (default)
	2	slow_decay [15:0]	slow decay time of weak signal handling
			120 … 12500 (ms) = 120 ms … 12.5 s slow attack time 2000 = 2 s (default)
	3	fast_attack [15:0]	fast attack time of weak signal handling
			10 … 1200 (*0.1 ms) = 1 ms … 120 ms fast attack time 20 = 2 ms (default)
	4	fast_decay [15:0]	fast decay time of weak signal handling
			20 … 5000 (*0.1 ms) = 2 ms … 500 ms fast attack time 20 = 2 ms (default)

Application example FM_Set_StHiBlend_Time (1, 120, 500, 80, 160) Slow 120 / 500 ms, fast 8 / 16 ms

I²C example (hex) `[ w 20 46 01 0078 01F4 0050 00A0 ]` Slow 120 / 500 ms, fast 8 / 16 ms

module	32	FM	
cmd	**71**	**Set_StHiBlend_ Mod**	mode, start, slope, shift
index	1	mode [15:0]	modulation dependent weak signal handling
			0 = off (default)
			1 = on (independent modulation timer)
	2	start	weak signal handling modulation start

		[15:0]	100 … 1000 [*0.1 %] = control when modulation falls below 10% … 100% 240 = 24% (default) (note: for FM band 100% modulation equals 75 kHz deviation)
	3	slope [15:0]	weak signal handling modulation range
			30 … 1000 (*0.1 %) = control over modulation range of 3% … 100% 120 = 12% (default)
	4	shift [15:0]	weak signal handling control shift
			50 … 1000 (*0.1 %) = maximum weak signal control shift of 5% … 100% 670 = 67% (default) (percentage of the control range from _Min limit to _Max limit)

module	32	FM	
cmd	**72**	**Set_StHiBlend_ Level**	mode, start, slope
index	1	mode [15:0]	timer selection
			0 = off (only for evaluation)
			1 = fast timer control
			2 = slow timer control
			3 = dual timer control; combined fast and slow timer control (default)
	2	start [15:0]	weak signal handling level start
			300 … 660 [*0.1 dBμV] = control when level below 30 dBμV … 66 dBμV 600 = 60 dBμV (default)
	3	slope [15:0]	weak signal handling level range
			60 … 300 [*0.1 dB] = control over level range of 6 dB … 30 dB 240 = 24 dB (default)

module	32	FM	
cmd	**73**	**Set_StHiBlend_ Noise**	mode, start, slope
index	1	mode [15:0]	timer selection
			0 = off
			1 = fast timer control
			2 = slow timer control
			3 = dual timer control; combined fast and slow timer control (default)
	2	start [15:0]	FM weak signal handling noise start
			0 … 800 [*0.1 %] = control when noise above 0… 80% of USN detector 160 = 16% (default)
	3	slope [15:0]	FM weak signal handling noise range
			100 … 1000 [*0.1 %] = control over range of 10… 100% of USN detector 140 = 14% (default)

Note: Suggested is 8% start for improved field performance.

module	32	FM	
cmd	**74**	**Set_StHiBlend_ Mph**	mode, start, slope
index	1	mode [15:0]	timer selection
			0 = off
			1 = fast timer control
			2 = slow timer control
			3 = dual timer control; combined fast and slow timer control (default)
	2	start [15:0]	FM weak signal handling multipath start
			0 … 800 [*0.1 %] = control when mph above 0… 80% of WAM detector 160 = 16% (default)
	3	slope [15:0]	FM weak signal handling multipath range
			100 … 1000 [*0.1 %] = control over range of 10… 100% of WAM detector 140 = 14% (default)

Note: Suggested is 8% start for improved field performance.

module	32	FM	
cmd	**75**	**Set_StHiBlend_ Max**	mode, limit
index	1	mode [15:0]	weak signal handling (dynamic control)
			0 = off
			1 = on; maximum dynamic control defined by limit parameter (default)
	2	limit [15:0]	StHiBlend dynamic attenuation limit
			2700 … 7000 [Hz] = 2.7 kHz … 7 kHz StHiBlend max. reduction of channel separation bandwidth 4000 = 4 kHz (default)

Application example	FM_Set_StHiBlend_Max (1, 1, 3000)	3 kHz maximum reduction of channel separation bandwidth
I²C example (hex)	[w 20 **4B** 01 0001 0BB8]	3 kHz maximum reduction of channel separation bandwidth

module	32	FM	
cmd	**76**	**Set_StHiBlend_ Min**	mode, limit
index	1	mode [15:0]	strong signal handling
			0 = off; channel separation bw is not limited (default)
			1 = on; minimum control limit set by limit parameter
	2	limit [15:0]	StHiBlend fixed attenuation limit
			3000 … 15000 [Hz] = 3 kHz … 15 kHz StHiBlend min. reduction of channel separation bandwidth 7000 = 7 kHz (default)

Application example	FM_Set_StHiBlend_Min (1, 1, 7000)	fixed 7 kHz channel separation bandwidth
I²C example (hex)	[w 20 **4C** 01 0001 1B68]	fixed 7 kHz channel separation bandwidth

Note: For a normal control behavior Set_StHiBlend_Min always should set a weaker signal handling limit (i.e. a higher frequency) than Set_StHiBlend_Max.

3.22 FM / AM cmd 80 Set_Scaler

Fine tuning of sound amplitude between FM and AM analog radio sound.

module	32 / 33	FM / AM	
cmd	**80**	**Set_Scaler**	gain
index	1	gain [15:0] (signed)	channel gain
			-120 … +60 [*0.1 dB] = -12 … +6 dB analog radio signal gain 0 = 0 dB (default)

Application example	FM_Set_Scaler (1, -30)	FM analog radio -3 dB gain scaling
I²C example (hex)	`[ w 20 50 01 FFE2 ]`	FM analog radio -3 dB gain scaling

Note: For fine tuning of FM and AM digital radio sound amplitude see 3.25 FM / AM cmd 83 Set_DR_Blend.

3.23 FM cmd 81 Set_RDS

Control of the FM Radio Data System demodulator and decoder system.

module	32	FM	
cmd	**81**	**Set_RDS**	mode, restart, interface
index	1	mode [15:0]	RDS operation control
			0 = off (RDS function disabled)
			1 = decoder mode (default); output of RDS group data (block A, B, C, D) from Get_RDS_Status/Get_RDS_Data; FM cmd = 130/131
			2 = demodulator mode; output of raw demodulator data from Get_RDS_Status/Get_RDS_Data; FM cmd = 130/131
	2	restart [15:0]	RDS decoder restart
			0 = no control
			1 = manual restart; start looking for new RDS signal immediately
			2 = automatic restart after tuning (default); start looking for new RDS signal after Preset, Search, Jump or Check tuning action (see FM cmd = 1)
	3	interface [15:0]	RDS pin signal functionality
			0 = no pin interface (default)
			2 = data-available status output; active low (GPIO feature 'DAVN')
			4 = legacy 2-wire demodulator data and clock output ('RDDA' and 'RDCL')

Application example	FM_Set_RDS (1, 1, 2, 2)	Enable data-available status signal pin
I²C example (hex)	[w 20 **51** 01 0001 0002 0002]	Enable data-available status signal pin

See 4.2 FM cmd 130 / 131 Get_RDS for information on RDS data read.

Note: RDS 'DAVN' signal (interface = 2) can be output at any of the available GPIO pins. To receive raw demodulator data use of 'demodulator mode' is advised (mode = 2), the 2-wire output option (interface = 4) is available for legacy use only and not suggested for new designs.
For pin signals a GPIO pin assignment is required; see 3.39 APPL cmd 3 Set_GPIO.

3.24 FM / AM cmd 82 Set_QualityStatus

Enable and define interrupt use or status pin output for quality detector status flag.

module	32 / 33	FM / AM	
cmd	**82**	**Set_QualityStatus**	mode, interface
index	1	mode [15:0]	quality status flag after tuning ready
			0 = no flag set after tuning (default)
			[8:0] : 10 … 320 (* 0.1 ms) = set flag at 1 … 32 ms after tuning ready
			[15] : 1 = set flag when FM AF_Update quality result is available
	2	interface [15:0]	quality status pin signal functionality
			0 = no pin interface (default)
			2 = quality status output; active low ('QSI')

Application example	FM_Set_QualityStatus (1, 32968, 2)	Set status pin at 20 ms or AFU result
I²C example (hex)	[w 20 **52** 01 80C8 0002]	Set status pin at 20 ms or AFU result

For pin signals a GPIO pin assignment is required; see 3.39 APPL cmd 3 Set_GPIO.

Note: the mode parameter timer setting is rounded to 1 ms step size.

3.25 FM / AM cmd 83 Set_DR_Blend

Available for TEF6688 and TEF6689 only.

Control of digital radio blend functionality and digital radio scaler.

module	32 / 33	FM / AM	
cmd	**83**	**Set_DR_Blend**	mode, in_time, out_time, gain
index	1	mode [15:0]	blend pin use (DR_BL input)
			0 = Standard pin use : DR Blend pin High = digital radio (default)
			1 = Inverted pin use : DR Blend pin Low = digital radio
			2 = No pin use; Force blend to digital radio
			3 = No pin use; Force blend to analog radio
	2	in_time [15:0]	blend time from analog radio to digital radio
			10 … 5000 [*0.1 ms] = 1 … 500 ms
			50 = 5 ms (default)
	3	out_time [15:0]	blend time from digital radio to analog radio
			10 … 5000 [*0.1 ms] = 1 … 500 ms
			50 = 5 ms (default)
	4	gain [15:0] (signed)	digital radio channel gain
			-180 … +60 [*0.1 dB] = -18 … +6 dB digital radio signal gain 0 = 0 dB (default)

Application example	FM_Set_DR_Blend (1, 2, 50, 50, -60)	force 5 ms blend to digital (-6 dB)
I²C example (hex)	`[ w 20 53 01 0002 0032 0032 FFC4 ]`	force 5 ms blend to digital (-6 dB)

Note: blend is functional only when digital radio is enabled (see 3.13 FM / AM cmd 30 Set_DigitalRadio) and radio is selected as an audio input source (see 3.32 AUDIO cmd 12 Set_Input).

3.26 FM / AM cmd 84 Set_DR_Options

For TEF6688 and TEF6689 only.

Control of digital radio I/O functionality. Note: DR output is functional only when digital radio is enabled (see 3.13 FM / AM cmd 30 Set_DigitalRadio).

module	32 / 33	FM / AM		
cmd	**84**	**Set_DR_Options**	samplerate, mode, format	
index	1	samplerate [15:0]	baseband digital radio sample rate (DR_I2S output)	
			0 = automatic frequency selection based on tuning frequency (default)	
			6500 = 650 kHz (not for normal application use)	
			6750 = 675 kHz (not for normal application use)	
	2	mode [15:0]	baseband digital radio pin mode	
			[15:8] =	BCK and WS pin mode
				34 = standard operation, voltage output (default)
			[7:0] =	Data pin(s) mode
				2 = voltage output
				4 = open drain (‘pull down’) (default)
	3	format [15:0]	baseband digital radio format select	
			16 = I^2S 16 bit, ‘3 wire’ interface with single I/Q signal line (DR_I_DATA) (f_{DR_BCK} = 32 * sample rate)	
			4112 = I^2S 16 bit, ‘4 wire’ interface with independent I and Q signal lines (f_{DR_BCK} = 16 * sample rate) (default)	

Application example

FM_Set_DR_Options (1, 0)	automatic DR sample rate selection
FM_Set_DR_Options (1, 0, 8706, 16)	3-wire bus with voltage output data

I²C example (hex)

[w 20 **54** 01 0000]	automatic DR sample rate selection
[w 20 **54** 01 0000 2202 0010]	3-wire bus with voltage output data

Note: writing of parameters mode and format is optional

Note: Digital radio audio I/O is defined by AUDIO cmd 22 Set_Dig_IO (see 3.35); signal = 32; IIS_SD_0.

Note: samplerate parameter setting changes are executed at the next tuning action.

3.27 FM / AM cmd 85 Set_Specials

Special radio options for evaluation and extended application use.

module	32 / 33	FM / AM	
cmd	**85**	**Set_Specials**	ana_out
index	1	ana_out [15:0]	audio output use
			0 = normal operation (default)
			1 = DAC_L : FM MPX wideband (DARC) signal / DAC_R : FM mono audio
			2 = L : digital radio left channel / R : analog radio left channel

Application example

FM_Set_Specials (1, 1) DARC/VICS output mode
FM_Set_Specials (1, 2) digital radio time alignment test

I²C example (hex)

[w 20 **55** 01 0001] DARC/VICS output mode
[w 20 **55** 01 0002] digital radio time alignment test

Note: setting ana_out = 1 acts on the DAC output and is available for FM only. FM stereo signal remains available from the digital audio I2S output (IIS_SD_1).

Note: setting ana_out = 2 acts on both the DAC and the digital audio I²S output. DAC source selection or I²S output source selection override this digital radio test option.

Device version V102 note:
Setting ana_out = 2 requires an audio input selection of 'radio' and digital radio must be disabled (or the blend signal in inactive state). Digital radio gain scaling is not included. This behavior is equal to device version V101.

3.28 FM cmd 86 Set_Bandwidth_Options

Additional control option of the FM automatic bandwidth radio selectivity filter.

module	32	FM	
cmd	**86**	**Set_Bandwidth_Options**	modulation
index	1	modulation [15:0]	extended API: FM automatic bandwidth boost on modulation 660 … 1330 (*0.1 %) = 66 … 133 % modulation (= 50 … 100 kHz FM dev.) Modulation index where bandwidth is boosted to maximum bandwidth. 950 = 95 % (default)

Application example FM_Set_Bandwidth_Options (1, 900) Set 90 % modulation for max. boost

I²C example (hex) `[ w 20 56 01 0384 ]` Set 90 % modulation for max. boost

Note: Adaptation of the default value is not advised in general but allows for specific performance fine-tuning on specific conditions. Feature innovation may cause extended API defaults and control to change with firmware release

For main FM automatic bandwidth control and additional control options see 3.3 FM / AM cmd 10 Set_Bandwidth.

The modulation control option requires initialization version p2.17 or higher.

3.29 FM cmd 90 … 92 Set_StereoBandBlend

For TEF6687 and TEF6689 only.

Control of the FMSI stereo improvement and extension system.
To enable the FMSI system see FM cmd 32 Set_StereoImprovement.

'Set_StBandBlend_Time' defines the weak signal handling response times.

'Set_StBandBlend_Gain' defines the weak signal handling sensitivity for the four available audio bands.

'Set_StBandBlend_Bias' defines the system operation on the condition of good quality reception with low modulation.

module	32	FM	
cmd	**90**	**Set_StBandBlend_Time**	attack, decay
index	1	attack [15:0]	attack time of FMSI weak signal handling
			10 … 1000 (ms) = 10 ms … 1 s attack time (control time towards mono) 50 = 50 ms (default)
	2	decay [15:0]	decay time of FMSI weak signal handling
			10 … 1000 (ms) = 10 ms … 1 s attack time (control time towards stereo) 50 = 50 ms (default)

Application example	FM_Set_StBandBlend_Time (1, 100, 30)	FMSI 100 ms attack, 30 ms decay
I²C example (hex)	[w 20 **5A** 01 0064 001E]	FMSI 100 ms attack, 30 ms decay

Note: Because the FMSI weak signal handling is dominantly defined by modulation best results can be found with equal time settings or maybe even slow attack with fast decay as shown in the example.

module	32	FM	
cmd	**91**	**Set_StBandBlend_Gain**	band1, band2, band3, band4
index	1	band1 [15:0]	control sensitivity for low frequency audio band
			500 … 1500 [*0.1 %] = 50% … 150% weak … strong control to mono 1000 = 100% (default)
	2	band2 [15:0]	control sensitivity for audio band around 2 kHz
			500 … 1500 [*0.1 %] = 50% … 150% weak … strong control to mono 1000 = 100% (default)
	3	band3 [15:0]	control sensitivity for audio band around 5 kHz
			500 … 1500 [*0.1 %] = 50% … 150% weak … strong control to mono 1000 = 100% (default)
	4	band4 [15:0]	control sensitivity for high frequency audio band
			500 … 1500 [*0.1 %] = 50% … 150% weak … strong control to mono 1000 = 100% (default)

Application example	FM_Set_StBandBlend_Gain (1, 1000, 1000, 1000, 1000)	FMSI sensitivity control
I²C example (hex)	[w 20 **5B** 01 03E8 03E8 03E8 03E8]	FMSI sensitivity control

module	32	FM	
cmd	**92**	**Set_StBandBlend_Bias**	band1, band2, band3, band4
index	1	band1 [15:0] signed	control bias for low frequency audio band -250 … +250 [*0.1 %] = -25% … +25% stereo … mono bias -75 = -7.5% (default)
	2	band2 [15:0] signed	control bias for audio band around 2 kHz -250 … +250 [*0.1 %] = -25% … +25% stereo … mono bias -35 = -3.5% (default)
	3	band3 [15:0] signed	control bias for audio band around 5 kHz -250 … +250 [*0.1 %] = -25% … +25% stereo … mono bias -25 = -2.5% (default)
	4	band4 [15:0] signed	control bias for high frequency audio band -250 … +250 [*0.1 %] = -25% … +25% stereo … mono bias -25 = -2.5% (default)

Application example	FM_Set_StBandBlend_Bias (1, 0, 0, 0, 0)	FMSI bias control
I²C example (hex)	[w 20 **5C** 01 0000 0000 0000 0000]	FMSI bias control

Note: The control bias settings determine the blending for good quality conditions with low modulation.

3.30 AUDIO cmd 10 Set_Volume

Setting of audio volume.

module	48	AUDIO	
cmd	**10**	**Set_Volume**	volume
index	1	volume [15:0] (signed)	audio volume
			-599 … +240 = -60 … +24 dB volume 0 = 0 dB (default)

Application example	AUDIO_Set_Volume (1, -100)	Set -10 dB volume gain
I²C example (hex)	[w 30 **0A** 01 FF9C]	Set -10 dB volume gain

Note: Depending on the source signal a volume setting over 0 dB may introduce signal clipping.

Note: TEF668X volume settings down to volume = -40 dB are accurate within 1 dB, lower volume shows increasing inaccuracy and step size. Setting -60 dB and lower sets mute.

3.31 AUDIO cmd 11 Set_Mute

Enable and disable of the audio mute.

module	48	AUDIO	
cmd	**11**	**Set_Mute**	mode
index	1	mode [15:0]	audio mute
			0 = mute disabled
			1 = mute active (default)

Application example	AUDIO_Set_Mute (1, 0)	Disable mute, allow audio output
I²C example (hex)	[w 30 **0B** 01 0000]	Disable mute, allow audio output

3.32 AUDIO cmd 12 Set_Input

Input select; selection of audio input source signal.

module	48	AUDIO	
cmd	**12**	**Set_Input**	source
index	1	source [15:0]	audio source select
			0 = radio (default) (analog radio or digital radio when enabled and available)
			32 = I²S digital audio input IIS_SD_0
			240 = sine wave generator

Application example AUDIO_Set_Input (1, 32) Select external I²S audio source
AUDIO_Set_Input (1, 240) Select sine wave generator

I²C example (hex)
[w 30 0C 01 0020] Select external I²S audio source
[w 30 0C 01 00F0] Select sine wave generator

3.33 AUDIO cmd 13 Set_Output_Source

Output select; selection of source signal for audio output.

module	48	AUDIO	
cmd	**13**	**Set_Output_Source**	signal, source
index	1	signal [15:0]	audio output
			33 = I²S digital audio output IIS_SD_1
			128 = DAC L/R output
	2	source [15:0]	source
			4 = analog radio
			32 = I²S digital audio input IIS_SD_0
			224 = audio processor (default)
			240 = sine wave generator

Application example AUDIO_Set_Output_Source (1, 33, 04) Select analog radio on I²S output

I²C example (hex) [w 30 0D 01 0011 00F0] Select analog radio on I²S output

By default both the DAC output and the IIS_SD_1 output signal are taken from the audio processor, i.e. with signal defined by AUDIO_Set_Input, _Set_Volume and _Set_Mute. Set_Output_Source allows for an alternative output signal selection, directly connecting to one of the available source signals without processing.

Note: Command Set_Output_Source requires a signal definition, i.e. include index = 1

3.34 AUDIO cmd 21 Set_Ana_Out

Definition of analog output signals.

module	48	AUDIO	
cmd	**21**	**Set_Ana_Out**	signal, mode
index	1	signal [15:0]	analog audio output
			128 = DAC L/R output
	2	mode [15:0]	output mode
			0 = off (power down)
			1 = output enabled (default)

Application example	AUDIO_Set_Ana_Out (1, 128, 0)	Disable DAC output
I^{2}C example (hex)	`[ w 30 15 01 0080 0000 ]`	Disable DAC output

3.35 AUDIO cmd 22 Set_Dig_IO

Definition of digital input and output audio signals.

module	48	AUDIO	
cmd	**22**	**Set_Dig_IO**	signal, mode, format, operation, samplerate
index	1	signal [15:0]	digital audio input / output
			32 = I^{2}S digital audio IIS_SD_0 (input)
			33 = I^{2}S digital audio IIS_SD_1 (output)
	2	mode [15:0]	I/O mode
			0 = off (default)
			1 = input (only available for signal = 32)
			2 = output (only available for signal = 33)
	3	format [15:0]	digital audio format select
			16 = I^{2}S 16 bits (f_{IIS_BCK} = 32 * samplerate)
			32 = I^{2}S 32 bits (f_{IIS_BCK} = 64 * samplerate) (default)
			272 = lsb aligned 16 bit (f_{IIS_BCK} = 64 * samplerate)
			274 = lsb aligned 18 bit (f_{IIS_BCK} = 64 * samplerate)
			276 = lsb aligned 20 bit (f_{IIS_BCK} = 64 * samplerate)
			280 = lsb aligned 24 bit (f_{IIS_BCK} = 64 * samplerate)
	4	operation [15:0]	operation mode
			0 = slave mode; IIS_BCK and IIS_WS input defined by source (default)
			256 = master mode; IIS_BCK and IIS_WS output defined by device
	5	samplerate [15:0]	audio sample rate select
			3200 = 32.0 kHz

		4410 = 44.1 kHz (default)
		4800 = 48.0 kHz

Application example AUDIO_Set_Dig_IO (1, 33, 2, 32, 256, 4800) Dig. output 32 bit I²S, master, 48 kHz.

I²C example (hex) `[ w 30 16 01 0021 0002 0020 0100 12C0 ]` Dig. output 32 bit I²S, master, 48 kHz.

Note: Command Set_Dig_IO requires a signal definition, i.e. include index = 1.

Note: A TEF668X digital audio signal always employs 16 active (msb) bits.

Note: In some cases settings of ‘operation’ or ‘samplerate’ are not independently selectable, e.g. because of shared BCK and WS pins. The control setting is based on the signal with lowest enumeration value in such a case.

Note: f_{IIS_BCK} indicates the output frequency in master mode operation and the required input frequency for slave mode operation of lsb aligned formatted output signals. Slave mode operation of input signals and I²S formatted output signals also allows for other bit clock rates of (16 … 32) * 2 * samplerate.

3.36 AUDIO cmd 23 Set_Input_Scaler

Fine tuning of sound amplitude of external sources. For each of the available external sources a separate sound amplitude correction can be programmed for use when the audio input is selected (see 3.32 AUDIO cmd 12 Set_Input).

module	48	AUDIO	
cmd	**23**	**Set_Input_Scaler**	source, gain
index	1	source [15:0]	audio source
			32 = I²S digital audio input : IIS_SD_0
	2	gain [15:0] (signed)	external source channel gain
			-120 … +60 [*0.1 dB] = -12 … +6 dB external source signal gain 0 = 0 dB (default)

Application example AUDIO_Set_Input_Scaler (1, 32, -60) Scale I²S input 0 by -6 dB

I²C example (hex) `[ w 30 17 01 0020 FFC4 ]` Scale I²S input 0 by -6 dB

Note: Command Set_Input_Scaler requires a source definition, i.e. include index = 1.

Note: Scaling of digital radio signal from IIS_SD_0 is defined by radio control FM / AM cmd 83 Set_DR_Blend (see 3.25).

3.37 AUDIO cmd 24 Set_WaveGen

Definition of the internal sine wave and offset generator signal.

The wave generator can be selected as an audio source (see 3.32 AUDIO cmd 12 Set_Input) and is intended for test purposes only.

module	48	AUDIO	
cmd	**24**	**Set_WaveGen**	mode, offset, amplitude1, frequency1, amplitude2, frequency2
index	1	mode [15:0]	mode
			0 = wave signal off (default)
			1 = wave 1 signal on Left channel
			2 = wave 2 signal on Right channel
			3 = wave 1 signal on Left channel and wave 2 signal on Right channel
			5 = wave 1 signal on Left and Right channel
			6 = wave 2 signal on Left and Right channel
			7 = wave 1 + wave 2 signal on Left and Right channel
	2	offset [15:0]	DC offset
			-32768 … + 32767 (* 1 LSB of 16 bit) = max negative … max positive. 0 = no offset (default)
	3	amplitude1 [15:0] signed	wave 1 amplitude
			-300 … 0 (*0.1 dB) = -30 … 0 dB -200 = -20 dB (default)
	4	frequency1 [15:0]	wave 1 frequency
			10 … 20000 (*1 Hz) = 10 Hz … 20 kHz 400 = 400 Hz (default)
	5	amplitude2 [15:0] signed	wave 2 amplitude
			-300 … 0 (*0.1 dB) = -30 … 0 dB -200 = -20 dB (default)
	6	frequency2 [15:0]	wave 2 frequency
			10 … 20000 (*1 Hz) = 10 Hz … 20 kHz 1000 = 1 kHz (default)

Application example	AUDIO_Set_WaveGen (1, 0, 128, -200, 1000, -200, 1000))	Set offset to +128 LSB
	AUDIO_Set_WaveGen (1, 5, 0, -100, 400, -200, 1000)	Set -10 dB, 400 Hz sine
I²C example (hex)	[w 30 **18** 01 0000 0080 FF38 03E8 FF38 03E8]	Set offset to +128 LSB
	[w 30 **18** 01 0005 0000 FF9C 0190 FF38 03E8]	Set -10 dB, 400 Hz sine

Note: The reference for amplitude is digital full scale peak to peak (FS_{PP}); i.e. 0 dB represents a maximum undistorted sine wave signal when no offset is applied.

The DC offset is available on both Left and Right channel for all mode settings.

For mode = 7 the signals of wave 1 and wave 2 are added together, for undistorted signal the combined amplitudes of wave 1 and wave 2 should not exceed 0 dB.

3.38 APPL cmd 1 Set_OperationMode

Device power control.

module	64	APPL	
cmd	**1**	**Set_OperationMode**	mode
index	1	mode [15:0]	device operation mode
			0 = normal operation
			1 = radio standby mode (low-power mode without radio functionality) (default)

Application example	APPL_Set_OperationMode (1, 1)	Put device in radio standby mode
I²C example (hex)	`[ w 40 01 01 0001 ]`	Put device in radio standby mode

Note: FM and AM commands are available during both operation modes allowing for radio initialization of both FM and AM operation during radio standby mode.

Mode = ‘normal operation’ will return to the radio operation as defined before standby (unless other selections were made during radio standby mode).
Alternatively a radio tuning action of Preset or Search (see 3.1 FM / AM cmd 1 Tune_To) will enable normal operation.

3.39 APPL cmd 3 Set_GPIO

Define general purpose and application pin use.

module	64	APPL	
cmd	**3**	**Set_GPIO**	pin, module, feature
index	1	pin [15:0]	GPIO number
			0 … 2 = GPIO number
	2	module [15:0]	module
			32 = FM
			33 = AM
	3	feature [15:0]	feature
			0 = no use (default) (FM / AM)
			1 = general purpose input (FM / AM)
			2 = general purpose output ‘0’ (FM / AM)
			3 = general purpose output ‘1’ (FM / AM)
			257 = output RDS (FM : see cmd 81 ‘DAVN’)
			258 = output QSI (FM / AM : see cmd 82 ‘timer and AF_Update flag’)
			259 = output QSI + RDS (active ‘low’ if ‘DAVN’ is active or ‘QSI’ is active)
			260 = output RDDA (FM : see cmd 81 ‘RDDA, RDCL legacy option’)
			261 = output RDCL (FM : see cmd 81 ‘RDDA, RDCL legacy option’)
			262 = output AGC (FM : see cmd 11 ‘AGC step extension’)

Application example	APPL_Set_GPIO (1, 0, 32, 257)	Output ‘DAVN’ at GPIO 0 for FM
	APPL_Set_GPIO (1, 0, 33, 3)	Output ‘high’ at GPIO 0 for AM
I²C example (hex)	[w 40 03 01 0000 0020 0101]	Output ‘DAVN’ at GPIO 0 for FM
	[w 40 03 01 0000 0021 0003]	Output ‘high’ at GPIO 0 for AM

Note: Command Set_GPIO requires a GPIO number definition, i.e. include index = 1.

Note: General purpose input use is limited to GPIO 0.

Note: A module setting of FM or AM is active for the appropriate radio mode only, allowing independent feature definitions for FM and AM.

Note: Feature signals RDS, QSI and AGC are all ‘active low’.

Note: Definition and enabling of assigned features is available
from FM cmd 81 Set_RDS for ‘RDS’, ‘RDDA’ and ‘RDCL’ (see 3.23),
from FM / AM cmd 82 Set_QualityStatus for ‘QSI’ (see 3.24) and
from FM / AM cmd 11 Set_RFAG for ‘AGC’ (see 3.4).

3.40 Idle state - APPL cmd 4 Set_ReferenceClock

This command is only available during 'idle state'.

Several different frequencies can be used for the crystal oscillator or the external reference clock. For proper functioning the reference frequency must be entered before activation of the device, the command is therefore available during 'idle' state only.

module	64	APPL	
cmd	**4**	**Set_ReferenceClock**	frequency_msb, frequency_lsb, type
index	1	frequency_msb [15:0]	MSB part of the reference clock frequency
			[31:16]
	2	frequency_lsb [15:0]	LSB part of the reference clock frequency
			[15:0]
			frequency [*1 Hz] (default = 9216000)
	3	type [15:0]	clock type
			0 = crystal oscillator operation (default)
			1 = external clock input operation

Application example

APPL_Set_ReferenceClock (1, 846, 23214, 1)	Set external reference 55466670 Hz
APPL_Set_ReferenceClock (1, 61, 2304, 0)	Set crystal reference 4 MHz
APPL_Set_ReferenceClock (1, 140, 40960, 0)	Set crystal reference 9.216 MHz
APPL_Set_ReferenceClock (1, 183, 6912, 0)	Set crystal reference 12 MHz

I²C example (hex)

[w 40 **04** 01 034E 5AAE 0001]	Set external reference 55466670 Hz
[w 40 **04** 01 003D 0900 0000]	Set crystal reference 4 MHz
[w 40 **04** 01 008C A000 0000]	Set crystal reference 9.216 MHz
[w 40 **04** 01 00B7 1B00 0000]	Set crystal reference 12 MHz

TEF668X supported frequencies: 4.000 MHz, 9.216 MHz, 12.000 MHz, 55.46667 MHz.

Note: Supported frequencies for digital radio use are 9.216, 12.000 and 55.46667 MHz.

Note: 55.46667 MHz is for clock input use only and not supported as a crystal frequency.

Accuracy of the reference clock frequency setting is not critical, approximate values are translated to actual supported frequencies.

3.41 Idle state - APPL cmd 5 Activate

This command is only available during ‘idle state’.

After the reference clock frequency has been defined the device must be put in active state to allow for further initialization and control. After activation the device will be in operational mode ‘radio standby’.

module	64	APPL	
cmd	**5**	**Activate**	mode
index	1	mode [15:0]	1 = goto ‘active’ state with operation mode of ‘radio standby’

Application example APPL_Activate (1, 1) Go from ‘idle state’ to ‘active state’.

I²C example (hex) `[ w 40 05 01 0001 ]` Go from ‘idle state’ to ‘active state’.

Note: Setting mode = 1 is the only available setting.

4. Read commands

Read commands make certain specific information available for read-out. Reading consists of writing a module, a command and an index value (i.e. similar to a write command) followed by a read of the requested data.

The module defines the processing part that is addressed. Modules are integral functional parts of the device that can be regarded sub-devices. Modules in the TEF668X offering read data are 32 ‘FM’ for FM radio, 33 ‘AM’ for AM radio and 64 ‘APPL’ for application and system information.

The command value defines the set of read data of interest.

The index value is present for future use to allow reading of certain specific data parts out of the available command read data.
Device version V102 requires index = 1 to be used. (I.e. equal to device version V101.)
For evaluation purposes also index = 0 is supported.

The first actual read data starts from index = 1.

For evaluation purposes reading may also start from index = 0 in which case the first data word contains a confirmation of the data following (see 5.7.1).

Read commands are only available in the device ‘active state’ operation modes (with the exception of certain APPL read commands) and only available for enabled modules.

- idle state: valid read data from ‘APPL’ read of operation status, device identification and I²C write checking.
- active state = radio standby: valid read data from ‘AUDIO’ and ‘APPL’ module.
- active state = FM: valid read data from ‘AM’, ‘AUDIO’ and ‘APPL’.
- active state = AM: valid read data from ‘FM’, ‘AUDIO’ and ‘APPL’.

For detailed information on the I²C protocol for read commands see 5.3 Read control.

4.1 FM / AM cmd 128 / 129 Get_Quality

Read status of the tuner reception quality information

Get_Quality_Status will read status and possibly data with the status and any frozen data (like e.g. available after AF_Update tuning) remaining unchanged. Get_Quality_Status is intended for status read only (i.e. status polling) but data may be sampled when desired.

Get_Quality_Data will read status and data with the status and any frozen data (like e.g. available after AF_Update tuning) released after read, allowing for new data updates. Get_Quality_Data is intended for data reading with status informing about data content and validity.

module	32 / 33	FM / AM			
cmd	**128**	**Get_Quality_Status**	FM : | status, level, usn, wam, offset, bandwidth, modulation		
	129	**Get_Quality_Data**	AM : | status, level, noise, co_channel, offset, bandwidth, modulation		
index	1	status [15:0]	quality detector status		
			[15] =	AF_update flag	
				0 = continuous quality data with time stamp	
				1 = AF_Update sampled data	
			[14:10] =	reserved	
			[9:0] =	quality time stamp	
				0 = tuning is in progress, no quality data available	
				1 … 320 (* 0.1 ms) = 0.1 … 32 ms after tuning, quality data available, reliability depending on time stamp	
				1000 = > 32 ms after tuning quality data continuously updated	
	2	level [15:0] (signed)	level detector result		
			-200 … 1200 (0.1 * dBμV) = -20 … 120 dBμV RF input level actual range and accuracy is limited by noise and agc		
	3	usn / noise [15:0]	noise detector		
			FM	ultrasonic noise detector	
				0 … 1000 (*0.1 %) = 0 … 100% relative usn detector result	
			AM	high frequency noise detector	
				0 … 50000 (*0.1 %) = 0 … 5000% noise relative to wanted signal 1000 = 100% is approximate equal noise and wanted signal	
	4	wam / co-channel [15:0]	FM multipath detector / AM co-channel detector		
			FM	'wideband-AM' multipath detector	
				0 … 1000 (*0.1 %) = 0 … 100% relative wam detector result	
			AM	co-channel detector	
				0 = no co-channel detected	
				1 = co-channel detected (based on selected criteria)	
	5	offset [15:0] (signed)	radio frequency offset		
			-1200 … 1200 (*0.1 kHz) = -120 kHz … 120 kHz radio frequency error		

		actual range and accuracy is limited by noise and bandwidth	
6	bandwidth [15:0]	IF bandwidth	
		FM	560 … 3110 [*0.1 kHz] = IF bandwidth 56 … 311 kHz; narrow … wide
		AM	30 … 80 [*0.1 kHz] = IF bandwidth 3 … 8 kHz; narrow … wide
7	modulation [15:0]	modulation detector	
		FM	0 … 1000 [*0.1 %] = 0 … 100% modulation = 0 … 75 kHz FM dev. 1000 … 2000 [*0.1 %] = 100% … 200% over-modulation range (modulation results are an approximate indication of actual FM dev.)
		AM	0 … 1000 [*0.1 %] = 0 … 100% AM modulation index 1000 … 2000 [*0.1 %] = 100% … 200% peak modulation range (peak modulation results vary depending on the modulation setup)

Application example	FM_Get_Quality_Status (1, (status))	Poll status
	FM_Get_Quality_Data (1, (status .. modulation))	Read status and all available data
I²C example (hex)	[w 20 **80** 01 [r *0014*]	Poll status *(2 ms after tuning)*
	[w 20 **81** 01 [r ???? ???? … ????]	Read status and all available data

Note: A tuning action will reset the status information and release the frozen AF_Update sampled quality data should the AF data not have been read before.

The status quality time stamp starts updating as soon as tuning is established and new sampled data becomes available for an AF_Update tuning action (see 3.1 FM / AM cmd 1 Tune_To : mode = 3) and new continuous data becomes available for Preset, Search, Jump or Check tuning actions (mode = 1, 2, 4 or 5.)

The AM co-channel criteria can be defined from 3.6 AM cmd 14 Set_CoChannelDet.

4.2 FM cmd 130 / 131 Get_RDS

Poll status (and data) or read status and data of the FM RDS demodulator and decoder.

Get_RDS_Status returns status (and data). The status and stored data (when complete data is available) will remain unchanged. Get_RDS_Status use is suggested for status read only (i.e. status polling) but data can be sampled when desired.

Get_RDS_Data returns status and data. The status and stored data (when complete data is available) will be released allowing data updating. Get_RDS_Data is intended for data reading including status information.

4.2.1 RDS read modes

The radio data system feature of FM RDS and RBDS data reception can operate in two distinctive modes as defined by the FM cmd 81 Set_RDS mode parameter.
The mode setting defines the type of data available from the Get_RDS_Status and Get_RDS_Data commands and the timing associated with 'data-available' signaling.

Decoder mode is the default mode (mode = 1) where the received RDS data is additionally decoded and output in RDS group format as defined by the RDS standard. Error correction is executed and error detection allows for discriminating between data results judged reliable, less reliable and not reliable by the RDS error detection scheme.

The optional **demodulator mode** (mode = 2) allows for output of 'raw' RDS bit data taken directly after demodulation. The data is output in 32 bit chunks for easy read-out. Additional data processing is required in the connected μC for RDS synchronization, decoding and error handling.

In both modes RDS data is output through an internal data buffer capable of storing multiple sets of output data for relaxed requirements on read timing.

4.2.2 Read data definition for RDS decoder mode

FM cmd 81 Set_RDS; mode = 1.

module	32	FM		
cmd	**130**	**Get_RDS_Status**	| status, A_block, B_block, C_block, D_block, dec_error	
	131	**Get_RDS_Data**		
index	1	status [15:0]	FM RDS reception status	
			[15] =	data available flag
				0 = no data available (incomplete group or no first PI)
				1 = RDS group data or first PI data available
			[14] =	data loss flag
				0 = no data loss
				1 = previous data was not read, replaced by newer data
			[13] =	data available type
				0 = group data; continuous operation
				1 = first PI data; data with PI code following decoder sync.
			[12] =	group type

			0 = type A; A-B-C-D group (with PI code in block A)
			1 = type B; A-B-C'-D group (with PI code in block A and C')
		[11:10] =	reserved
		[9] =	synchronization status
			0 = RDS decoder not synchronized; no RDS data found
			1 = RDS decoder synchronized; RDS data reception active
		[8: 0] =	reserved
2	A_block [15:0]	A block data	
3	B_block [15:0]	B block data	
4	C_block [15:0]	C block data	
5	D_block [15:0]	D block data	
6	dec_error [15:0]	error code (determined by decoder)	
		[15:14] =	A block error code
		[13:12] =	B block error code
		[11:10] =	C block error code
		[9:8] =	D block error code
		0 : no error; block data was received with matching data and syndrome 1 : small error; possible 1 bit reception error detected; data is corrected 2 : large error; theoretical correctable error detected; data is corrected 3 : uncorrectable error; no data correction possible	
		[7:0] =	reserved

Application example

FM_Get_RDS_Status (1, (status)) — Poll status
FM_Get_RDS_Data (1, (status … dec_error)) — Read status and all available data

I²C example

```
[ w  20 82 01 [ r  8200 ]
[ w  20 83 01 [ r  ???? ???? … ???? ]
```

Poll status *(RDS available, sync'd)*
Read status and all available data

4.2.3 RDS read operation for decoder mode

The availability of RDS decoder data is signaled by the status bit 15.

If new and complete information is available this is signaled by status[15] = 1 and RDS group status and data is stored for μC read. RDS status and data can be read from commands Get_RDS_Status and Get_RDS_Data equally but only the command Get_RDS_Data clears the information from the internal storage buffer.

Optional an interrupt (‘DAVN’) can be generated at the occurrence of RDS data available, see 3.23 FM cmd 81 Set_RDS to enable this option (interface = 2) and 3.39 APPL cmd 3 Set_GPIO for output pin selection of the data available interrupt signal. The interrupt is set and released at the same conditions as the status[15] bit.

The RDS system includes an RDS data buffer capable of storing up to 22 RDS data sets of group data allowing for a delayed read action on the data available signaling. RDS data can be read from the device using Get_RDS_Data repeatedly with the data available signal remaining active until the RDS data storage buffer is empty.

In the unlikely case that available data was not read in time causing the RDS data buffer to become full and new group data is available then the oldest data will be overwritten by new data. This loss of buffered data is indicated by the status bit 14 = 1.

Depending on the desired setup of the μC control software three ways of operation are suggested for the reading of RDS decoder data.

1. **Non synchronized operation (data polling):**
   Repeated Get_RDS_Data read of RDS status and data.
   When status[15] = 1 then the RDS data is used, otherwise the data is ignored.

   To avoid data loss a single Get_RDS_Data read should be executed at least every 87 ms. or a burst of up to 22 Get_RDS_Data reads should be executed at least every 1.90 sec. taking advantage of the RDS data buffer.

2. **Status synchronized operation (status polling):**
   Repeated Get_RDS_Status read of status[15].
   When status[15] = 1 (i.e. data available) is found perform a Get_RDS_Data read of RDS status and data.

   To avoid data loss Get_RDS_Status the polling should be executed at least every 87 ms. allowing for inclusion of a single Get_RDS_Data read or at least every 1.90 sec. allowing for inclusion of up to 22 Get_RDS_Data reads taking advantage of the RDS data buffer.

3. **Interrupt synchronized operation (interrupt pin):**
   Setting of ‘DAVN’ interrupt output option and GPIO pin connected to μC.
   When interrupt active is found (pin low) perform a Get_RDS_Data read of RDS status and data.

   To avoid data loss a single Get_RDS_Data read should be performed within 87 ms. after interrupt or a burst of up to 22 Get_RDS_Data reads should be executed within 1.92 sec. after interrupt taking advantage of the RDS data buffer.

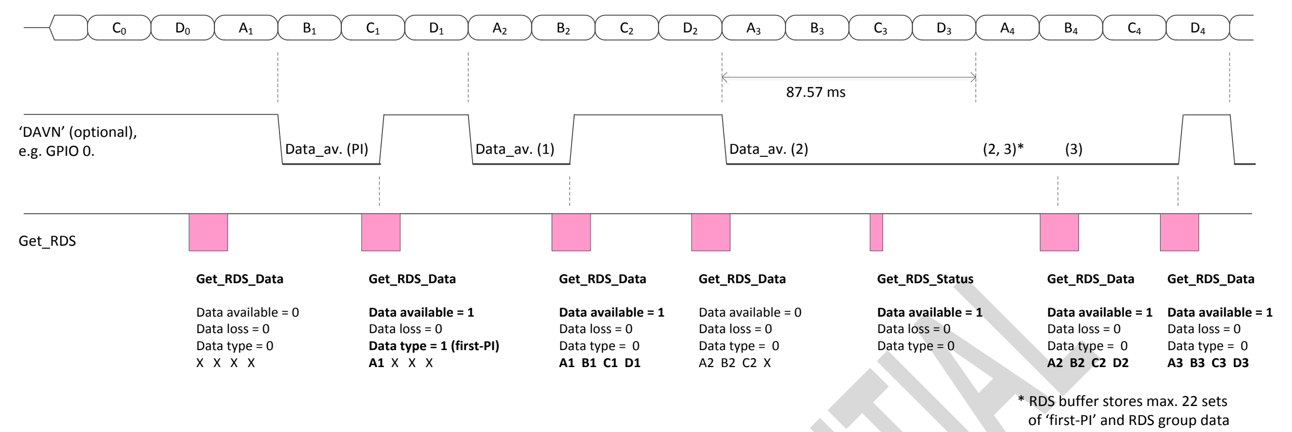


Fig 2. Example of RDS decoder status and data by I²C bus read and optional GPIO 'DAVN' interrupt use.

4.2.4 Read data definition for RDS demodulator mode

[FM cmd 81 Set_RDS](); mode = 2.

module	32	FM	
cmd	**130**	**Get_RDS_Status**	| status, raw_data_high, raw_data_low
	131	**Get_RDS_Data**	
index	1	status [15:0]	FM RDS reception status
			[15] = 0 : no data available [15] = 1 : 32 bit of raw demodulator data available
			[14] = 0 : no data loss [14] = 1 : previous data was not read, replaced by newer data
			[13 … 0] = reserved
	2	raw_data_high [15:0]	MSB part of the 32 bit raw demodulator data ([31:16])
	3	raw_data_low [15:0]	LSB part of the 32 bit raw demodulator data ([15:0]).

Application example	FM_Get_RDS_Status (1, (status))	Poll status
	FM_Get_RDS_Data (1, (status, raw_data))	Read status and available data
I²C example	`[ w 20 82 01 [ r 8000 ]`	Poll status *(RDS raw data available)*
	`[ w 20 83 01 [ r ???? ???? ???? ]`	Read status and available data

4.2.5 RDS read for demodulator mode operation

Except for the different data content and associated timings the read operation for demodulator mode equals the operation for decoder mode.

The availability of 32 bit of RDS demodulator data is signaled by the status bit.

If new and complete information is available this is signaled by status[15] = 1 and 32 bit of raw RDS data is stored for µC read. RDS status and data can be read from commands Get_RDS_Status and Get_RDS_Data equally but only the command Get_RDS_Data clears the information from the internal storage buffer.

Optional an interrupt ('DAVN') can be generated at the occurrence of RDS data available, see 3.23 FM cmd 81   Set_RDS to enable this option (interface = 2) and 3.39 APPL cmd 3   Set_GPIO for output pin selection of the data available interrupt signal. The interrupt is set and released at the same conditions as the status[15] bit.

The RDS system includes an RDS data buffer capable of storing up to 50 RDS data sets of 32 bit raw data allowing for a delayed read action on the data available signaling. RDS data can be read from the device using Get_RDS_Data repeatedly with the data available signal remaining active until the RDS data storage buffer is empty.

In the unlikely case that the controlling µC has not read the available data in time causing the RDS data buffer to become full and again 32 bits of new data are available then the oldest data will be overwritten by the new data. This loss of buffered data is indicated by the status bit 14 = 1.

Depending on the desired setup of the µC control software three ways of operation are suggested for the reading of RDS demodulator data.

1. **Non synchronized operation (data polling):**
   Repeated Get_RDS_Data read of RDS status and data.
   If status[15] = 1 then the RDS data is used, otherwise the data is ignored.

   To avoid data loss a single Get_RDS_Data read should be executed at least every 26 ms. or a burst of up to 50 Get_RDS_Data reads should be executed at least every 1.34 sec. taking advantage of the RDS data buffer.

2. **Status synchronized operation (status polling):**
   Repeated Get_RDS_Status read of status[15].
   When status[15] = 1 (i.e. data available) is found perform a Get_RDS_Data read of RDS status and data.

   To avoid data loss Get_RDS_Status the polling should be executed at least every 26 ms. allowing for inclusion of a single Get_RDS_Data read or at least every 1.34 sec. allowing for inclusion of up to 50 Get_RDS_Data reads taking advantage of the RDS data buffer.

3. **Interrupt synchronized operation (interrupt pin):**
   Setting of 'DAVN' interrupt output option and GPIO pin connected to µC.
   When interrupt active is found (pin low) perform a Get_RDS_Data read of RDS status and data.

   To avoid data loss a single Get_RDS_Data read should be performed within 26 ms. after interrupt or a burst of up to 50 Get_RDS_Data reads should be executed within 1.34 sec. after interrupt taking advantage of the RDS data buffer.

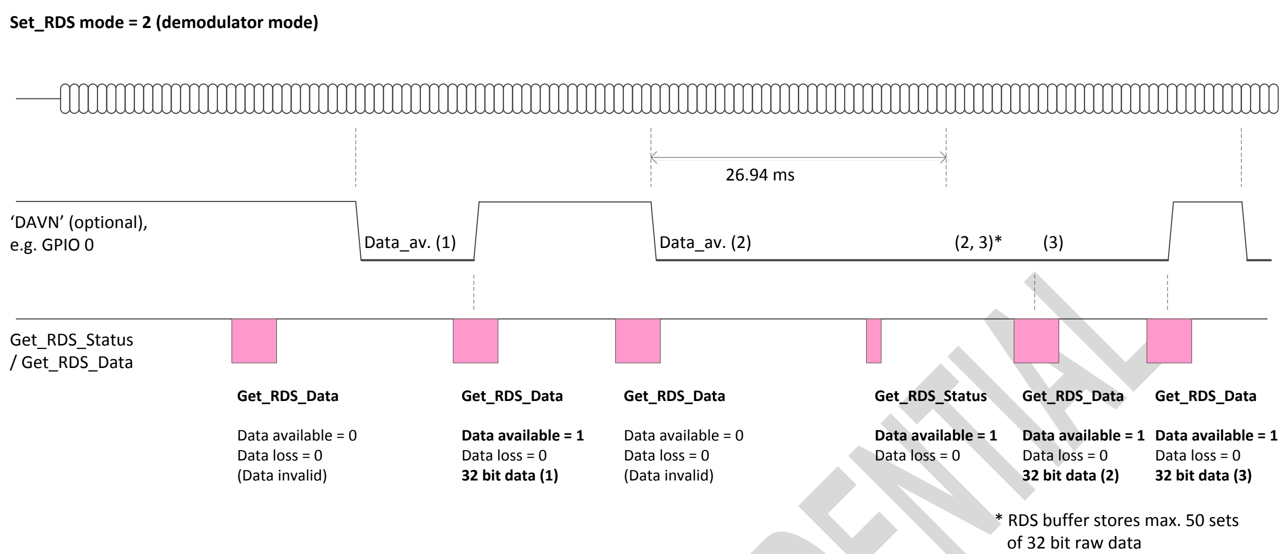


Fig 3. Example of RDS demodulator status and data by I²C bus read and optional GPIO 'DAVN' interrupt use.

4.3 FM / AM cmd 132 Get_AGC

Read attenuation setting of the RF AGC. The overall antenna signal attenuation is found by addition of the input_att and feedback_att value.

module	32 / 33	FM / AM	
cmd	**132**	**Get_AGC**	| input_att, feedback_att
index	1	input_att [15:0]	RF AGC input attenuation
			FM 0 … 420 (0.1* dB) = 0 … 42 dB attenuation
			AM 0 … 420 (0.1* dB) = 0 … 42 dB attenuation
	2	feedback_att [15:0]	RF AGC feedback attenuation
			FM 0 … 60 (0.1* dB) = 0 … 6 dB attenuation
			AM 0 … 180 (0.1* dB) = 0 … 18 dB attenuation

Application example	FM_Get_AGC (1, (input_att, feedback_att))	Read AGC attenuation settings
I²C example	`[ w 20 84 01 [ r 00B4 003C ]`	Read AGC attenuation settings *(18 dB + 6 dB RF attenuation)*

Note: The TEF668X RF AGC employs 6 dB step size, i.e. read values of 0, 60, 120…

Note: The maximum FM input attenuation of 42 dB can be realized only by means of FM RF AGC extension (see 3.4 FM / AM cmd 11 Set_RFAG).

4.4 FM / AM cmd 133 Get_Signal_Status

Read information about the received radio signal.

module	32 / 33	FM / AM	
cmd	**133**	**Get_Signal_Status**	| status
index	1	status [15:0]	Radio signal information
			[15] = 0 : mono signal [15] = 1 : FM stereo signal (stereo pilot detected)
			[14] = 0 : analog signal [14] = 1 : digital signal (blend input activated by digital processor or control) (TEF6688 and TEF6689 only)

Application example	FM_Get_Signal_Status (1, (status))	Read availability of stereo and digital
I²C example	`[ w 20 85 01 [ r 8000 ]`	Read availability of stereo and digital *(stereo signal found)*

4.5 FM / AM cmd 134 Get_Processing_Status

Read information about the internal processing status (weak signal handling).
This information is intended for evaluation use only.

module	32/33	FM / AM		
cmd	**134**	**Get_Processing_Status**	| softmute, highcut, stereo, sthiblend	
index	1	softmute [15:0]	Softmute control state	
			0 … 1000 (*0.1%) = 0 % minimum … 100 % max. softmute attenuation	
	2	highcut [15:0]	Highcut control state	
			0 … 1000 (*0.1%) = 0 % minimum … 100 % max. audio freq. limitation	
	3	stereo [15:0]	FM Stereo blend control state	
			0 … 1000 (*0.1%) = 0 % minimum … 100 % max. stereo att. (= mono)	
	4	sthiblend [15:0]	FM Stereo high blend control state	
			0 … 1000 (*0.1%) = 0 % minimum … 100 % max. stereo freq. limitation	
	5	stband_1_2 [15:0]	FMSI band 1 and band 2 (TEF6687 and TEF6689 only)	
			[15:8]	FMSI control state band 1, low band
				0 … 100 (%) = 0% (stereo) … 100% (mono) band 1
			[7:0]	FMSI control state band 2, 2 kHz band
				0 … 100 (%) = 0% (stereo) … 100% (mono) band 2
	6	stband_3_4 [15:0]	FMSI band 3 and band 4 (TEF6687 and TEF6689 only)	
			[15:8]	FMSI control state band 3, 5 kHz band
				0 … 100 (%) = 0% (stereo) … 100% (mono) band 3
			[7:0]	FMSI control state band 4, high band
				0 … 100 (%) = 0% (stereo) … 100% (mono) band 4

Application example FM_Get_Processing_Status (1, (softmute, …)) Read weak signal processing status

I²C example

`[ w 20 86 01 [ r 0000 019A 03B6 03E8 ]` Read weak signal processing status
(sm 0%, hc 41%, st 95%, shb 100%)

`[ w 20 86 01 [ r 0000 019A 0000 0000 0014 3284 ]` Read weak signal processing status
(sm 0%, hc 41%, stereo 0%, shb 0%, fmsi 0%, 20%, 50%, 100%)

Note: 0 % equals minimum control, as defined by the weak signal '_Min' setting.
100 % equals maximum control, as defined by the weak signal '_Max' setting.

4.6 FM / AM cmd 135 Get_Interface_Status

Available for TEF6688 and TEF6689 only.

Information about radio I/O functionality; DR I²S output.

module	32 / 33	FM / AM	
cmd	**135**	**Get_Interface_Status**	| samplerate
index	1	samplerate [15:0]	Baseband digital radio sample rate (DR_I2S output)
			0 = interface disabled (digital radio disabled)
			6500 = 650 kHz
			6750 = 675 kHz

Application example FM_Get_Interface_Status (1, (samplerate)) automatic DR sample rate selection

I²C example (hex) `[ w 20 87 01 [ r 1A5E ]` automatic DR sample rate selection *(675 kHz)*

4.7 APPL cmd 128 Get_Operation_Status

This read command is also available during 'boot state' and during 'idle state'.

Read information about the operation state.

module	64	APPL	
cmd	**128**	**Get_Operation_Status** | status	
index	1	status [15:0]	Device operation status
			0 = boot state; no command support
			1 = idle state
			2 = active state; radio standby
			3 = active state; FM
			4 = active state; AM

Application example	APPL_Get_Operation_Status (1, (status))	Read operation status
I²C example	[w 40 **80** 01 [r 0003]	Read operation status *(active state FM)*

Note: The value 0 indicates boot state (reset state after power-on, power dip or reference frequency disruption). Actually all get commands will return 0 values during boot state and no command support is available.

See chapter 6 Device start-up on start-up device control and initialization.

4.8 APPL cmd 129 Get_GPIO_Status

Read information about the input state of designated input pins (see 3.39 APPL cmd 3 Set_GPIO).

module	64	APPL	
cmd	**129**	**Get_GPIO_Status** | status	
index	1	status [15:0]	input state (when assigned for input use)
			[2] = input state of GPIO_2 (no input use suggested for TEF668X)
			[1] = input state of GPIO_1 (no input use suggested for TEF668X)
			[0] = input state of GPIO_0 (0 = low, 1 = high)

Application example	APPL_Get_GPIO_Status (1, (status))	Read input state of GPIO input pins
I²C example	[w 40 **81** 01 [r 0001]	Read input state of GPIO input pins *(input GPIO_0 high)*

Note: Because of the TEF668X designated input use of GPIO_1 and GPIO_2 during power-up only GPIO_0 is suggested for application as a general purpose input.

4.9 APPL cmd 130 Get_Identification

This read command is also available during ‘idle state’.

Read information about the device type and variant.

module	64	APPL			
cmd	**130**	**Get_Identification**	| device, hw_version, sw_version		
index	1	device [15:0]	device type and variant		
			[15:8]	type identifier	
				9 = TEF668X ‘Lithio’ series	
			[7:0]	variant identifier	
				14 = TEF6686 ‘Lithio’	
				1 = TEF6687 ‘Lithio FMSI’	
				9 = TEF6688 ‘Lithio DR’	
				3 = TEF6689 ‘Lithio FMSI DR’	
	2	hw_version [15:0]	hardware version		
			[15:8]	major number	
				1	
			[7:0]	minor number	
				0	
	3	sw_version [15:0]	firmware version		
			[15:8]	major number	
				2 = ‘2’	
			[7:0]	minor number	
				0 = ‘.00’	

Application example	APPL_Get_Identification (1, (device..))	Read device identification
I²C example	`[ w 40 82 01 [ r 090E 0100 0200 ]`	Read device identification *(TEF6688, hw 1.0, sw 2.00)*

Note: The type number version designation ‘/V102’ is derived from the major hw_version and the major sw_version number.

4.10 APPL cmd 131 Get_LastWrite

This read command is also available during 'idle state'.

Read data content of the last write transmission.

module	64	APPL	
cmd	**131**	**Get_LastWrite**	| size/module, cmd/ index, parameter1, parameter2, parameter3, …
index	1	size/module [15:0]	transmission size (number of parameters) and module number
			[15:8] = 0 … 6 : number of parameters of the last write transmission
			[7:0] = 0 … 255 : module value of the last write transmission
	2	cmd/index [15:0]	command byte number and index byte value
			[15:8] = 0 … 255 : cmd value of the last write transmission
			[7:0] = 0 ... 255 : index value of the last write transmission
	3	parameter1 [15:0]	first parameter
			0 … 65535 = value of the first parameter (when available)
	4	parameter2 [15:0]	second parameter
			0 … 65535 = value of the second parameter (when available)
	5	parameter3 [15:0]	third parameter
			0 … 65535 = value of the third parameter (when available)
	6	parameter4 [15:0]	fourth parameter
			0 … 65535 = value of the fourth parameter (when available)
	7	parameter5 [15:0]	fifth parameter
			0 … 65535 = value of the fifth parameter (when available)

Application example	APPL_Get_LastWrite (1, (size...parameter))	Read back last write transmission
I²C example	[w 40 **83** 01 [r *0120 1F01 02EE 0000…0000*]	Read back last write transmission *(FM_Set_Deemphasis = '75 µs')*

5. I²C bus protocol

5.1 I²C protocol

TEF668X control parameters are 16 bit wide. The I²C bus native unit is the byte, multi-byte values like 16 bit parameters are transmitted MSB byte first.

With external application of a pull down resistor at GPIO_2 (10 kΩ to ground) the I²C device address for TEF668X is C8h for write and C9h for read operations. Alternatively application of a pull-up resistor (10 kΩ to Vdd) at pin GPIO_2 allows for use of device address CAh for write and CBh for read instead.

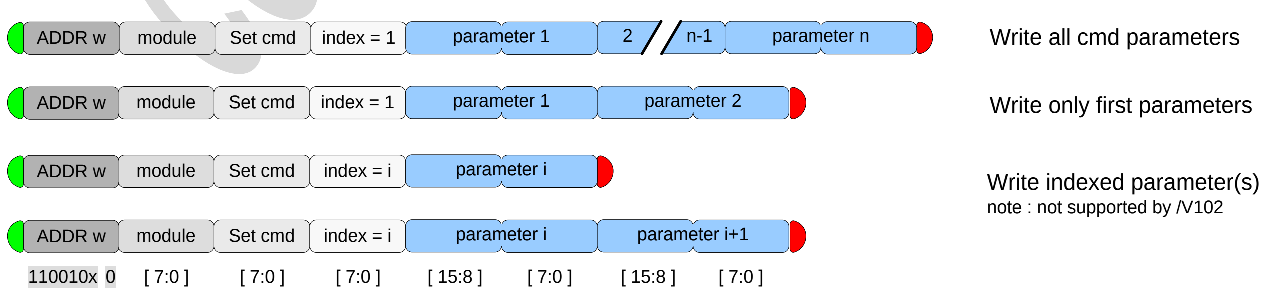
Note: GPIO_1 must be pulled low (10 kΩ to ground) during power-on to ensure proper operation.
Note: GPIO_2 must be pulled low or high (10 kΩ) during power-on and activation for a defined I²C address. Pin open is not a defined state.

5.2 Write control

Standard write transmissions to the TEF668X consist of an I²C start condition and an 8 bit hardware device address for write as depicted by the I²C standard.
Next an 8 bit module identifier is transmitted that can be regarded as a kind of internal device address for function blocks like FM radio, AM radio, audio and system.
Control is then indicated by an 8 bit command identifier and an 8 bit parameter index allows for sub-addressing within the command parameter space, followed by one or more 16 bit parameters for actual control.
The end of transmission is indicated by an I²C standard stop condition. Because the I²C bus format includes this explicit stop condition no 'size' indication is needed as may be required by certain other bus formats.

Note: Device version V102 only supports the use of index = 1 and all parameters described in this user manual need to be transmitted.
This behavior is equal to device version V101.

In Fig 4 examples of these transmissions are shown.



'ADDR w' is the I²C device address for write (C8h or CAh) depending on the address select pin application.

Fig 4. Examples of I²C write control; set command

TEF668X uses only a fraction of the possible number of modules, commands and parameters. The choice for a 24 bit wide parameter address space is for future extendibility.

Writing to disabled modules is supported and will store the data for later use. Enabling of modules (where applicable) is supported by specific module commands which may imply automatic disabling of other module(s) as e.g. is the case when switching between FM and AM radio module operation.

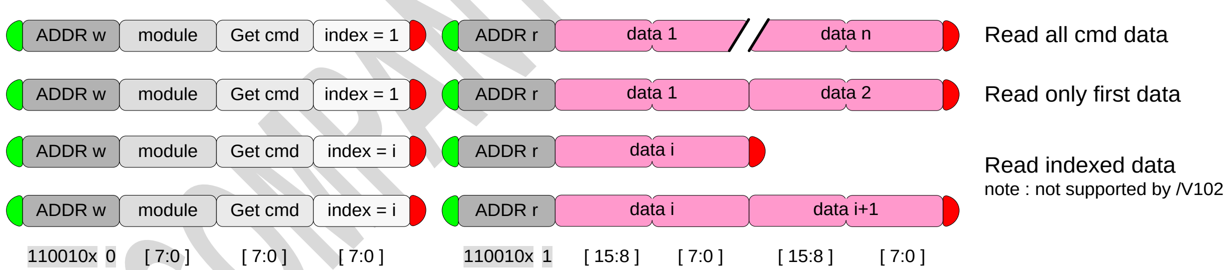
5.3 Read control

Standard reading from the TEF668X consists of a write transmission for definition of the requested data followed by the actual read transmission for obtaining the data.
Note: this is normal practice because the I²C specification does not support read addressing within a read transmission.
Read data is 16 bit wide (or multiples of 16 bit) transmitted with the MSB byte first.

For reading of received data or status information special ‘get’ commands are defined. For future extendibility and reading of data parts within larger data blocks an index setting is included similar to the write definition.

Index = 1 is the standard case with read data starting from the first data word.

Note: Device version V102 only supports the use of index = 1, it is allowed however to read less than the number of data words described in this user manual.
This behavior is equal to device version V101.
For evaluation purposes index = 0 is supported also (see 5.7.1).



‘ADDR r’ is the I²C device address for read (C9h or CBh) depending on the address select pin application.

Fig 5. Examples of I²C read control; get command

Certain timing requirements exist for TEF668X read control; see chapter 5.6 for details.

TEF668X ‘Get’ commands as published in this user manual are without parameter use.
For future extensions the protocol however allows for ‘Get’ commands with parameters.

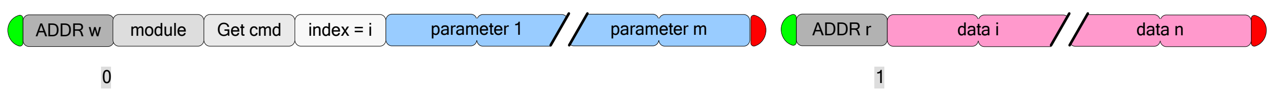


Fig 6. Example of a possible get command with parameter(s)

5.4 I²C repeated start

The I²C specification allows the joining of multiple I²C transmissions by use of I²C ‘repeated start’. This way of operation ensures the set of I²C transmissions will not be interrupted by another transmission from a second microcontroller on the bus (multi-master setup).

TEF668X supports the use of I²C ‘repeated start’ without restriction. This means TEF668X handles I²C transmissions separated by an I²C stop and start condition in exactly the same way as I²C transmissions ‘joined’ by an I²C repeated start condition.

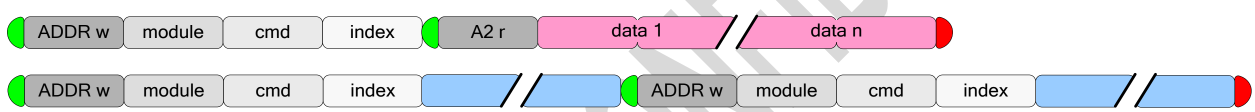


Fig 7. Examples of I²C transmissions with repeated start

5.5 Polling device presence

Checking for presence of the device on the I²C bus without any data transfer is possible by only writing of the device write address. The I²C standard acknowledge will signal device presence.

Fig 8. Example of testing device presence.

5.6 I²C read timing requirements

The TEF668X supports I²C clock speeds up to 400 kHz in accordance with the I²C ‘fast mode’ specification. TEF668X write operations require no special attention, read operations however require a minimum of 50 us time to guarantee read data setup.

The 50 us timing requirement is measured from the write transmission finish to the first read data; i.e. from the I²C ‘stop’ or ‘repeated start’ condition (= SDA edge) to the end of the device address ‘acknowledge’ (= falling edge of the 9th SCL clock pulse)

For 400 kHz bus operation the special control option of index = 0 offers a simple solution to meet this read timing requirement:

A setting of index = 0 will add an additional read word in front of the standard read data. This read word allows for special transmission evaluation options (see chapter 5.7 Special control) but can be ignored for normal operation. For 400 kHz operation the special index 0 read word ensures a proper setup timing for the required read data of index = 1 and higher. The special index 0 word itself however must be ignored.

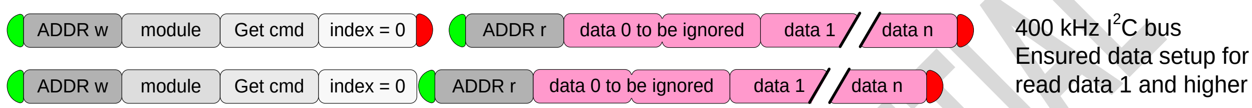


Fig 9. Example of I²C read control with guaranteed 400 kHz operation; get command index = 0

Use of index = 0 is probably the most convenient way to ensure proper read data settling for I²C fast mode bus operation.

Three alternative operation means are depicted below that may be of use, e.g. when reliable index = 0 read data is desired at high speed:

Alternative 1 : Maximum I²C bus speed limit.

A bus speed setting of 184 kHz or lower will guarantee the required data setup time. Microcontrollers generally do not employ the ‘fast mode’ worst-case timing for the full device address transmission meaning a microcontroller ‘200 kHz’ bus speed setting will ensure safe read operation in many cases.

Alternative 2 : 400 kHz I²C bus speed with microcontroller delay.

Use of separate transmissions and a timed delay of 27 us or higher between the write transmission ‘stop’ condition and the read transmission ‘start’ will guarantee the required read data setup time.

Alternative 3 : 400 kHz I²C bus speed with dual ‘repeated-start’.

In case use of ‘repeated-start’ is desired as well as 400 kHz bus operation a ‘dummy’ write address transmission can be inserted between the functional write and read transmission.

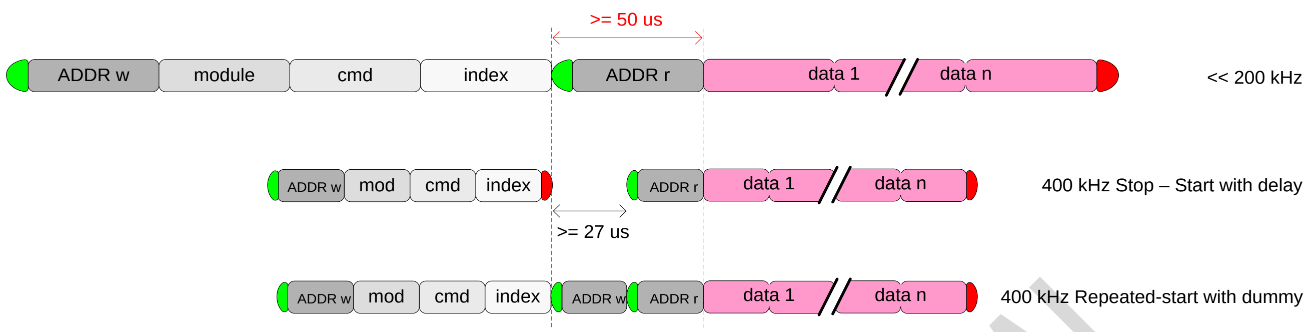


Fig 10. Examples of alternative I²C read control with guaranteed read data setup

5.7 Special control

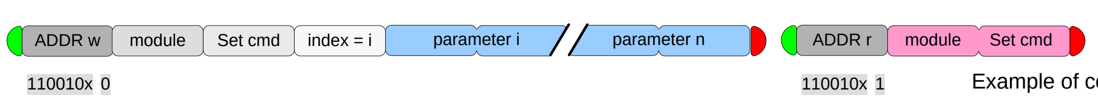
To support evaluation and debugging of the device control special control options are available.

5.7.1 Set command confirmation; special evaluation read control

For standard operation data reading is limited to status and information read data requested by a preceding ‘get’ command.

To this purpose TEF668X puts the requested data in its output registers after reception and evaluation of a valid ‘get’ command. TEF668X however also places a data word in its output registers after reception of a ‘set’ command, either offering confirmation of the command reception by returning the module and cmd value or delivering an error code in case of an invalid control. This data field is not intended for generic use but can be read during control software development for debugging purposes.

Condition :	Read data word :
Valid command	module / cmd
No command received	00 00h
Invalid command value	FF FFh
Invalid module value	FF FEh
Invalid index value	FF FDh (note: currently only index = 0 or 1 is permitted)
Invalid parameter value	FF FCh (note: not available in general)
Invalid state	FF FAh (= command not available in current state)



Example of confirmation read after set-command

Fig 11. Example of write command with evaluation data read

5.7.2 Get command confirmation; special evaluation read control

For standard operation read command data reading is limited to application status and information data.

However similar to write commands also read commands can optionally deliver confirmation of the read command reception or an error in case of invalid control.

To this purpose use of index = 0 with a ‘get’ command has a special meaning where as the first data word the module and cmd value are returned or an error code in case of invalid control.

Condition :	Read data word :
Get command data available	module / cmd
No command received	00 00h
Get command data not available yet	FF F8h*
Invalid command value	FF FFh
Invalid module value	FF FEh
Invalid index value	FF FDh (note: currently only 0 and 1 are allowed)
Invalid state	FF FAh (= command not available in current state)

* All TEF668X read commands show ‘instant’ data delivery, therefore error value FF F8h shall never be found as long as the read timing requirement of 50 us is met (see 5.6). In case of not meeting the read timing requirement also error value 00 00h may be found occasionally.

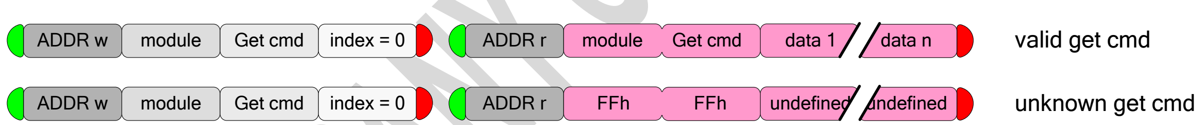


Fig 12. Examples of I²C read control with confirmation; get command index = 0

Note: The 00 00h and FF FFh … FF F8h error codes are also returned as the first data word in case of index = 1 use but may be confused with standard expected return data.

6. Device start-up

6.1 Introduction

The TEF668X is powered by a single supply voltage. No supply power-up requirements are known to exist.

After power-on the device is found in a pre-defined reset state (boot state). A sequence of control transmissions will bring the device into idle state followed by active state to realize the desired user operation mode, function and performance.

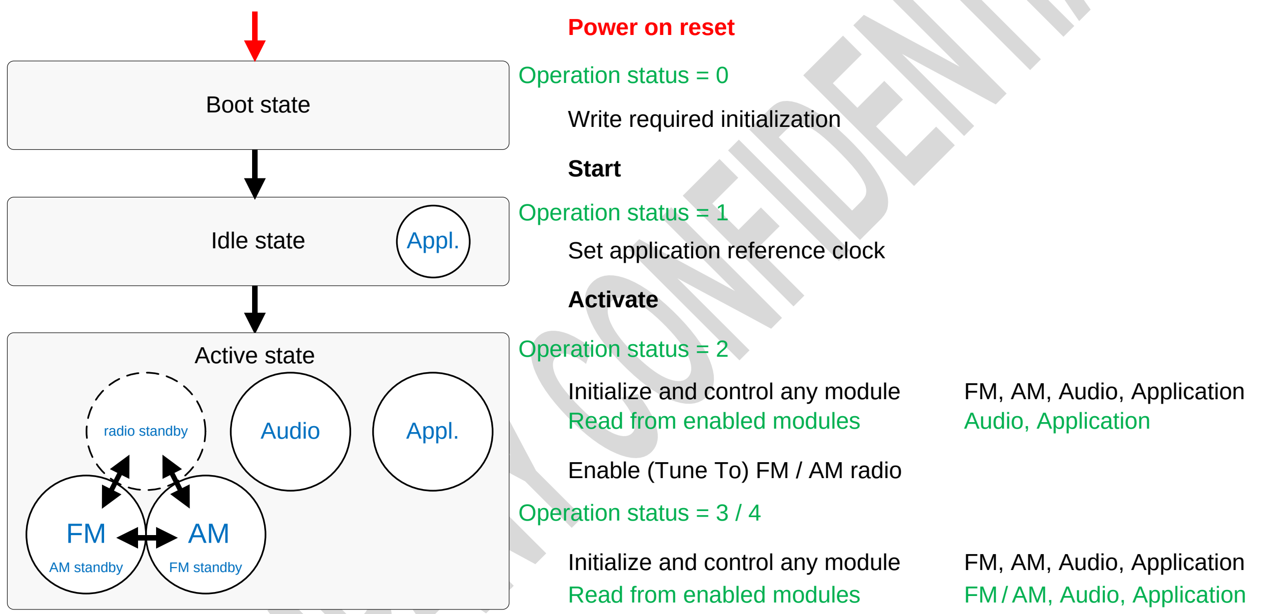


Fig 13. Block diagram of device start-up control sequence

Boot state and idle state have no function other than offering the minimum set of controls required for proper active state operation.

State transitions take a small amount of time and care should be taken to ensure a certain state is entered before any of the belonging control transmissions is started. After transmission of a ‘Start’ or ‘Activate’ state transition command it is advised to check the operation status by I^{2}C read until the new state is found.

TEF668X state transition times will fall within the following limits:

Power-on → Boot state : power supply voltage settling + 5 ms.
(or clock active + 5 ms in case of external clock application)

Boot state → Idle state : 50 ms.

Idle state → Active state : 100 ms.

6.2 Start-up I²C control transmission sequence

- Supply power on
- Wait until device is found present on the I²C bus ('boot state') :
  - Repeat **APPL_Get_Operation_Status** read until I²C acknowledge from device; status = 0 ('boot state') is found.
    `[ w 40 80 01 [ r 0000 ]`

    Alternatively Wait radio supply power settling time + 5 ms.

    In case of external clock application wait for clock active + 5 ms.
- Send required initializations :
  - See 6.2.1 Required initialization I2C transmission – I2C example
    and 6.2.2 Required initialization I2C transmission – C code include file
- Start :
  - `[ w 14 0001 ]`
- Wait until device is found in 'idle state' :
  - Repeat **APPL_Get_Operation_Status** read until status = 1 ('idle state') is found.
    `[ w 40 80 01 [ r 0001 ]`

    Alternatively Wait 50 ms.
- Set reference frequency
  - **APPL_Set_ReferenceClock** freq. = 55466670/9216000/4000000, type = 0/1.
    `[ w 40 04 01 034E 5AAE 0001 ]` *: 55.46667 MHz external reference.*
    `[ w 40 04 01 003D 0900 0000 ]` *: 4 MHz crystal reference.*
    Not required for default 9.216 MHz crystal use.
- Activate :
  - **APPL_Activate** mode = 1.
    `[ w 40 05 01 0001 ]`
- Wait until device is found in 'active state radio standby' :
  - Repeat **APPL_Get_Operation_Status** read until status = 2 ('radio standby state') is found.
    `[ w 40 80 01 [ r 0002 ]`

    Alternatively Wait 100 ms.
- Full API control is available from here for all modules.
  Audio and Application are on, FM and AM radio are in low-power standby.
  - *Example* **FM_**, **AM_**, **AUDIO_** and **APLL_** desired user settings*: module initialization.*
  - *Example* **AUDIO_Set_Mute** mode = 0 *: disable mute.*
    `[ w 30 0B 01 0000 ]`
  - *Example* **FM_Tune_To** mode = 1, frequency = 8930 *: FM radio 89.3 MHz.*
    `[ w 20 01 01 0001 22E2 ]`

6.2.1 Required initialization I²C transmission – I²C example

The following I²C transmissions (version p2.22) are a required part of the V102 boot state device initialization.

Use of these I²C transmissions is required for proper and full function and performance as described in this user manual. Version p2.22 is a minor update over p2.21.

Note: The transmission example below shows a data content of 12 words for every '1B' data transmission. The data stream can be split in any desired length on (2-byte) word boundaries with every data transmission starting with hex value 1B.

- ```
  [ w  1C  0000 ]
  [ w  1C  0074 ]
  ```
- ```
  [ w  1B  F000 3838 D080 F000 3840 D080 43B2 3843 D080 F000 7000 C2F7 ]
  [ w  1B  F000 3874 D080 80FC 3917 D080 C238 2011 40B7 9FA7 391C D280 ]
  [ w  1B  9FA7 3926 D280 F000 392D D080 F000 3930 D080 9041 3952 DD80 ]
  [ w  1B  F000 3A29 D080 F000 3956 D080 F000 3A2B D080 C4A2 0216 6004 ]
  [ w  1B  F000 39C3 D080 F000 39EB D080 9001 3958 D080 F000 38F9 D080 ]
  [ w  1B  F000 395F D280 F000 3963 D080 4384 396D D080 F000 3970 D080 ]
  [ w  1B  F000 3974 D080 9E30 18F9 D280 F000 397A D080 F000 397D D080 ]
  [ w  1B  3077 39E2 D080 F000 3980 D080 3200 3982 D080 F000 3984 D080 ]
  [ w  1B  F000 39CB D080 F000 39F9 D080 A801 3A17 D080 F000 3A36 D080 ]
  [ w  1B  F000 3A3D D080 F000 3A3F D080 F000 3A53 D080 F000 3A56 D080 ]
  [ w  1B  F000 3A59 D080 F000 3A5C D080 F000 7000 F000 F000 3A61 D080 ]
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[ w  1B  1000 04F4 6000 1000 02E3 6000 1000 009A 6000 F000 1000 F000 ]
[ w  1B  F000 1000 F000 F000 16D3 6008 F000 FF93 6000 F000 FE37 6000 ]
[ w  1B  1000 FDD9 6000 1000 FE9F 6000 1000 0385 6000 1000 0D6B 6000 ]
[ w  1B  1000 1684 6000 1000 1E49 6000 1000 1E49 6000 1000 1684 6000 ]
[ w  1B  1000 0D6B 6000 1000 0385 6000 1000 FE9F 6000 1000 FDD9 6000 ]
[ w  1B  1000 FE37 6000 1000 FF93 6000 F000 1000 F000 F000 1000 F000 ]
[ w  1B  F000 16E3 6008 F000 0064 6000 F000 FFA8 6000 1000 FFA6 6000 ]
[ w  1B  1000 FFDF 6000 1000 0001 6000 1000 0128 6000 1000 012F 6000 ]
[ w  1B  1000 FD23 6000 1000 FDA1 6000 1000 0389 6000 1000 0254 6000 ]
[ w  1B  1000 FE7D 6000 1000 008C 6000 1000 FBE1 6000 1000 F942 6000 ]
[ w  1B  1000 0C47 6000 1000 0EA2 6000 1000 EC43 6000 1000 EACE 6000 ]
[ w  1B  1000 1746 6000 1000 1746 6000 1000 EACE 6000 1000 EC43 6000 ]
[ w  1B  1000 0EA2 6000 1000 0C47 6000 1000 F942 6000 1000 FBE1 6000 ]
[ w  1B  1000 008C 6000 1000 FE7D 6000 1000 0254 6000 1000 0389 6000 ]
[ w  1B  1000 FDA1 6000 1000 FD23 6000 1000 012F 6000 1000 0128 6000 ]
[ w  1B  1000 0001 6000 1000 FFDF 6000 1000 FFA6 6000 1000 FFA8 6000 ]
[ w  1B  1000 0064 6000 F000 1000 F000 F000 1000 F000 F000 170B 6008 ]
[ w  1B  F000 0003 6000 F000 54C0 6000 1000 0005 6000 1000 0005 6000 ]
[ w  1B  1000 000F 6000 1000 000F 6000 1000 09C0 6000 1000 0A20 6000 ]
[ w  1B  1000 1D40 6000 1000 1E60 6000 F000 1000 F000 F000 1000 F000 ]
[ w  1B  F000 7000 D008 ]
```

- ```
  [ w  1C  0000 ]
  [ w  1C  0075 ]
  ```
- ```
  [ w  1B  4013 402F 4168 41C1 4214 44DE 44E9 45FB 4611 47C5 47FC 4D5D ]
  [ w  1B  4E56 4E58 4E5B 4D83 4E0A 4E0B 4E49 4E53 4F92 4FEA 5041 5074 ]
  [ w  1B  5080 5660 56D4 56D9 5829 59B4 5A3A 5B79 5BA2 5BEF 5DDC 603A ]
  [ w  1B  6088 60A8 619F 61B6 61DF 6214 6259 629B 62A1 6369 643B 6609 ]
  [ w  1B  66E7 670B 671A 6729 6887 6899 68A7 68B2 ]
  ```
- ```
  [ w  1C  0000 ]
  ```



  ```

### 6.2.2 Required initialization I²C transmission – C code include file

The following data sets (p2.22) are a required part of boot state device initialization. The C code in this chapter can be included in C program code of a host µC and describes the same data as the I²C script example of chapter 6.2.1.
The C code may be copied from this document but the C code include file can also be found as part of the PC GUI control program installation (.../documentation/PATCH.c).

```
/*
* Copyright Catena / NXP semiconductors
* Creation date: 2015 02 16 9:57:36
* Version: 2.00 - p2.22
*
* Usage:
*   Compile and link this C-file and declare in the source-file for required initialization transmissions the following:
*
* extern const size_t LutSize;
* extern const unsigned char * pLutBytes;
*
* extern const size_t PatchSize;
* extern const unsigned char * pPatchBytes;
*
* The source for required initialization transmissions should create the following set of I2C transmissions:
*
* [w 1C 0000]   script example: S C8 1C 00 00 P
* [w 1C 0074]   script example: S C8 1C 00 74 P
* [w 1B <pPatchBytes>]   script example: S C8 1B F0 00 .... P
*   PatchSize of pPatchBytes can be divided (on a 2 byte boundary) in separate transmissions all starting with command identifier 0x1B.
* [w 1C 0000]   script example: S C8 1C 00 00 P
* [w 1C 0075]   script example: S C8 1C 00 75 P
* [w 1B <pLutBytes>]   script example: S C8 1B 40 13 .... P
*   LutSize of pLutBytes can be divided (on a 2 byte boundary) in separate transmissions all starting with command identifier 0x1B.
* [w 1C 0000]   script example: S C8 1C 00 00 P
*
*/

#include <stdlib.h>

extern const size_t PatchSize;
extern const unsigned char * pPatchBytes;

static const unsigned char PatchByteValues[] =
{
   0xF0, 0x00, 0x38, 0x38, 0xD0, 0x80, 0xF0, 0x00, 0x38, 0x40, 0xD0, 0x80, 0x43, 0xB2, 0x38, 0x43, 0xD0, 0x80, 0xF0, 0x00, 0x70, 0x00, 0xC2, 0xF7,
   0xF0, 0x00, 0x38, 0x74, 0xD0, 0x80, 0x80, 0xFC, 0x39, 0x17, 0xD0, 0x80, 0xC2, 0x38, 0x20, 0x11, 0x40, 0xB7, 0x9F, 0xA7, 0x39, 0x1C, 0xD2, 0x80,
   0x9F, 0xA7, 0x39, 0x26, 0xD2, 0x80, 0xF0, 0x00, 0x39, 0x2D, 0xD0, 0x80, 0xF0, 0x00, 0x39, 0x30, 0xD0, 0x80, 0x90, 0x41, 0x39, 0x52, 0xDD, 0x80,
   0xF0, 0x00, 0x3A, 0x29, 0xD0, 0x80, 0xF0, 0x00, 0x39, 0x56, 0xD0, 0x80, 0xF0, 0x00, 0x3A, 0x2B, 0xD0, 0x80, 0xC4, 0xA2, 0x02, 0x16, 0x60, 0x04,
   0xF0, 0x00, 0x39, 0xC3, 0xD0, 0x80, 0xF0, 0x00, 0x39, 0xEB, 0xD0, 0x80, 0x90, 0x01, 0x39, 0x58, 0xD0, 0x80, 0xF0, 0x00, 0x38, 0xF9, 0xD0, 0x80,
   0xF0, 0x00, 0x39, 0x5F, 0xD2, 0x80, 0xF0, 0x00, 0x39, 0x63, 0xD0, 0x80, 0x43, 0xB4, 0x39, 0x6D, 0xD0, 0x80, 0xF0, 0x00, 0x39, 0x70, 0xD0, 0x80,
   0xF0, 0x00, 0x39, 0x74, 0xD0, 0x80, 0x9E, 0x30, 0x18, 0xF9, 0xD2, 0x80, 0xF0, 0x00, 0x39, 0x7A, 0xD0, 0x80, 0xF0, 0x00, 0x39, 0x7D, 0xD0, 0x80,
   0x30, 0x77, 0x39, 0xE2, 0xD0, 0x80, 0xF0, 0x00, 0x39, 0x80, 0xD0, 0x80, 0x32, 0x00, 0x39, 0x82, 0xD0, 0x80, 0xF0, 0x00, 0x39, 0x84, 0xD0, 0x80,
   0xF0, 0x00, 0x39, 0xCB, 0xD0, 0x80, 0xF0, 0x00, 0x39, 0xF9, 0xD0, 0x80, 0xA8, 0x01, 0x3A, 0x17, 0xD0, 0x80, 0xF0, 0x00, 0x3A, 0x36, 0xD0, 0x80,
   0xF0, 0x00, 0x3A, 0x3D, 0xD0, 0x80, 0xF0, 0x00, 0x3A, 0x3F, 0xD0, 0x80, 0xF0, 0x00, 0x3A, 0x53, 0xD0, 0x80, 0xF0, 0x00, 0x3A, 0x56, 0xD0, 0x80,
   0xF0, 0x00, 0x3A, 0x59, 0xD0, 0x80, 0xF0, 0x00, 0x3A, 0x5C, 0xD0, 0x80, 0xF0, 0x00, 0x70, 0x00, 0xF0, 0x00, 0xF0, 0x00, 0x3A, 0x61, 0xD0, 0x80,
   0xF0, 0x00, 0x3A, 0x22, 0xD2, 0x80, 0xF0, 0x00, 0x3A, 0x6F, 0xD0, 0x80, 0x00, 0x43, 0x3A, 0x7E, 0xD9, 0x80, 0xF0, 0x00, 0x3A, 0x88, 0xD0, 0x80,
   0xF0, 0x00, 0x3A, 0xDE, 0xD0, 0x80, 0xF0, 0x00, 0x3A, 0xE1, 0xD0, 0x80, 0xF0, 0x00, 0x3A, 0xF2, 0xD0, 0x80, 0x2E, 0x40, 0x3B, 0x90, 0xD0, 0x80,
   0xF0, 0x00, 0x3B, 0x9A, 0xD0, 0x80, 0xF0, 0x00, 0x0E, 0x3F, 0x60, 0x00, 0x50, 0x10, 0x28, 0xD8, 0xD2, 0x80, 0x91, 0x01, 0x01, 0x36, 0x60, 0x00,
   0xF0, 0x00, 0x70, 0x00, 0xA0, 0x18, 0xF0, 0x00, 0x70, 0x00, 0xA0, 0xD8, 0xF0, 0x00, 0x70, 0x00, 0xA0, 0xF9, 0xF0, 0x00, 0x70, 0x00, 0xA1, 0xB5,
   0xF0, 0x00, 0x70, 0x00, 0xA2, 0x09, 0xF0, 0x00, 0x70, 0x00, 0xA2, 0x34, 0xF0, 0x00, 0x70, 0x00, 0xA2, 0x4C, 0xF0, 0x00, 0x20, 0x31, 0xD0, 0x80,
   0xF0, 0x00, 0x04, 0xC1, 0x60, 0x08, 0xF0, 0x00, 0x01, 0x01, 0xD2, 0x80, 0xF0, 0x00, 0x00, 0x30, 0xD0, 0x80, 0x00, 0x7F, 0x60, 0x02, 0xE2, 0x00,
   0xF0, 0x00, 0x0E, 0x22, 0x60, 0x0A, 0xF0, 0x00, 0x00, 0xFF, 0x60, 0x03, 0xF0, 0x00, 0x01, 0x42, 0xD2, 0x80, 0x90, 0x03, 0x40, 0x02, 0xF0, 0x00,
   0x90, 0x43, 0x01, 0x70, 0xD1, 0x80, 0xF0, 0x00, 0x01, 0x69, 0xD0, 0x80, 0x0E, 0x69, 0x60, 0x0A, 0xA3, 0x52, 0x20, 0x23, 0x00, 0x01, 0x60, 0x01,
   0xF0, 0x00, 0x70, 0x00, 0xF0, 0x00, 0xC4, 0xCB, 0x70, 0x00, 0xF0, 0x00, 0xCA, 0x09, 0x30, 0x23, 0xF0, 0x00, 0xC2, 0xCB, 0x70, 0x00, 0xF0, 0x00,
   0xF0, 0x00, 0x30, 0x23, 0xD0, 0x08, 0x82, 0x00, 0x0D, 0x50, 0x60, 0x08, 0xF0, 0x00, 0x0D, 0x51, 0x60, 0x09, 0x30, 0x00, 0x21, 0x80, 0x60, 0x01,
   0xF0, 0x00, 0x40, 0x32, 0xF0, 0x00, 0x30, 0x11, 0x45, 0xF3, 0xF0, 0x00, 0x30, 0x92, 0x2D, 0x30, 0x60, 0x04, 0x31, 0x13, 0x2D, 0x40, 0x60, 0x05,
   0x31, 0x94, 0x7F, 0xFF, 0x60, 0x06, 0x32, 0x15, 0x0D, 0x61, 0x60, 0x0A, 0x32, 0x96, 0x0D, 0x6B, 0x60, 0x0B, 0x33, 0x10, 0x0D, 0x50, 0x60, 0x01,
   0x33, 0x90, 0x0D, 0x5C, 0x60, 0x02, 0x30, 0x21, 0x0D, 0x63, 0x60, 0x03, 0x30, 0x31, 0x0D, 0x75, 0x60, 0x0C, 0x30, 0xA2, 0x8D, 0x00, 0x60, 0x01,
   0x30, 0xB3, 0x01, 0x73, 0x60, 0x02, 0x30, 0x41, 0x00, 0x25, 0x60, 0x03, 0x30, 0xC2, 0x40, 0x44, 0xF0, 0x00, 0x31, 0x43, 0x40, 0x35, 0xF0, 0x00,
   0x31, 0xC4, 0x64, 0x00, 0x60, 0x06, 0x32, 0x45, 0x1F, 0x40, 0x60, 0x07, 0x32, 0xC6, 0x70, 0x00, 0xF0, 0x00, 0x33, 0x47, 0x1E, 0xBC, 0x60, 0x0D,
   0x33, 0xC0, 0x01, 0x22, 0x60, 0x01, 0x34, 0x40, 0xFD, 0xEE, 0x60, 0x02, 0x30, 0x51, 0x7B, 0x8F, 0x60, 0x03, 0x30, 0xD2, 0xC4, 0x29, 0x60, 0x04,
   0x31, 0x51, 0x1E, 0xC2, 0x60, 0x0E, 0x32, 0x53, 0xFF, 0x0D, 0x60, 0x02, 0x32, 0xD4, 0x7D, 0x2E, 0x60, 0x03, 0x30, 0x61, 0xC1, 0x9A, 0x60, 0x04,
   0x30, 0xE2, 0x70, 0x00, 0xF0, 0x00, 0x31, 0x61, 0x70, 0x00, 0xF0, 0x00, 0x32, 0x63, 0x70, 0x00, 0xF0, 0x00, 0x32, 0xE4, 0x70, 0x00, 0xD0, 0x08,
   0xF0, 0x00, 0x03, 0x70, 0xD2, 0x80, 0xF0, 0x00, 0x70, 0x00, 0xA0, 0x02, 0xF0, 0x00, 0x70, 0x00, 0xA0, 0x59, 0xF0, 0x00, 0x02, 0x15, 0xD0, 0x80,
   0xF0, 0x00, 0x0D, 0x51, 0x60, 0x0F, 0xF0, 0x00, 0x05, 0x17, 0x60, 0x0E, 0x23, 0xF6, 0x70, 0x00, 0xF0, 0x00, 0xF0, 0x00, 0x21, 0x63, 0x41, 0xF5,
   0x91, 0x8F, 0x21, 0xF8, 0x40, 0x74, 0xC3, 0xEF, 0x21, 0xE0, 0xF0, 0x00, 0xC3, 0xA4, 0x33, 0xF7, 0xF0, 0x00, 0xD8, 0x5B, 0x70, 0x00, 0xF0, 0x00,
   0x82, 0x18, 0x70, 0x00, 0xF0, 0x00, 0x9F, 0xAF, 0x18, 0x00, 0xF0, 0x00, 0x9F, 0x0F, 0x31, 0xF8, 0x90, 0x02, 0xF0, 0x00, 0x70, 0x00, 0x90, 0x28,
   0xF0, 0x00, 0x70, 0x00, 0xD0, 0x08, 0xF0, 0x00, 0x22, 0x78, 0xF0, 0x00, 0x16, 0xD3, 0x60, 0x09, 0xA0, 0x7F, 0x35, 0xF0, 0x1E, 0xBC, 0x60, 0x0D,
   0xF0, 0x00, 0x0D, 0x61, 0x60, 0x08, 0xF0, 0x00, 0x03, 0xA5, 0xD2, 0x80, 0xF0, 0x00, 0x1E, 0xC2, 0x60, 0x0D, 0xF0, 0x00, 0x0D, 0x6B, 0x60, 0x08,
   0xF0, 0x00, 0x03, 0xA5, 0xD2, 0x80, 0xF0, 0x00, 0x21, 0x00, 0xF0, 0x00, 0x83, 0x6D, 0x22, 0xF1, 0xF0, 0x00, 0xF0, 0x00, 0x23, 0x77, 0xF0, 0x00,
   0x90, 0x41, 0x36, 0x70, 0xF0, 0x00, 0x9E, 0x79, 0x70, 0x00, 0x90, 0x01, 0xF0, 0x00, 0x32, 0xF1, 0xD0, 0x08, 0x91, 0xC7, 0x33, 0x75, 0xF0, 0x00,
   0xF0, 0x00, 0x34, 0x70, 0xE6, 0x00, 0xF0, 0x00, 0x34, 0xF0, 0xE6, 0x00, 0xF0, 0x00, 0x24, 0x74, 0xF0, 0x00, 0xF0, 0x00, 0x24, 0xF3, 0xF0, 0x00,
   0x8C, 0x24, 0x26, 0xF2, 0x40, 0x16, 0x8A, 0x1B, 0x34, 0x74, 0x4F, 0xF5, 0x82, 0xB7, 0x34, 0xF3, 0xF0, 0x00, 0xF0, 0x00, 0x20, 0x71, 0x90, 0x05,
   0x83, 0x04, 0x70, 0x00, 0xF0, 0x00, 0x8E, 0x67, 0x70, 0x00, 0xF0, 0x00, 0xF0, 0x00, 0x70, 0x00, 0x90, 0x02, 0xF0, 0x00, 0x36, 0xF6, 0xF0, 0x00,
   0xF0, 0x00, 0x34, 0xF0, 0x80, 0x06, 0x82, 0xAF, 0x70, 0x00, 0xF0, 0x00, 0x82, 0x1B, 0x70, 0x00, 0xD0, 0x09, 0x8E, 0x5F, 0x70, 0x00, 0xF0, 0x00,
   0xF0, 0x00, 0x70, 0x00, 0xD0, 0x09, 0xF0, 0x00, 0x36, 0xF5, 0xF0, 0x00, 0xF0, 0x00, 0x34, 0x70, 0xF0, 0x00, 0x40, 0x11, 0x27, 0x72, 0xA2, 0xF5,
   0x90, 0x8A, 0x20, 0xF3, 0xA2, 0xF4, 0x8E, 0xD7, 0x37, 0x72, 0xF0, 0x00, 0xF0, 0x00, 0x37, 0xF1, 0xE6, 0x00, 0xF0, 0x00, 0x70, 0x00, 0xD0, 0x08,
   0xF0, 0x00, 0x22, 0x7A, 0xF0, 0x00, 0x16, 0xC3, 0x60, 0x09, 0xA0, 0x58, 0xF0, 0x00, 0x18, 0x20, 0xF0, 0x00, 0xF0, 0x00, 0x35, 0x70, 0xF0, 0x00,
   0xF0, 0x00, 0x32, 0x7A, 0xD0, 0x08, 0x82, 0x00, 0x0D, 0x51, 0x60, 0x08, 0x40, 0x03, 0x70, 0x00, 0xF0, 0x00, 0x33, 0x80, 0x70, 0x00, 0xF0, 0x00,
   0x21, 0x06, 0x70, 0x00, 0xF0, 0x00, 0x37, 0x00, 0x70, 0x00, 0xF0, 0x00, 0x37, 0x80, 0x40, 0x15, 0xF0, 0x00, 0x36, 0x83, 0x70, 0x00, 0xF0, 0x00,
   0x33, 0x05, 0x0D, 0x61, 0x60, 0x09, 0x32, 0x86, 0x0D, 0x6B, 0x60, 0x0A, 0x32, 0x10, 0x70, 0x00, 0xF0, 0x00, 0x32, 0x90, 0x70, 0x00, 0xF0, 0x00,
   0x33, 0x10, 0x70, 0x00, 0xF0, 0x00, 0x33, 0x90, 0x70, 0x00, 0xF0, 0x00, 0x34, 0x10, 0x70, 0x00, 0xF0, 0x00, 0x34, 0x90, 0x70, 0x00, 0xF0, 0x00,
   0x31, 0x10, 0x70, 0x00, 0xF0, 0x00, 0x31, 0x90, 0x70, 0x00, 0xF0, 0x00, 0x32, 0x20, 0x70, 0x00, 0xF0, 0x00, 0x32, 0xA0, 0x70, 0x00, 0xF0, 0x00,
   0x33, 0x20, 0x70, 0x00, 0xF0, 0x00, 0x33, 0xA0, 0x70, 0x00, 0xF0, 0x00, 0x34, 0x20, 0x70, 0x00, 0xF0, 0x00, 0x34, 0xA0, 0x70, 0x00, 0xF0, 0x00,
   0x31, 0x20, 0x70, 0x00, 0xF0, 0x00, 0x31, 0xA0, 0x70, 0x00, 0xF0, 0x00, 0x82, 0x00, 0x0D, 0x30, 0x60, 0x0A, 0x0D, 0x40, 0x60, 0x0B, 0xC0, 0x10,
   0xF0, 0x00, 0x10, 0x20, 0xF0, 0x00, 0x0D, 0x51, 0x60, 0x0C, 0xC0, 0x10, 0xF0, 0x00, 0x10, 0x30, 0xF0, 0x00, 0xF0, 0x00, 0x35, 0xC0, 0xD0, 0x08,
   0xF0, 0x00, 0x0D, 0x75, 0x60, 0x0F, 0xF0, 0x00, 0x05, 0x63, 0x60, 0x0E, 0x24, 0xF7, 0x05, 0x1D, 0x60, 0x0D, 0x25, 0x76, 0x70, 0x00, 0xF0, 0x00,
   0x91, 0xC7, 0x20, 0xE8, 0x40, 0x15, 0x91, 0x8F, 0x21, 0xE9, 0xD4, 0x09, 0xC3, 0xEF, 0x20, 0x00, 0x40, 0x12, 0x9F, 0xBE, 0x20, 0x11, 0x58, 0x03,
   0xA0, 0x80, 0x35, 0x77, 0x90, 0x01, 0xF0, 0x00, 0x70, 0x00, 0xD0, 0x08, 0xF0, 0x00, 0x21, 0xF5, 0xF0, 0x00, 0xA0, 0xCA, 0x22, 0x54, 0xF0, 0x00,
   0xCC, 0x09, 0x05, 0x17, 0x60, 0x0C, 0x83, 0x2C, 0x70, 0x00, 0xF0, 0x00, 0x8A, 0x61, 0x70, 0x00, 0xF0, 0x00, 0xAE, 0x48, 0x22, 0x45, 0xA2, 0xBD,
   0xA2, 0x28, 0x20, 0x78, 0xF0, 0x00, 0xF0, 0x00, 0x35, 0xF0, 0xF0, 0x00, 0xF0, 0x00, 0x18, 0x00, 0xF0, 0x00, 0xF0, 0x00, 0x30, 0x78, 0xF0, 0x00,
   0x16, 0xE3, 0x60, 0x09, 0xA0, 0x27, 0x89, 0x01, 0x23, 0xF4, 0xF0, 0x00, 0xF0, 0x00, 0x20, 0xF2, 0xF0, 0x00, 0x82, 0x61, 0x21, 0x73, 0xF0, 0x00,
   0xA0, 0x50, 0x36, 0x70, 0xF0, 0x00, 0xA0, 0x58, 0x23, 0x72, 0xE1, 0x40, 0xA8, 0x01, 0x22, 0xF3, 0xF0, 0x00, 0x90, 0x49, 0x22, 0x75, 0xE0, 0x40,
   0x80, 0x61, 0x70, 0x00, 0xF0, 0x00, 0x8A, 0x51, 0x33, 0xF1, 0xF0, 0x00, 0xA0, 0x58, 0x70, 0x00, 0xF0, 0x00, 0xAF, 0x48, 0x70, 0x00, 0xF0, 0x00,
   0xF0, 0x00, 0x34, 0x70, 0xD0, 0x08, 0x82, 0x00, 0x0D, 0x75, 0x60, 0x08, 0x90, 0x09, 0x0D, 0x00, 0x60, 0x09, 0xF0, 0x00, 0x35, 0x00, 0xF0, 0x00,
   0xF0, 0x00, 0x33, 0x80, 0xC0, 0x28, 0xF0, 0x00, 0x10, 0x10, 0xF0, 0x00, 0xF0, 0x00, 0x34, 0x81, 0xD0, 0x08, 0x82, 0x49, 0x0D, 0x75, 0x60, 0x08,
   0xF0, 0x00, 0x70, 0x00, 0x8F, 0xFD, 0x04, 0x00, 0x60, 0x00, 0xA2, 0xA3, 0x8E, 0xC0, 0x40, 0x00, 0x60, 0x05, 0x60, 0x00, 0x60, 0x05, 0xE6, 0x00,
   0xC8, 0x1B, 0x70, 0x00, 0xF0, 0x00, 0xD8, 0xDB, 0x0D, 0x51, 0x60, 0x08, 0x83, 0x5B, 0x70, 0x00, 0xF0, 0x00, 0x9E, 0xBA, 0x30, 0x03, 0xF0, 0x00,
   0xF0, 0x00, 0x30, 0x84, 0xD4, 0x09, 0xF0, 0x00, 0x70, 0x00, 0x8F, 0xAF, 0xF0, 0x00, 0x0D, 0x75, 0x60, 0x08, 0xF0, 0x00, 0x0D, 0x51, 0x60, 0x09,
   0xF0, 0x00, 0x24, 0x03, 0xF0, 0x00, 0xF0, 0x00, 0x27, 0x94, 0xD0, 0x08, 0xA0, 0x03, 0x70, 0x00, 0xF0, 0x00, 0x00, 0x11, 0x08, 0x00, 0xF0, 0x00,
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0xF0, 0x00, 0x23, 0xEA, 0xD2, 0x80, 0xF0, 0x00, 0x23, 0xDE, 0xD2, 0x80, 0xA9, 0x88, 0x70, 0x00, 0xF0, 0x00, 0xAB, 0xF8, 0x23, 0xE4, 0xD2, 0x80,
0x46, 0x43, 0x21, 0x42, 0xA0, 0x20, 0xA0, 0x98, 0x70, 0x00, 0xF0, 0x00, 0xF0, 0x00, 0x23, 0xE7, 0xD2, 0x80, 0xF0, 0x00, 0x23, 0xC6, 0xD2, 0x80,
0x90, 0x00, 0x70, 0x00, 0xF0, 0x00, 0xF0, 0x00, 0x70, 0x00, 0xDC, 0x09, 0xF0, 0x00, 0x23, 0xCE, 0xD0, 0x80, 0x47, 0xE5, 0x70, 0x00, 0xF0, 0x00,
0x40, 0x16, 0x20, 0xD3, 0xA0, 0x18, 0x83, 0x5D, 0x20, 0x52, 0xF0, 0x00, 0xC2, 0xF5, 0x21, 0x54, 0x98, 0x07, 0xC2, 0xB6, 0x70, 0x00, 0x90, 0x02,
```

```
    0xF0, 0x00, 0x70, 0x00, 0x90, 0x05, 0xF0, 0x00, 0x70, 0x00, 0x80, 0x02, 0xC2, 0xB6, 0x70, 0x00, 0xF0, 0x00, 0xF0, 0x00, 0x70, 0x00, 0xD4, 0x09,
    0x82, 0x64, 0x70, 0x00, 0xF0, 0x00, 0xF0, 0x00, 0x70, 0x00, 0xDC, 0x09, 0xF0, 0x00, 0x31, 0x51, 0xF0, 0x00, 0xF0, 0x00, 0x30, 0xD2, 0xD0, 0x08,
    0x0D, 0xEF, 0x60, 0x0B, 0xA0, 0x0C, 0x9E, 0x79, 0x20, 0x36, 0xF0, 0x00, 0xF0, 0x00, 0x20, 0x45, 0xF0, 0x00, 0x9F, 0xBC, 0x70, 0x00, 0xE0, 0x40,
    0x91, 0x45, 0x70, 0x00, 0xD0, 0x09, 0x26, 0x44, 0x27, 0x2D, 0xD5, 0x80, 0x91, 0x86, 0x70, 0x00, 0xF0, 0x00, 0xF0, 0x00, 0x27, 0x32, 0xD5, 0x80,
    0xF0, 0x00, 0x70, 0x00, 0xAF, 0x67, 0x2F, 0x41, 0x27, 0x36, 0xD0, 0x80, 0xF0, 0x00, 0x29, 0x15, 0xD2, 0x80, 0xF0, 0x00, 0x3B, 0x9E, 0xD2, 0x80,
    0xF0, 0x00, 0x28, 0x88, 0xD0, 0x80, 0xF0, 0x00, 0x70, 0x00, 0xD0, 0x08, 0xF0, 0x00, 0x16, 0xC3, 0x60, 0x08, 0xF0, 0x00, 0x00, 0x9A, 0x60, 0x00,
    0xF0, 0x00, 0x02, 0xE3, 0x60, 0x00, 0x10, 0x00, 0x04, 0xF4, 0x60, 0x00, 0x10, 0x00, 0x06, 0xFF, 0x60, 0x00, 0x10, 0x00, 0x09, 0x07, 0x60, 0x00,
    0x10, 0x00, 0x0B, 0x10, 0x60, 0x00, 0x10, 0x00, 0x0D, 0x1F, 0x60, 0x00, 0x10, 0x00, 0x0F, 0x65, 0x60, 0x00, 0x10, 0x00, 0x0F, 0x65, 0x60, 0x00,
    0x10, 0x00, 0x0D, 0x1F, 0x60, 0x00, 0x10, 0x00, 0x0B, 0x10, 0x60, 0x00, 0x10, 0x00, 0x09, 0x07, 0x60, 0x00, 0x10, 0x00, 0x06, 0xFF, 0x60, 0x00,
    0x10, 0x00, 0x04, 0xF4, 0x60, 0x00, 0x10, 0x00, 0x02, 0xE3, 0x60, 0x00, 0x10, 0x00, 0x00, 0x9A, 0x60, 0x00, 0xF0, 0x00, 0x10, 0x00, 0xF0, 0x00,
    0xF0, 0x00, 0x10, 0x00, 0xF0, 0x00, 0xF0, 0x00, 0x16, 0xD3, 0x60, 0x08, 0xF0, 0x00, 0xFF, 0x93, 0x60, 0x00, 0xF0, 0x00, 0xFE, 0x37, 0x60, 0x00,
    0x10, 0x00, 0xFD, 0xD9, 0x60, 0x00, 0x10, 0x00, 0xFE, 0x9F, 0x60, 0x00, 0x10, 0x00, 0x03, 0x85, 0x60, 0x00, 0x10, 0x00, 0x0D, 0x6B, 0x60, 0x00,
    0x10, 0x00, 0x16, 0x84, 0x60, 0x00, 0x10, 0x00, 0x1E, 0x49, 0x60, 0x00, 0x10, 0x00, 0x1E, 0x49, 0x60, 0x00, 0x10, 0x00, 0x16, 0x84, 0x60, 0x00,
    0x10, 0x00, 0x0D, 0x6B, 0x60, 0x00, 0x10, 0x00, 0x03, 0x85, 0x60, 0x00, 0x10, 0x00, 0xFE, 0x9F, 0x60, 0x00, 0x10, 0x00, 0xFD, 0xD9, 0x60, 0x00,
    0x10, 0x00, 0xFE, 0x37, 0x60, 0x00, 0x10, 0x00, 0xFF, 0x93, 0x60, 0x00, 0xF0, 0x00, 0x10, 0x00, 0xF0, 0x00, 0xF0, 0x00, 0x10, 0x00, 0xF0, 0x00,
    0xF0, 0x00, 0x16, 0xE3, 0x60, 0x08, 0xF0, 0x00, 0x00, 0x64, 0x60, 0x00, 0xF0, 0x00, 0xFF, 0xA8, 0x60, 0x00, 0x10, 0x00, 0xFF, 0xA6, 0x60, 0x00,
    0x10, 0x00, 0xFF, 0xDF, 0x60, 0x00, 0x10, 0x00, 0x00, 0x01, 0x60, 0x00, 0x10, 0x00, 0x01, 0x28, 0x60, 0x00, 0x10, 0x00, 0x01, 0x2F, 0x60, 0x00,
    0x10, 0x00, 0xFD, 0x23, 0x60, 0x00, 0x10, 0x00, 0xFD, 0xA1, 0x60, 0x00, 0x10, 0x00, 0x03, 0x89, 0x60, 0x00, 0x10, 0x00, 0x02, 0x54, 0x60, 0x00,
    0x10, 0x00, 0xFE, 0x7D, 0x60, 0x00, 0x10, 0x00, 0x00, 0x8C, 0x60, 0x00, 0x10, 0x00, 0xFB, 0xE1, 0x60, 0x00, 0x10, 0x00, 0xF9, 0x42, 0x60, 0x00,
    0x10, 0x00, 0x0C, 0x47, 0x60, 0x00, 0x10, 0x00, 0x0E, 0xA2, 0x60, 0x00, 0x10, 0x00, 0xEC, 0x43, 0x60, 0x00, 0x10, 0x00, 0xEA, 0xCE, 0x60, 0x00,
    0x10, 0x00, 0x17, 0x46, 0x60, 0x00, 0x10, 0x00, 0x17, 0x46, 0x60, 0x00, 0x10, 0x00, 0xEA, 0xCE, 0x60, 0x00, 0x10, 0x00, 0xEC, 0x43, 0x60, 0x00,
    0x10, 0x00, 0x0E, 0xA2, 0x60, 0x00, 0x10, 0x00, 0x0C, 0x47, 0x60, 0x00, 0x10, 0x00, 0xF9, 0x42, 0x60, 0x00, 0x10, 0x00, 0xFB, 0xE1, 0x60, 0x00,
    0x10, 0x00, 0x00, 0x8C, 0x60, 0x00, 0x10, 0x00, 0xFE, 0x7D, 0x60, 0x00, 0x10, 0x00, 0x02, 0x54, 0x60, 0x00, 0x10, 0x00, 0x03, 0x89, 0x60, 0x00,
    0x10, 0x00, 0xFD, 0xA1, 0x60, 0x00, 0x10, 0x00, 0xFD, 0x23, 0x60, 0x00, 0x10, 0x00, 0x01, 0x2F, 0x60, 0x00, 0x10, 0x00, 0x01, 0x28, 0x60, 0x00,
    0x10, 0x00, 0x00, 0x01, 0x60, 0x00, 0x10, 0x00, 0xFF, 0xDF, 0x60, 0x00, 0x10, 0x00, 0xFF, 0xA6, 0x60, 0x00, 0x10, 0x00, 0xFF, 0xA8, 0x60, 0x00,
    0x10, 0x00, 0x00, 0x64, 0x60, 0x00, 0xF0, 0x00, 0x10, 0x00, 0xF0, 0x00, 0xF0, 0x00, 0x10, 0x00, 0xF0, 0x00, 0xF0, 0x00, 0x17, 0x0B, 0x60, 0x08,
    0xF0, 0x00, 0x00, 0x03, 0x60, 0x00, 0xF0, 0x00, 0x54, 0xC0, 0x60, 0x00, 0x10, 0x00, 0x00, 0x05, 0x60, 0x00, 0x10, 0x00, 0x00, 0x05, 0x60, 0x00,
    0x10, 0x00, 0x00, 0x0F, 0x60, 0x00, 0x10, 0x00, 0x00, 0x0F, 0x60, 0x00, 0x10, 0x00, 0x09, 0xC0, 0x60, 0x00, 0x10, 0x00, 0x0A, 0x20, 0x60, 0x00,
    0x10, 0x00, 0x1D, 0x40, 0x60, 0x00, 0x10, 0x00, 0x1E, 0x60, 0x60, 0x00, 0xF0, 0x00, 0x10, 0x00, 0xF0, 0x00, 0xF0, 0x00, 0x10, 0x00, 0xF0, 0x00,
    0xF0, 0x00, 0x70, 0x00, 0xD0, 0x08
};

const size_t PatchSize = sizeof(PatchByteValues);
const unsigned char * pPatchBytes = &PatchByteValues[0];

extern const size_t LutSize;
extern const unsigned char * pLutBytes;

static  unsigned char LutByteValues[] =
{
    0x40, 0x13, 0x40, 0x2F, 0x41, 0x68, 0x41, 0xC1,
    0x42, 0x14, 0x44, 0xDE, 0x44, 0xE9, 0x45, 0xFB,
    0x46, 0x11, 0x47, 0xC5, 0x47, 0xFC, 0x4D, 0x5D,
    0x4E, 0x56, 0x4E, 0x58, 0x4E, 0x5B, 0x4D, 0x83,
    0x4E, 0x0A, 0x4E, 0x0B, 0x4E, 0x49, 0x4E, 0x53,
    0x4F, 0x92, 0x4F, 0xEA, 0x50, 0x41, 0x50, 0x74,
    0x50, 0x80, 0x56, 0x60, 0x56, 0xD4, 0x56, 0xD9,
    0x58, 0x29, 0x59, 0xB4, 0x5A, 0x3A, 0x5B, 0x79,
    0x5B, 0xA2, 0x5B, 0xEF, 0x5D, 0xDC, 0x60, 0x3A,
    0x60, 0x88, 0x60, 0xA8, 0x61, 0x9F, 0x61, 0xB6,
    0x61, 0xDF, 0x62, 0x14, 0x62, 0x59, 0x62, 0x9B,
    0x62, 0xA1, 0x63, 0x69, 0x64, 0x3B, 0x66, 0x09,
    0x66, 0xE7, 0x67, 0x0B, 0x67, 0x1A, 0x67, 0x29,
    0x68, 0x87, 0x68, 0x99, 0x68, 0xA7, 0x68, 0xB2
};

const size_t LutSize =  sizeof(LutByteValues);
const unsigned char * pLutBytes = &LutByteValues[0];
```

6.2.3 Required initialization I²C transmission – version p2.22

Initialization version p2.22 is a required part of the V102 device startup.

Initialization version p2.22 offers the following updates over earlier releases:

Performance

- Improved performance at FM 104 MHz for digital radio = off
- Improved performance for FM 96.9 MHz HD radio reception
- Corrected level extension for maximum AM RF AGC step

Initialization version p2.22 includes all the advantages offered from earlier versions:

Fix

- p2.19: Supporting manual selection of the digital radio sample rate (3.26 FM / AM cmd 84 Set_DR_Options); not supported for p2.17.
- p2.15: AM Shortwave use: resolved failing reception after switching from FM 94.1 MHz to AM Shortwave band
- p2.15: External FM AGC application and AFU, Jump or Check tuning: resolved wrong mute slope after internal FM AGC step
- p2.14: Radio tuning robustness, resolving issue of wrong quality read and muted audio after > 65000 tunings with less than 32 ms between tuning actions
- p2.14: Erroneous level result in high signal conditions (in certain cases depending on RF AGC threshold, level step correction and level offset settings)
- p2.14: Resolved potential issue of boot state robustness
- p2.13: Tuning action sequence FM Check – FM Preset and FM Check – FM Search; resolved issue of frozen weak signal handling
- p2.13: Tuning action sequence FM Check – FM Jump – … – FM Check; proper weak signal handling start at closing of FM Check (by Jump, AFU or End action)
- p2.12: Resolved critical issue of muted FM radio after temperature change
- p2.12: Resolved critical issue on variant read
- p2.12: Resolved issue concerning AM noise blanker false triggering on specific condition of 30 kHz adjacent signal with HD radio digital modulation
- p2.12: Improved digital radio large signal handling

New feature

- p2.21: Extension of noise blanker control options (3.9, 3.10, 3.11, 3.12)
- p2.17: Extension of FM automatic bandwidth control options (3.3 FM / AM cmd 10 Set_Bandwidth
- p2.13: Minimum IF bandwidth control (3.3 FM / AM cmd 10 Set_Bandwidth)
- p2.09: AM noise detector (4.1 FM / AM cmd 128 / 129 Get_Quality)
- p2.09: AM co-channel detector (3.6 AM cmd 14 Set_CoChannelDet and 4.1)

Performance

- p2.19: Avoidance of digital radio BCK harmonics in FM digital radio bandwidth.
- p2.17: Improved spurious performance for multiple tuner application, particularly with SAF775X.
- p2.15: FM multipath suppression and AFU, Jump tuning: resolved audio amplitude disturbance after Jump / AFU tuning from high to low signal condition
- p2.13: Optimized digital radio large signal handling timing and adapted threshold
- p2.10: Reduction of potential whistle in the AM SW band at the crystal frequency
- p2.10: Improved digital radio high level signal response and fast settling at tuning
- p2.09: Avoidance of potential whistle at 77.40 MHz

Next to the above published advantages the behavior is otherwise equivalent to the previous device version V101 with p01.24 initialization but including:

- Resolved control issue regarding disabling of FM Highcut ‘deemphasis’ option

6.3 Operation state description

6.3.1 Boot state

After power-on the device is found in ‘boot state’, controlled by the integrated power-on-reset detection.
Parallel to the supply power detection a clock signal detector is present which ensures boot state is entered only when a clock signal is present in order to safeguard the external clock application case.

In case of a harmful disruption of the power supply voltage (power dip) or reference clock signal the present operation state will be reset and boot state will be available after power supply voltage and reference signal are re-established.

In boot state the device functionality is reduced to the bare minimum defined by hardware only.

Required additions to the built-in firmware can be loaded up from the host µC to the internal RAM of the device.

‘Boot state’ is identified by

- The I²C bus is active; I²C transmissions are acknowledged by the device.
  (Note: the I²C device address has been determined during power-on).
- The device is in full power-down.
- GPIO and digital output pins are ‘open’.
- No API commands are available; only hardware support.
  API commands are ignored and do not harm the boot state operation.
- Reading APPL_Get_Operation_Status returns ‘boot state’ (0).
  Note: This API read operation is defined by the fact that any API read will return ‘0’ here.
  This property can be used by the radio system µC to detect an unforeseen power dip occurrence or unforeseen disruption of the (external) clock reference signal.
- The device can receive certain dedicated hardware commands and data;
  Device version V102 requires an initialization at this point for function and performance.
- Command ‘Start’ will bring the device into ‘idle state’.
  Note: The ‘Start’ command is made up of I²C data byte values “14h 00h 01h”.
  In API definition style this equals a transmission of module = 20, cmd = 0, index = 1 and no parameters.

6.3.2 Idle state

Changing ‘boot state’ to ‘idle state’ takes a time of less than 50 ms.
Presence of ‘idle state’ can be verified by APPL_Get_Operation_Status returning ‘idle state’ (status = 1).

In ‘idle state’ very limited control functionality is available, only specific API commands required for system definition are available here.

‘Idle state’ is identified by

- The I²C bus is active; I²C transmissions are acknowledged by the device.

- The device is in power-down.
- GPIO and digital output pins are ‘open’.
- Reading APPL_Get_Operation_Status will return ‘idle state’ (1).
- The device can receive certain API commands for application definition purposes (APPL_Set_ReferenceClock).
- The device can return certain API status information (APPL_Get_Identification, APPL_Get_Last_Write).
- Command APPL_Activate will bring the device into ‘active state’ = radio standby.

6.3.3 Active state

Changing ‘idle state’ to ‘active state’ takes a time of less than 100 ms.
Presence of ‘active state’ can be verified by APPL_Get_Operation_Status returning the radio standby ‘active state’ (2).

On first activation pin states do not change and the device enters the reduced power state of ‘radio standby’.

The full set of API commands is available now allowing initialization of the different modules including the disabled modules of ‘FM’ and ‘AM’. The operation mode can be completed now by enabling either FM or AM radio operation and releasing the audio mute.

‘Active state’ is identified by

- The I²C bus is active; I²C transmissions are acknowledged by the device.
- The device is in operation (initial operation mode is ‘radio standby’)
- At initial ‘radio standby’ operation the DR and GPIO pins are ‘open’.
- In FM / AM operation the DR and GPIO pins are in their selected FM / AM state (and default state ‘open’ when not initialized).
- In ‘radio standby’ operation, after FM or AM, the DR pins remain in their previous radio state (with invalid data) and GPIO radio features are disconnected (i.e. GPIO pins are ‘open’).
- Reading APPL_Get_Operation_Status will return one of the ‘active’ states; radio standby (2), FM (3) or AM (4).
- The device can handle API commands for all modules for additional initialization and control including disabled modules like FM and/or AM.
- API get commands result in valid read data for enabled modules only.

7. Overview of available commands

Table 1. Command overview - write

	Module	Cmd		1	2	3	4
3.1	FM/AM	1	**Tune_To**	mode	frequency [kHz]		
3.2	FM	2	**Set_Tune_Options**	afu_bw_mode	afu_bandw [kHz]	mute_time [ms]	sample_time [ms]
3.3	FM/AM	10	**Set_Bandwidth**	mode	bandwidth [kHz]	sensitivity [%]	lo_sensitivity [%]
				min_bandwidth	nom._bandwidth	control_attack	
3.4	FM/AM	11	**Set_RFAGC**	start [dBuV]	extension		
3.5	AM	12	**Set_Antenna**	attenuation [dB]			
3.6	AM	14	**Set_CoChannelDet**	mode	restart	sensitivity	count
3.7	FM	20	**Set_MphSuppression**	mode			
3.8	FM	22	**Set_ChannelEqualizer**	mode			
3.9	FM	23	**Set_NoiseBlanker**	mode	sensitivity [%]		modulation
				offset	attack	decay	
3.10	FM	24	**Set_NoiseBlanker_Options**	blank_time	blank_time2	blank_mod.	
3.11	AM	23	**Set_NoiseBlanker**	mode	sensitivity [%]	gain	blank_time
3.12	AM	24	**Set_NoiseBlanker_Audio**	mode	sensitivity [%]		blank_time
3.13	FM/AM	30	**Set_DigitalRadio**	mode			
3.14	FM	31	**Set_Deemphasis**	timeconstant [us]			
3.15	FM	32	**Set_StereoImprovement**	mode			
3.16	FM/AM	38	**Set_LevelStep**	step1 [dB]	step2 [dB]	step3 [dB]	step4 [dB]
				step5 [dB]	step6 [dB]	step7 [dB]	
3.17	FM/AM	39	**Set_LevelOffset**	offset [dB]			
3.18	FM/AM	40	**Set_SoftMute_Time**	slow_attack [ms]	slow_decay [ms]	fast_attack [ms]	fast_decay [ms]
	AM	41	**Set_SoftMute_Mod**	mode	start [mod %]	slope [mod %]	shift [control %]
	FM/AM	42	**Set_SoftMute_Level**	mode	start [dBuV]	slope [dB]	
	FM	43	**Set_SoftMute_Noise**	mode	start [%]	slope [%]	
	FM	44	**Set_SoftMute_Mph**	mode	start [%]	slope [%]	
	FM/AM	45	**Set_SoftMute_Max**	mode	limit [dB]		
3.19	FM/AM	50	**Set_HighCut_Time**	slow_attack [ms]	slow_decay [ms]	fast_attack [ms]	fast_decay [ms]
	FM/AM	51	**Set_HighCut_Mod**	mode	start [mod %]	slope [mod %]	shift [control %]
	FM/AM	52	**Set_HighCut_Level**	mode	start [dBuV]	slope [dB]	

	Module	Cmd		1	2	3	4
	FM	**53**	**Set_HighCut_Noise**	mode	start [%]	slope [%]	
	FM	**54**	**Set_HighCut_Mph**	mode	start [%]	slope [%]	
	FM/AM	**55**	**Set_HighCut_Max**	mode	limit [Hz]		
	FM/AM	**56**	**Set_HighCut_Min**	mode	limit [Hz]		
	FM/AM	**57**	**Set_LowCut_Max**	mode	limit [Hz]		
	FM/AM	**58**	**Set_LowCut_Min**	mode	limit [Hz]		
	FM/AM	**59**	**Set_HighCut_Options**	mode			
3.20	FM	**60**	**Set_Stereo_Time**	slow_attack [ms]	slow_decay [ms]	fast_attack [ms]	fast_decay [ms]
	FM	**61**	**Set_Stereo_Mod**	mode	start [mod %]	slope [mod %]	shift [control %]
	FM	**62**	**Set_Stereo_Level**	mode	start [dBuV]	slope [dB]	
	FM	**63**	**Set_Stereo_Noise**	mode	start [%]	slope [%]	
	FM	**64**	**Set_Stereo_Mph**	mode	start [%]	slope [%]	
	FM	**65**	**Set_Stereo_Max**	mode			
	FM	**66**	**Set_Stereo_Min**	mode	limit [dB]		
3.21	FM	**70**	**Set_StHiBlend_Time**	slow_attack [ms]	slow_decay [ms]	fast_attack [ms]	fast_decay [ms]
	FM	**71**	**Set_StHiBlend_Mod**	mode	start [mod %]	slope [mod %]	shift [control %]
	FM	**72**	**Set_StHiBlend_Level**	mode	start [dBuV]	slope [dB]	
	FM	**73**	**Set_StHiBlend_Noise**	mode	start [%]	slope [%]	
	FM	**74**	**Set_StHiBlend_Mph**	mode	start [%]	slope [%]	
	FM	**75**	**Set_StHiBlend_Max**	mode	limit [Hz]		
	FM	**76**	**Set_StHiBlend_Min**	mode	limit [Hz]		
3.22	FM/AM	**80**	**Set_Scaler**	gain [dB]			
3.23	FM	**81**	**Set_RDS**	mode	restart	interface	
3.24	FM/AM	**82**	**Set_QualityStatus**	mode	interface		
3.25	FM/AM	**83**	**Set_DR_Blend**	mode	in_time [ms]	out_time [ms]	gain [dB]
3.26	FM/AM	**84**	**Set_DR_Options**	samplerate	mode	format	
3.27	FM/AM	**85**	**Set_Specials**	ana_out			
3.28	FM	**86**	**Set_Bandwidth_Options**	modulation [%]			
3.29	FM	**90**	**Set_StBandBlend_Time**	attack	decay		
	FM	**91**	**Set_StBandBlend_Gain**	band1	band2	band3	band4
	FM	**92**	**Set_StBandBlend_Bias**	band1	band2	band3	band4
3.30	AUDIO	**10**	**Set_Volume**	volume [dB]			
3.31	AUDIO	**11**	**Set_Mute**	mode			
3.32	AUDIO	**12**	**Set_Input**	source			
3.33	AUDIO	**13**	**Set_Output_Source**	signal	source		

	Module	Cmd		1	2	3	4
3.34	AUDIO	**21**	**Set_Ana_Out**	signal	mode		
3.35	AUDIO	**22**	**Set_Dig_IO**	signal	mode	format	operation
				samplerate			
3.36	AUDIO	**23**	**Set_Input_Scaler**	source	gain [dB]		
3.37	AUDIO	**24**	**Set_WaveGen**	mode	offset	amplitude1	frequency1
				amplitude2	frequency2		
3.38	APPL	**1**	**Set_OperationMode**	mode			
3.39	APPL	**3**	**Set_GPIO**	pin	module	feature	
3.40	APPL	**4**	**Set_ReferenceClock**	frequency_msb	frequency_lsb	type	
3.41	APPL	**5**	**Activate**	mode			

Table 2. Command overview - read

	Module	Cmd		1	2	3	4
4.1	FM/AM	**128**	**Get_Quality_Status**	status	level	usn / noise	wam / co_channel
				offset	bandwidth	modulation	
	FM/AM	**129**	**Get_Quality_Data**	status	level	usn / noise	wam / co_channel
				offset	bandwidth	modulation	
4.2	FM	**130**	**Get_RDS_Status**	status	a_block	b_block	c_block
				d_block	dec_error		
	FM	**131**	**Get_RDS_Data**	status	a_block	b_block	c_block
				d_block	dec_error		
4.3	FM/AM	**132**	**Get_AGC**	input_att	feedback_att		
4.4	FM/AM	**133**	**Get_Signal_Status**	status (stereo, digital)			
4.5	FM/AM	**134**	**Get_Processing_Status**	softmute	highcut	stereo	sthiblend
				stband_1_2	stband_3_4		
4.6	FM/AM	**135**	**Get_Interface_Status**	samplerate			
4.7	APPL	**128**	**Get_Operation_Status**	status			
4.8	APPL	**129**	**Get_GPIO_Status**	status (pin state)			
4.9	APPL	**130**	**Get_Identification**	device (type, variant)	hw_version (main, sub)	sw_version	
4.10	APPL	**131**	**Get_LastWrite**	size / module	cmd / index	parameter	parameter
				parameter	parameter	parameter	parameter

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9. List of figures

10. List of tables

11. Contents

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