TEF668XA User Manual

Device version /V205

Rev. 1.6 — 18 August 2016 **User Manual**

Document information

Info	Content
Keywords	Lithio, TEF6686A, TEF6687A, TEF6688A, TEF6689A, /V205, firmware 5.00, API, I²C bus, control, car radio
Abstract	Overview of TEF668XA series device control

Revision history

Rev	Date	Description
		'Lithio' TEF6686A, TEF6687A, TEF6688A and TEF6689A, device version V205, user manual Description of the TEF668XA /V205 control interface (API) and related information
1.6	20160818	Changes from Rev. 1.5 indicated by change bar 3.1 extension of FM tuning range to 64 MHz (p5.10) 6.2.1, 6.2.2, 6.2.3 updated V205 required initialization (p5.10) 6.3.4 moved command control state column next to default states
1.5	20160624	6.3.4 new chapter with overview of digital I/O pin mode defaults and control 5.7.1 added FF FBh return code indication of invalid parameter write attempt
1.4	20160414	- FM and AM module commands in separate sections with cross references 3.1.1 added information on End mute and not critical tuning control time 3.26 added description of introduced test option use with audio input select 4 corrected valid read data 4.1.1 added application information on FM quality detector timing and use 4.7.1 added application information on AM quality detector timing and use 4.16, 7 added read information of internal radio sample rate 6.2.1, 6.2.2, 6.2.3 updated V205 required initialization (p5.09) 6.3.2 included GPIO_3 in pin state description
1.2	20151216	3.1.1 added information on band change tuning time 3.17 added optional independent limit setting of FM softmute on noise and multipath 3.25 added current output level selection options 3.26 added note detail 3.53 added current output level selection options 6.2.1, 6.2.2, 6.2.3 updated V205 required initialization (p5.05) 6.3.1, 6.3.2, 6.3.3 description of reset condition for all three operation states 6.3.2, 6.3.3 added details on default pin state and configuration
1.1	20151006	3.8 corrected offset description range and default 6.2.1, 6.2.2, 6.2.3 updated V205 required initialization (p5.02)
1.0	20150910	6.2.1, 6.2.2, 6.2.3 added V205 required initialization (p5.01)
0.6	20150723	Device version V205 Changes from the previous device version V102 user manual Rev 1.8 (= V102 p2.23): - Updated references to V205 (= firmware version 5.00) - Additional changes: 3, 4, 5.2, 5.7.1, 5.7.2 added information on new supported use of command index 3.5 added new FM antenna attenuation control and 'FM-off' input impedance control 3.13, 3.14, 3.18, 7 added new features Set_Highcut_Fix and Set_Lowcut_Fix 3.22 added new option of RDS data buffer flush 3.22, 4.2.1 added new feature of FM FULL SEARCH extended RDS reception

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Revision history

Rev	Date	Description
		3.25 added new current output (‘virtual ground’) option for DR signal pins
		3.53 added new current output (‘virtual ground’) option for audio I^2S signal pins
		3.57, 4.13 added new GPIO 3 (with limitation note on audio I^2S use case)
		3.58, 5.1 added new 55.46667 MHz crystal option (requires pull-up application)
		3.58 removed restriction on 4 MHz crystal use; now also available for digital radio
		4.14 adapted version identification to V205
		6.2.1, 6.2.2, 6.2.3 initialization sequence example and list of new features for V205
		7 separated command overview of FM and AM module

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1. Introduction

TEF668XA ('Lithio') is a series of unparalleled single-chip car radio devices with an upper mainstream to high-end performance and feature set. The Lithio series consists of four variants; TEF6686A, TEF6687A, TEF6688A and TEF6689A.

All Lithio variants offer worldwide FM band reception as well as full AM band reception up to 27 MHz. In addition to the TEF6686A feature set the variants TEF6687A and TEF6689A (Lithio FMSI and Lithio FMSI DR) offer the added performance of extended FM stereo reception and the new improved 'FULL SEARCH' RDS data reception. The variants TEF6688A and TEF6689A (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 TEF668XA 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 TEF668XA device version V205 specifically (TEF668XA/V205).

2. Control interface

2.1 Overview

The TEF668XA 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.

TEF668XA 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 TEF668XA interface definition is compatible also with the TEF665XA (Atomic-2) and TEF701XA (Sabre) series of devices, although differing in available commands reflecting the available functionality. The interface is compatible with the TEA685XA (Tiger-2) series as well.

The API template of TEF668XA and compatible devices will be used in future NXP car-radio developments also, offering familiar control with an additional variation in supported functions and features.

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

TEF668XA control is organized in modules. Modules are independent functional blocks that can be regarded sub-devices within the main device.

The TEF668XA 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 allows modules to be prepared and initialized before use.

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

Module commands contain parameters for control of behavior and option selections.

The control is organized in such a way that devices can support writing of a single parameter up to writing of all parameters available for a given command.

Device version V205 does indeed offer this flexibility and allows writing of a specific parameter or a range of parameters.

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 TEF668XA. 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 TEF668XA will realize the nearest available setting.

Fig 1 represents the TEF668XA control interface as seen from the host controller.

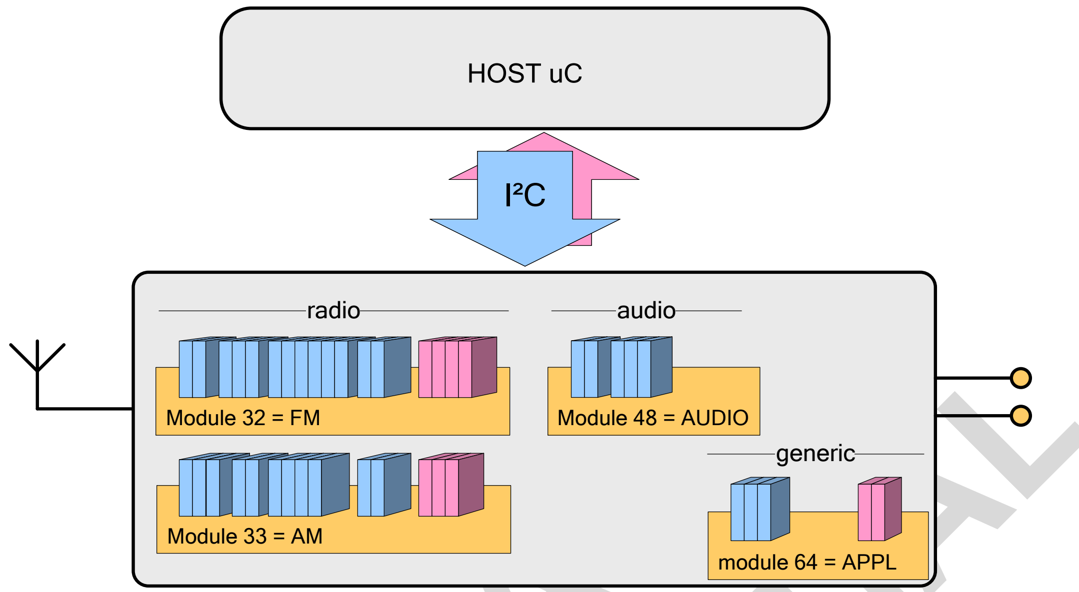


Fig 1. I²C control – TEF668XA

2.2 Background

The control interface of the TEF668XA is characterized by the following benefits:

- 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 very detailed parameter setting and allows for range extension where needed in the future.
- Reduced control effort: As available from device version V205 the interface allows for single parameter manipulation simplifying user control software.

Although no direct compatibility is present it can be noted that the TEF668XA command interface shares most of its API functionality with products like TEF663X (Hero), TEF664X (Helio) and SAF775X (DiRaNA3). A translation from this generation API style radio control to the TEF668XA 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. A write transmission 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 as sub-devices. Available modules in the TEF668XA 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 allows for writing of a certain specific parameter or parameter range out of the available command parameters.

Device version V205 fully supports the use of index parameter addressing.
(Note previous versions V102 and V101 required index = 1 and all documented command parameters to be transmitted.)

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 cmd 1 Tune_To

Tuning within the FM radio band.

The command can also be executed when the FM module is disabled (i.e. with the device in radio-standby mode or AM mode operation). In this case the operation mode is changed to FM mode first before the actual tuning is performed.

module	32	FM		
cmd	**1**	**Tune_To**	mode, frequency	
index	1	mode [15:0]	tuning actions	
			1 = Preset	Tune to new program with short mute time Enable FM radio where applicable
			2 = Search	Tune to new program and stay muted Enable FM radio where applicable
			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
			7 = End	Release the mute of a Search or Check action (frequency is not required and ignored)
	2	frequency [15:0]	tuning frequency	
			6400 … 10800	64.00 … 108.00 MHz / 10 kHz step size

Application example	FM_Tune_To (1, 1, 8930)	Preset tuning to FM 89.3 MHz
	FM_Tune_To (1, 2, 10790)	Search tuning to FM 107.9 MHz
	FM_Tune_To (1, 7)	End (release mute of FM Search action)
I²C example (hex)	[w 20 **01** 01 0001 22E2]	Preset tuning to FM 89.3 MHz
	[w 20 **01** 01 0002 2A26]	Search tuning to FM 107.9 MHz
	[w 20 **01** 01 0007]	End (release mute of FM Search action)

For AM operation see chapter 3.29 AM cmd 1 Tune_To.

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 the TEF668XA tuning. The set of tuning actions offered by TEF668XA 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 can 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, Preset, 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 available quality possible, therefore time constants of the weak signal handling are controlled for fast settling to the new signal conditions within a small preset mute time of approx. 32 ms for FM bands.

mode = 2, Search:

mode = 2, Search, 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 FM Preset or FM Search will disable ‘radio standby’ or ‘AM’ operation and enable FM module operation.

Because of the initialization and signal settling required at band enabling the tuning time is extended by max. 15 ms when switching to FM module operation.

mode = 3, AF_Update:

mode = 3, AF_Update, 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 inaudible 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, Jump, 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 is assumed that the new frequency indeed contains the same program. Should it later be found this is not the case (e.g. from 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, Check, 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, End, 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.

An End action can be transmitted after a Search action at any time, Search mute remains for a minimum time of approx. 32 ms (i.e. equal to a Preset mute) or any longer time as defined by the End action.

An End action can be transmitted after a Check action at any time, Check mute remains for a minimum time of approx. 16 ms or any longer time as defined by the End action.

A tuning action can be interrupted by a new tuning action at any time, the new tuning action will start instantly.

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 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	FM	
cmd	**10**	**Set_Bandwidth**	mode, bandwidth, control_sensitivity, low_level_sensitivity, min_bandwidth, nominal_bandwidth, control_attack
index	1	mode [15:0]	IF bandwidth control mode
			0 = fixed
			1 = automatic (default)
	2	bandwidth [15:0]	fixed IF bandwidth
			560 … 3110 [*0.1 kHz] = IF bandwidth 56 … 311 kHz; narrow … wide 2360 = 236 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
	FM_Set_Bandwidth (1, 0, 2360, 1000, 1000)	with bandwidth = fixed 236 kHz
	FM_Set_Bandwidth (1, 1, 2360, 800, 1000)	with control_sensitivity = 80 %
	FM_Set_Bandwidth (4, 800)	low_level sensitivity = 80 % (indexed)
I²C example (hex)	[w 20 **0A** 01 0001 0938 03E8 03E8]	Standard parameters with FM default
	[w 20 **0A** 01 0000 0938 03E8 03E8]	with bandwidth = fixed 236 kHz
	[w 20 **0A** 01 0001 0938 0320 03E8]	with control_sensitivity = 80 %
	[w 20 **0A** 04 0320]	low_level sensitivity = 80 % (indexed)

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.

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.

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.

Modulation boost control is available from 3.27 FM cmd 86 Set_Bandwidth_Options.

For AM operation see chapter 3.30 AM cmd 10 Set_Bandwidth.

3.4 FM 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	FM	
cmd	**11**	**Set_RFAGC**	start, extension
index	1		RF AGC start
			840 … 920 [*0.1 dBµV) = 84 … 92 dBµV 920 = 92 dBµV (default)
	2	extension [15:0]	RF AGC step extension
			0 = integrated steps only (default)
			1 = AGC step extension from control output (GPIO feature ‘AGC’)

Application example	FM_Set_RFAGC (1, 890, 0)	FM RF AGC start at 89 dBµV, no ext.
I²C example (hex)	[w 20 **0B** 01 037A 0000]	FM RF AGC start at 89 dBµV, no ext.

Note: FM RF AGC step extension requires additional GPIO pin assignment; see 3.57 Set_GPIO APPL cmd = 3.

For AM operation see chapter 3.31 AM cmd 11 Set_RFAGC.

3.5 FM cmd 12 Set_Antenna

Antenna signal attenuation control (RF AGC minimum limit).

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

module	32	FM	
cmd	**12**	**Set_Antenna**	attenuation, off_mode
index	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)
	2	off_mode [15:0]	FM LNA attenuation setting used during FM off
			300 = 30 dB attenuation; FM LNA input impedance is medium
			420 = 42 dB attenuation; FM LNA input impedance is low (default)

Application example	FM_Set_Antenna (1, 60)	FM 6 dB antenna attenuation
	FM_Set_Antenna (2, 300)	FM medium imp. when ‘off’ (indexed)
I²C example (hex)	[w 20 **0C** 01 003C]	FM 6 dB antenna attenuation
	[w 20 **0C** 02 012C]	FM medium imp. when ‘off’ (indexed)

Note: parameter ‘attenuation’ can realize a certain amount of antenna signal attenuation by limitation of the minimum AGC setting. This function is not for general FM use.

Note: FM command parameter ‘off_mode’ can set a higher than default FM input impedance when FM reception is disabled (i.e. radio-standby or AM operation). This function is primarily intended for multi-tuner applications with shared antenna to avoid FM antenna signal attenuation at the other tuner.

For AM operation see chapter 3.32 AM cmd 12 Set_Antenna.

3.6 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.

3.7 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

3.8 FM cmd 23 Set_NoiseBlanker

Noise blanker option and sensitivity settings.

module	32	FM	
cmd	**23**	**Set_NoiseBlanker**	mode, sensitivity, level_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	level_sensitivity [15:0]	trigger sensitivity on level detection
			500 … 1500 [*0.1 %] = 50 … 150 % relative trigger sensitivity 1000 = 100 % (default)
	4	modulation [15:0]	extended API: modulation dependency on trigger sensitivity
			330 … 1660 [*0.1 %] = 33 … 166 % modulation (= 25 … 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 1250 = 125 % (default)
	5	offset [15:0]	extended API: sensitivity offset
			25 … 200 [*0.1 %] = 2.5 … 20 % fixed sensitivity threshold Pulse detection offset; prevent false triggering in good signal conditions 80 = 8 % (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 900 = 900 µs (default)
	7	decay [15:0]	extended API: trigger reference decay time
			150 … 6000 [*1 µs] = 150 µs … 6 ms Decay time of noise average filter used as reference for pulse detection 900 = 900 µs (default)

Application example	FM_Set_NoiseBlanker (1, 1, 1000, 1000)	FM default values
	FM_Set_NoiseBlanker (1, 1, 1000, 1000, 1250, 80, 900, 900)	defaults extended API
I²C example (hex)	[w 20 **17** 01 0001 03E8 03E8]	FM default values
	[w 20 **17** 01 0001 03E8 03E8 04E2 0050 0384 0384]	defaults extended API

Note: Extended API control parameters 4 to 7 are available for additional performance tuning. Change of 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: Extended API control parameters 4 to 7 are incompatible with version V102 (p2.21 and later) and different defaults and ranges apply. Re-use of V102 values is not possible and will cause sub-standard performance.

For AM operation see chapter 3.34 AM cmd 23 Set_NoiseBlanker.

3.9 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, blank_time_level
index	1	blank_time [15:0]	noise blanker blank time on low modulation 75 … 300 [*1 µs] = 75 … 300 µs 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 225 = 225 µs (default)
	2	blank_time2 [15:0]	noise blanker blank time on high modulation 75 … 300 [*1 µs] = 75 … 300 µs pulse stretch time Blank time for high modulation; compared to parameter 'blank time' an equal or smaller value is suggested optimized for modulation fidelity 112 = 112 µs (default)
	3	blank_modulation [15:0]	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)
	4	blank_time_level [15:0]	noise blanker blank time on level detection 100 … 400 [*1 µs] = 100 … 400 µs pulse stretch time 225 = 225 µs (default)

Application example	FM_Set_NoiseBlanker_Options (1, 225, 112, 250, 225)	Extended API default values
I²C example (hex)	[w 20 **18** 01 00E1 0070 00FA 00E1]	Extended API default values

Note: Extended API control as available from this command 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: Extended API control defaults differ from version V102 (p2.21 or later) and are new advised values. Re-use of V102 values is not suggested for optimal performance.

3.10 FM cmd 30 Set_DigitalRadio

Available for TEF6688A and TEF6689A only.

Enabling of I/O signal lines for external digital radio processor; DR I²S output and DR Blend input (enabling DR audio input from I2S_SD_0).

Note: See 3.25 FM cmd 84 Set_DR_Options for additional digital radio options.

module	32	FM	
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
I²C example (hex)	[w 20 **1E** 01 0001]	Enable digital radio for FM use

For AM operation see chapter 3.36 AM cmd 30 Set_DigitalRadio.

3.11 FM cmd 31 Set_Deemphasis

Selection of FM de-emphasis time constant

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

Application example FM_Set_Deemphasis (1, 750) 75 μs de-emphasis

I²C example (hex) `[ w 20 1F 01 02EE ]` 75 μs de-emphasis

3.12 FM cmd 32 Set_StereoImprovement

Available for TEF6687A and TEF6689A 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 used during enabled 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 enabled FMSI signal processing.

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

Note: The advised setting is ‘FMSI’ for improved field performance with extended stereo reception.

3.13 FM cmd 33 Set_Highcut_Fix

module	32	FM	
cmd	**33**	**Set_Highcut_Fix**	mode, limit
index	1	mode [15:0]	independent audio low-pass filter
			0 = off; high audio frequency bandwidth is not limited (default)
			1 = on; high audio frequencies are attenuated by 1st order ‘IIR’ low-pass
	2	limit [15:0]	fixed highcut attenuation
			1000 … 15000 [*1 Hz] = 1.0 … 15 kHz -3 dB att. for fixed highcut filter 10000 =10 kHz (FM default)

Application example	FM_Set_Highcut_Fix (1, 1, 10000)	FM 10 kHz fixed highcut attenuation
I²C example (hex)	[w 20 **21** 01 0001 2710]	FM 10 kHz fixed highcut attenuation

Note: A desired fixed highcut action is already available by limitation of the dynamic highcut control range from FM cmd 56 Set_Highcut_Min (3.18). Set_Highcut_Fix allows for an additional and independent fixed filter of first order ‘IIR’ low-pass type.

3.14 FM cmd 34 Set_Lowcut_Fix

module	32	FM	
cmd	**34**	**Set_Lowcut_Fix**	mode, limit
index	1	mode [15:0]	independent audio high-pass filter
			0 = off; low audio frequency bandwidth is not limited (default)
			1 = on; low audio frequencies are attenuated by 1st order ‘IIR’ high-pass
	2	limit [15:0]	fixed lowcut attenuation
			20 … 200 [*1 Hz] = 20 … 200 Hz -3 dB attenuation for fixed lowcut filter 30 =30 Hz (FM default)

Application example	FM_Set_Lowcut_Fix (1, 1, 20)	FM 20 Hz fixed lowcut attenuation
I²C example (hex)	[w 20 **22** 01 0001 0014]	FM 20 Hz fixed lowcut attenuation

Note: A desired fixed lowcut action is already available by limitation of the dynamic lowcut control range from FM cmd 58 Set_Lowcut_Min (3.18). Set_Lowcut_Fix allows for an additional and independent fixed filter of first order ‘IIR’ high-pass type.

For AM operation see chapters 3.37 AM cmd 33 Set_Highcut_Fix and 3.38 AM cmd 34 Set_Lowcut_Fix.

3.15 FM 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 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	FM	
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)
	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)
	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)
	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)
	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)
	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	FM_Set_LevelStep (1, 0, 0, -10, -20, -30, -40, -50)	FM increased level extension
	FM_Set_LevelStep (1, -10, -20, -30, -40, -50, -60, -60)	FM decreased level extension
I²C example (hex)	[w 20 **26** 01 0000 0000 FFF6 FFEC FFE2 FFD8 FFCE]	FM increased level extension
	[w 20 **26** 01 FFF6 FFEC FFE2 FFD8 FFCE FFC4 FFC4]	FM 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 number of feedback and input AGC steps. AGC steps higher than step 7 will employ the step 7 setting.

For AM operation see chapter 3.39 AM cmd 38 Set_LevelStep.

3.16 FM 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 cmd 128 / 129 Get_Quality). A standard use case is the compensation for an FM active antenna circuit.

module	32	FM	
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	FM_Set_LevelOffset (1, -60)	-6 dB level correction
I²C example (hex)	[w 20 **27** 01 FFC4]	-6 dB level correction

For AM operation see chapter 3.40 AM cmd 39 Set_LevelOffset.

3.17 FM 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_Level' sets the level sensitivity and enables slow and fast timing.

'Set_Softmute_Noise' sets the noise sensitivity with slow and fast timing and optional independent setting of the maximum amount of softmute attenuation.

'Set_Softmute_Mph' sets the multipath sensitivity with slow and fast timing and optional independent setting of the maximum amount of softmute attenuation.

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

For AM operation see chapter 3.41 AM cmd 40 … 45 Set_Softmute.

module	32	FM	
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)
	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)

Application example	FM_Set_Softmute_Time (1, 120, 500, 10, 20)	Slow 120 / 500 ms, fast 1 / 2 ms
I²C example (hex)	`[ w 20 28 01 0078 01F4 000A 0014 ]`	Slow 120 / 500 ms, fast 1 / 2 ms

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

module	32	FM	
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)
	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)

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 [15:0]	FM weak signal handling noise range
			100 … 1000 [*0.1 %] = control over range of 10… 100% of USN detector 1000 = 100% (default)
	4	limit_mode [15:0]	FM softmute on noise dynamic attenuation limit mode
			0 = generic limit set by FM cmd 45 Set_Softmute_Max (default)
			1 = independent limit set by parameter 5
	5	limit [15:0]	FM softmute on noise dynamic attenuation limit
			0 …. 400 [*0.1 dB] = 0 … 40 dB softmute maximum attenuation 60 = 6 dB (default)

Note: Setting limit_mode = 1 allows for an independent limit setting defining the maximum amount of softmute attenuation controlled by FM noise detection (USN). For proper softmute on noise function an independent limit setting shall be selected equal or smaller than the FM cmd 45 Set_Softmute_Max limit value.

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)
	4	limit_mode [15:0]	FM softmute on multipath dynamic attenuation limit mode
			0 = generic limit set by FM cmd 45 Set_Softmute_Max (default)
			1 = independent limit set by parameter 5
	5	limit [15:0]	FM softmute on multipath dynamic attenuation limit
			0 …. 400 [*0.1 dB] = 0 … 40 dB softmute maximum attenuation 60 = 6 dB (default)

Note: Setting limit_mode = 1 allows for an independent limit setting defining the maximum amount of softmute attenuation controlled by FM multipath detection (WAM). For proper softmute on multipath function an independent limit setting shall be selected equal or smaller than the FM cmd 45 Set_Softmute_Max limit value.

module	32	FM	
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)

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

3.18 FM cmd 50 … 59 Set_Highcut

Timing and quality sensitivity settings for the Highcut and Lowcut 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

'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.

For AM operation see chapter 3.42 AM cmd 50 … 58 Set_Highcut.

module	32	FM	
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)
	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)

Application example FM_Set_Highcut_Time (1, 200, 500, 10, 80) Slow 200 / 500 ms, fast 1 / 8 ms

I²C example (hex) `[ w 20 32 01 00C8 01F4 000A 0050 ]` Slow 200 / 500 ms, fast 1 / 8 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	FM	
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	FM	
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
			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)
	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)

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	FM	
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
			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 'de-emphasis' mode (Options '2')
			2700 … 7000 [*1 Hz] = 2.7 … 7 kHz 'FIR' highcut filter (Options '3')

Application example FM_Set_Highcut_Max (1, 1, 2400) FM 2.4 kHz max. Highcut attenuation

I²C example (hex) `[ w 20 37 01 0001 0960 ]` FM 2.4 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	FM	
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
	2	limit [15:0]	Highcut fixed attenuation limit
			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 'de-emphasis' (Options '2') 2122 = 75 μs de-emphasis / 3183 = 50 μs de-emphasis
			2700 … 15000 [*1 Hz] = 2.7 … 15 kHz 'FIR' highcut filter (Options '3')

Application example FM_Set_Highcut_Min (1, 1, 10000) FM 10 kHz min. Highcut attenuation

I²C example (hex) `[ w 20 38 01 0001 2710 ]` FM 10 kHz min. Highcut attenuation

Note: Limitation of the dynamic highcut control range as available from this command is best suited to define a desired 'fixed' highcut characteristic. An independent fixed filter of first order 'IIR' low-pass type is available from FM cmd 33 Set_Highcut_Fix.

Note: If characteristic 'de-emphasis' is selected from FM cmd 59 Set_Highcut_Options mode = 2, the FM cmd 31 Set_Deemphasis setting is ignored. Instead a de-emphasis definition is required by FM_Set_Highcut_Min of either mode = 1, limit = 2122 for 75 µs de-emphasis or mode = 1, limit = 3183 for 50 µs de-emphasis.

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	FM	
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
I²C example (hex)	`[ w 20 39 01 0001 0064 ]`	FM 100 Hz max. Lowcut attenuation

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

module	32	FM	
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
	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
I²C example (hex)	`[ w 20 3A 01 0001 000A ]`	FM 10 Hz min. Lowcut attenuation

Note: Limitation of the dynamic lowcut control range as available from this command is best suited to define a desired 'fixed' lowcut characteristic. An independent fixed filter of first order 'IIR' high-pass type is available from FM cmd 34 Set_Lowcut_Fix.

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 low-pass filter with controlled frequency (default)
			2 = de-emphasis; controlled frequency of the 50 / 75 μs de-emphasis filter
			3 = FIR; 'digital' high order low-pass filter with controlled frequency

Application example	FM_Set_Highcut_Options (1, 2)	FM 'de-emphasis' type Highcut control
I²C example (hex)	[w 20 **3B** 01 0002]	FM 'de-emphasis' 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 'de-emphasis' characteristics the FM cmd 31 Set_Deemphasis setting is ignored and the de-emphasis function requires a selection of 50 μs or 75 μs de-emphasis by FM_Set_Highcut_Min instead.

3.19 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)

Note: Set_Stereo_Level start settings are allowed to be selected as low as 0 dBμV in order to reduce the Stereo weak signal handling as may be desired for FMSI operation (3.12 FM cmd 32 Set_StereoImprovement).

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: Set_Stereo_Max mode 'off' is not suitable to disable Stereo handling as may be desired for FMSI operation (3.12 FM cmd 32   Set_StereoImprovement).
Setting mode 'off' at commands _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

3.20 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).

Employment of the FMSI 'FM stereo improvement' feature is suggested instead for the variants TEF6687A and TEF6689A realizing extended stereo performance. Stereo high blend is disabled in this case and FM Set_StHiBlend command settings are don't care.

See 3.12 FM cmd 32 Set_StereoImprovement.

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 [15:0]	weak signal handling modulation start
			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.

3.21 FM cmd 80 Set_Scaler

Fine tuning of FM sound amplitude for matching with AM analog radio sound.

module	32	FM	
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 digital radio sound amplitude see 3.24 FM cmd 83 Set_DR_Blend.

For AM operation see chapter 3.43 AM cmd 80 Set_Scaler.

3.22 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
			3 = 'FULL SEARCH' decoder mode; extended sensitivity RDS reception (for TEF6687A and TEF6689A only) standard mode = 1 compatible output of RDS group data (block A, B, C, D) 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 = flush; empty RDS output buffer (but maintain RDS synchronization)
	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.

RDS mode = 3 'FULL SEARCH' enables a special RDS demodulator and decoder system for improved RDS sensitivity reception. 'FULL SEARCH' is an optimized RDS channel decoder system utilizing soft decision and soft error detection techniques to achieve an improvement of RDS sensitivity at equal or better quality of output data. 'FULL SEARCH' RDS reception is available for TEF6687A and TEF6689A only.

Note: The restart parameter settings of 'manual restart' and 'flush' automatically return to the original restart setting of 'automatic restart' and 'no control'.

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 (interface = 4) is for legacy use only and is not suggested for new designs. For pin signals a GPIO pin assignment is required; see 3.57 APPL cmd 3 Set_GPIO.

3.23 FM cmd 82 Set_QualityStatus

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

module	32	FM	
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 3.57 APPL cmd 3 Set_GPIO.
Note: the mode parameter timer setting is rounded to 1 ms step size.

For AM operation see chapter 3.44 AM cmd 82 Set_QualityStatus.

3.24 FM cmd 83 Set_DR_Blend

Available for TEF6688A and TEF6689A only.

Control of digital radio blend functionality and digital radio scaler.

module	32	FM	
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: radio blend is functional only when digital radio is enabled (see 3.10 FM cmd 30 Set_DigitalRadio) and radio is selected as an audio input source (see 3.50 AUDIO cmd 12 Set_Input).

For AM operation see chapter 3.45 AM cmd 83 Set_DR_Blend.

3.25 FM cmd 84 Set_DR_Options

For TEF6688A and TEF6689A only.

Control of digital radio I/O functionality. Note: DR output is functional only when digital radio is enabled (see 3.10 FM cmd 30 Set_DigitalRadio).

module	32	FM		
cmd	**84**	**Set_DR_Options**	samplerate, mode, format	
index	1	samplerate [15:0]	baseband digital radio sample rate (DR I^{2}S 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 = voltage output (default)
				51 = current output (‘virtual ground’) 20 * I_0
				187 … 255 = current output level selection: [15:12] = 11 … 15 = BCK 6 … 31 * I_0 [11:8] = 11 … 15 = WS 6 … 31 * I_0
			[7:0] =	Data pin(s) mode
				2 = voltage output
				3 = current output (‘virtual ground’) 20 * I_0
				4 = open drain (‘pull down’) (default)
				11 … 15 = current output level selection 6 … 31 * I_0
	3	format [15:0]	baseband digital radio format select	
			16 = I^{2}S 16 bit, ‘3 wire’ interface with single I/Q signal line (DR_I_DATA) (f_{DR_BCK} = 32 * sample rate)	
			4112 = I^{2}S 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: The mode parameter defaults equal application of device versions V101 and V102, however wherever applicable the use of ‘virtual ground’ current output mode is advised.

Note: samplerate parameter setting changes are not executed immediately but delayed until the next Preset, Search, Check or Jump tuning action.

Note: The mode parameter current output level selection settings allow for alternative values of output current for BCK, WS and data pin signals:

mode [15:12] = 11 / 12 / 13 / 14 / 15 = BCK pin output current 6 / 10 / 15 / 20 / 31 * I_0
mode [11:8] = 11 / 12 / 13 / 14 / 15 = WS pin output current 6 / 10 / 15 / 20 / 31 * I_0
mode [7:0] = 11 / 12 / 13 / 14 / 15 = Data pin output current 6 / 10 / 15 / 20 / 31 * I_0
(typical current unit value I_0 = 22 uA).

The standard current value of 20 * I_0 may drive up to three virtual ground inputs in parallel with at least 6* I_0 input current each (employing resistors for current splitting). For applications where signal lines drive one or two virtual ground inputs lower current settings are advised for reduced crosstalk.

Note: For (digital radio) audio I/O see 3.53 AUDIO cmd 22 Set_Dig_IO; signal = 32.

For AM operation see chapter 3.46 AM cmd 84 Set_DR_Options.

3.26 FM cmd 85 Set_Specials

Special radio options for evaluation and extended application use.

module	32	FM	
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
I^{2}C 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, available for FM operation only. FM stereo signal remains available from the digital audio I2S output (I2S_SD_1). Audio input selection of an external source will show mono output of the selected source on DAC_R while maintaining FM MPX on DAC_L. 'Wave generator' selection is however not supported in this mode.

Note: setting ana_out = 2 requires an audio input selection of 'radio' and acts on both the DAC and the digital audio I^{2}S output. DAC source selection or I^{2}S output source selection override this digital radio test option for the respective output pins.

(Note: previous version limitations are resolved and digital radio gain scaling is included.)

For AM operation see chapter 3.47 AM cmd 85 Set_Specials.

3.27 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 see 3.3 FM cmd 10 Set_Bandwidth.

3.28 FM cmd 90 … 92 Set_StereoBandBlend

For TEF6687A and TEF6689A 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		control sensitivity for high frequency audio band

band4 [15:0]	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 -72 = -7.2% (default)
	2	band2 [15:0] signed	control bias for audio band around 2 kHz -250 … +250 [*0.1 %] = -25% … +25% stereo … mono bias -32 = -3.2% (default)
	3	band3 [15:0] signed	control bias for audio band around 5 kHz -250 … +250 [*0.1 %] = -25% … +25% stereo … mono bias -24 = -2.4% (default)
	4	band4 [15:0] signed	control bias for high frequency audio band -250 … +250 [*0.1 %] = -25% … +25% stereo … mono bias -24 = -2.4% (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.

3.29 AM cmd 1 Tune_To

Tuning within the AM radio band.

The command can also be executed when the AM module is disabled (i.e. with the device in radio-standby mode or FM mode operation). In this case the operation mode is changed to AM mode first before the actual tuning is performed.

module	33	AM		
cmd	**1**	**Tune_To**	mode, frequency	
index	1	mode [15:0]	tuning actions	
			1 = Preset	Tune to new program with short mute time Enable AM radio where applicable
			2 = Search	Tune to new program and stay muted Enable AM radio where applicable
			7 = End	Release the mute of a Search action (frequency is not required and ignored)
	2	frequency [15:0]	tuning frequency	
			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

AM_Tune_To (1, 1, 1008)	Preset tuning to AM 1008 MHz
AM_Tune_To (1, 2, 990)	Search tuning to AM 990 kHz
AM_Tune_To (1, 7)	End (release mute of AM Search action)

I²C example (hex)

[w 21 **01** 01 0001 03F0]	Preset tuning to AM 1008 MHz
[w 21 **01** 01 0002 03DE]	Search tuning to AM 990 kHz
[w 21 **01** 01 0007]	End (release mute of AM Search action)

For FM operation see 3.1 FM cmd 1 Tune_To

3.29.1 radio tuning actions with setting of band and frequency

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

The AM 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 the TEF668XA tuning. The set of tuning actions offered by TEF668XA 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 can realize a single basic routine by themselves.

A total of three mode tuning actions are defined for different types of AM 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 available 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. 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.

Preset and Search tuning also allows for band switching to AM. An AM Preset or AM Search action will disable 'radio standby' or 'FM' operation and enable AM module operation.

Because of the initialization and signal settling required at band enabling the tuning time is extended by max. 15 ms when switching to AM module operation.

mode = 7, End:

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

3.30 AM cmd 10 Set_Bandwidth

Fixed bandwidth selection of the radio selectivity filter.

module	33	AM		
cmd	**10**	**Set_Bandwidth**	mode, bandwidth	
index	1	mode [15:0]	IF bandwidth control mode 0 = fixed (default)	
	2	bandwidth [15:0]	fixed IF bandwidth 30 … 80 [*0.1 kHz] = IF bandwidth 3 … 8 kHz; narrow … wide 40 = 4.0 kHz (default)	

Application example	AM_Set_Bandwidth (1, 0, 40)	default IF bandwidth 4 kHz
	AM_Set_Bandwidth (1, 0, 60)	IF bandwidth 6 kHz
I²C example (hex)	[w 21 **0A** 01 0000 0028]	default IF bandwidth 4 kHz
	[w 21 **0A** 01 0000 003C]	IF bandwidth 6 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.

For FM operation see 3.3 FM cmd 10 Set_Bandwidth.

3.31 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).

module	33	AM	
cmd	**11**	**Set_RFAGC**	start
index	1	start [15:0]	RF AGC start
			940 … 1020 (*0.1 dBµV) = 94 … 102 dBµV 1000 = 100 dBµV (default)

Application example	AM_Set_RFAGC (1, 970)	AM RF AGC start at 97 dBµV
I²C example (hex)	[w 21 **0B** 01 03CA]	AM RF AGC start at 97 dBµV

For FM operation see 3.4 FM cmd 11 Set_RFAGC.

3.32 AM cmd 12 Set_Antenna

Antenna signal attenuation control (RF AGC minimum limit).

In case of an 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

Note: parameter ‘attenuation’ can realize a certain amount of antenna signal attenuation by limitation of the minimum AGC setting. This function is primarily intended for AM active antenna applications to avoid unnecessary AGC control during ‘normal’ signal level conditions.

For FM operation see 3.5 FM cmd 12 Set_Antenna.

3.33 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 cmd 128 / 129 Get_Quality for co-channel detection read.

3.34 AM cmd 23 Set_NoiseBlanker

Noise blanker option and sensitivity settings.

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 µs pulse stretch time Blanker pulse extension time 56 = 56 µs (default)

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

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.

For FM operation see chapter 3.8 FM cmd 23 Set_NoiseBlanker.

3.35 AM cmd 24 Set_NoiseBlanker_Audio

AM Audio noise blanker option 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	extended API; AM noise blanker time
			400 … 1200 [*1 µs] = 400 … 1200 µs 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, 1200)	sensitivity 120%; more suppression
	AM_Set_NoiseBlanker_Audio (1, 1, 1000, 0, 80)	AM defaults with extended API

I²C example (hex)		
	[w 21 18 01 0001 03E8]	AM default values
	[w 21 18 01 0001 04B0]	sensitivity 120%; more suppression
	[w 21 18 01 0001 03E8 0000 0320]	AM defaults with extended API

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.

3.36 AM cmd 30 Set_DigitalRadio

Available for TEF6688A and TEF6689A only.

Enabling of I/O signal lines for external digital radio processor; DR I²S output and DR Blend input (enabling DR audio input from I2S_SD_0).

Note: See 3.46 AM cmd 84 Set_DR_Options for additional digital radio options.

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

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

For FM operation see chapter 3.10 FM cmd 30 Set_DigitalRadio.

3.37 AM cmd 33 Set_Highcut_Fix

module	33	AM	
cmd	**33**	**Set_Highcut_Fix**	mode, limit
index	1	mode [15:0]	independent audio low-pass filter
			0 = off; high audio frequency bandwidth is not limited (default)
			1 = on; high audio frequencies are attenuated by 1st order ‘IIR’ low-pass
	2	limit [15:0]	fixed highcut attenuation
			1000 … 15000 [*1 Hz] = 1.0 … 15 kHz -3 dB att. for fixed highcut filter 3000 = 3 kHz (AM default)

Application example AM_Set_Highcut_Fix (1, 1, 3000) AM 3 kHz fixed highcut attenuation

I²C example (hex) `[ w 21 21 01 0001 0BB8 ]` AM 3 kHz fixed highcut attenuation

Note: A desired fixed highcut action is already available by limitation of the dynamic highcut control range from AM cmd 56 Set_Highcut_Min (3.42). Set_Highcut_Fix allows for an additional and independent fixed filter of first order ‘IIR’ low-pass type.

3.38 AM cmd 34 Set_Lowcut_Fix

module	33	AM	
cmd	**34**	**Set_Lowcut_Fix**	mode, limit
index	1	mode [15:0]	independent audio high-pass filter
			0 = off; low audio frequency bandwidth is not limited (default)
			1 = on; low audio frequencies are attenuated by 1st order ‘IIR’ high-pass
	2	limit [15:0]	fixed lowcut attenuation
			20 … 200 [*1 Hz] = 20 … 200 Hz -3 dB attenuation for fixed lowcut filter 100 = 100 Hz (AM default)

Application example AM_Set_Lowcut_Fix (1, 1, 100) AM 100 Hz fixed lowcut attenuation

I²C example (hex) `[ w 21 22 01 0001 0064 ]` AM 100 Hz fixed lowcut attenuation

Note: A desired fixed lowcut action is already available by limitation of the dynamic lowcut control range from AM cmd 58 Set_Lowcut_Min (3.42). Set_Lowcut_Fix allows for an additional and independent fixed filter of first order ‘IIR’ high-pass type.

For FM operation see chapter 3.13 FM cmd 33 Set_Highcut_Fix and 3.14.FM cmd 34 Set_Lowcut_Fix

3.39 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 (4.7 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	33	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 -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 -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 -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 -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 -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 (and 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 number of feedback and input AGC steps. AGC steps higher than step 7 will employ the step 7 setting.

For FM operation see chapter 3.15 FM cmd 38 Set_LevelStep.

3.40 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 (4.7 AM cmd 128 / 129 Get_Quality). A standard use case is the compensation for AM active antenna circuits (typical offset setting = -30 dB).

module	33	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

For FM operation see chapter 3.16 FM cmd 39 Set_LevelOffset.

3.41 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. Fast and slow response times are available for dual timer functionality, with enable options at the level command.

'Set_Softmute_Mod' enables modulation dependency and sets sensitivity.

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

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

For FM operation see chapter 3.17 FM cmd 40 … 45 Set_Softmute.

module	33	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 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 500 = 50 ms (AM default)

Application example AM_Set_Softmute_Time (1, 500, 4000, 100, 500) Slow 500 / 4000 ms, fast 10 / 50 ms

I²C example (hex) `[ w 21 28 01 01F4 0FA0 0064 01F4 ]` Slow 500 / 4000 ms, fast 10 / 50 ms

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	33	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 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 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	33	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 250 = 25 dB (AM default)

Application example	AM_Set_Softmute_Max (1, 1, 300)	AM 30 dB max. softmute attenuation
I²C example (hex)	`[ w 21 2D 01 0001 012C ]`	AM 30 dB max. softmute attenuation

Suggested AM setting for LW band is 33 dB limit.

3.42 AM cmd 50 … 58 Set_Highcut

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

'Set_Highcut_Time' defines the weak signal handling response times active for the level detector. 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_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.

For FM operation see chapter 3.18 FM cmd 50 … 59 Set_Highcut.

module	33	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 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 500 = 50 ms (AM default)

Application example AM_Set_Highcut_Time (1, 500, 4000, 100, 500) Slow 500 / 4000 ms, fast 10 / 50 ms

I²C example (hex) `[ w 21 32 01 01F4 0FA0 0064 01F4 ]` Slow 500 / 4000 ms, fast 10 / 50 ms

module	33	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)
	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	33	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
	2	start [15:0]	weak signal handling level start
			200 … 600 [*0.1 dBμV] = control when level is below 20 dBμV … 60 dBμV 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 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	33	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
			1350 … 7000 [*1 Hz] = 1.35 … 7 kHz Highcut maximum -3 dB att. 1800 = 1.8 kHz (AM default)

Application example	AM_Set_Highcut_Max (1, 1, 1500)	AM 1.5 kHz max. Highcut attenuation
I²C example (hex)	[w 21 37 01 0001 05DC]	AM 1.5 kHz max. Highcut attenuation

module	33	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
			1 = on; minimum control limit set by limit parameter (AM default)
	2	limit [15:0]	Highcut fixed attenuation limit
			2700 … 15000 [*1 Hz] = 2.7 … 15 kHz -3 dB att. for min. Highcut 6000 = 6 kHz (AM default)

Application example	AM_Set_Highcut_Min (1, 1, 3000)	AM 3 kHz min. Highcut attenuation
I²C example (hex)	[w 21 38 01 0001 0BB8]	AM 3 kHz min. Highcut attenuation

Note: Limitation of the dynamic highcut control range as available from this command is best suited to define a desired ‘fixed’ highcut characteristic. An independent fixed filter of first order ‘IIR’ low-pass type is available from AM cmd 33 Set_Highcut_Fix.

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	33	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	AM_Set_Lowcut_Max (1, 1, 300)	AM 300 Hz max. Lowcut attenuation
I²C example (hex)	[w 21 39 01 0001 012C]	AM 300 Hz max. Lowcut attenuation

module	33	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
			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	AM_Set_Lowcut_Min (1, 1, 30)	AM 30 Hz min. Lowcut attenuation
I²C example (hex)	[w 21 **3A** 01 0001 001E]	AM 30 Hz min. Lowcut attenuation

Note: Limitation of the dynamic lowcut control range as available from this command is best suited to define a desired ‘fixed’ lowcut characteristic. An independent fixed filter of first order ‘IIR’ high-pass type is available from AM cmd 34 Set_Lowcut_Fix.

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.

3.43 AM cmd 80 Set_Scaler

Fine tuning of AM sound amplitude for matching with FM analog radio sound.

module	33	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	AM_Set_Scaler (1, -30)	AM analog radio -3 dB gain scaling
I²C example (hex)	[w 21 **50** 01 FFE2]	AM analog radio -3 dB gain scaling

Note: For fine tuning of AM digital radio sound amplitude see 3.45 AM cmd 83 Set_DR_BlendFM cmd 83 Set_DR_Blend.

For FM operation see chapter 3.21 FM cmd 80 Set_Scaler.

3.44 AM cmd 82 Set_QualityStatus

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

module	33	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
	2	interface [15:0]	quality status pin signal functionality
			0 = no pin interface (default)
			2 = quality status output; active low (‘QSI’)

Application example	AM_Set_QualityStatus (1, 200, 2)	Set status pin at 20 ms
I²C example (hex)	`[ w 21 52 01 00C8 0002 ]`	Set status pin at 20 ms

For pin signals a GPIO pin assignment is required; see 3.57 APPL cmd 3 Set_GPIO.

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

For FM operation see chapter 3.23 FM cmd 82 Set_QualityStatus.

3.45 AM cmd 83 Set_DR_Blend

Available for TEF6688A and TEF6689A only.

Control of digital radio blend functionality and digital radio scaler.

module	33	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	AM_Set_DR_Blend (1, 2, 50, 50, -60)	force 5 ms blend to digital (-6 dB)
I²C example (hex)	`[ w 21 53 01 0002 0032 0032 FFC4 ]`	force 5 ms blend to digital (-6 dB)

Note: radio blend is functional only when digital radio is enabled (see 3.36 AM cmd 30 Set_DigitalRadio) and radio is selected as an audio input source (see 3.50 AUDIO cmd 12 Set_Input).

For FM operation see chapter 3.24 FM cmd 83 Set_DR_Blend.

3.46 AM cmd 84 Set_DR_Options

For TEF6688A and TEF6689A only.

Control of digital radio I/O functionality. Note: DR output is functional only when digital radio is enabled (see 3.36 AM cmd 30 Set_DigitalRadio).AM cmd 30 Set_DigitalRadio

module	33	AM		
cmd	**84**	**Set_DR_Options**	samplerate, mode, format	
index	1	samplerate [15:0]	baseband digital radio sample rate (DR I^2S 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 = voltage output (default)
				51 = current output (‘virtual ground’) 20 * I_0
				187 … 255 = current output level selection: [15:12] = 11 … 15 = BCK 6 … 31 * I_0 [11:8] = 11 … 15 = WS 6 … 31 * I_0
			[7:0] =	Data pin(s) mode
				2 = voltage output
				3 = current output (‘virtual ground’) 20 * I_0
				4 = open drain (‘pull down’) (default)
				11 … 15 = current output level selection 6 … 31 * I_0
	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	AM_Set_DR_Options (1, 0)	automatic DR sample rate selection
	AM_Set_DR_Options (1, 0, 8706, 16)	3-wire bus with voltage output data
I^2C example (hex)	[w 21 **54** 01 0000]	automatic DR sample rate selection
	[w 21 **54** 01 0000 2202 0010]	3-wire bus with voltage output data

Note: The mode parameter defaults equal application of device versions V101 and V102, however wherever applicable the use of ‘virtual ground’ current output mode is advised.

Note: samplerate parameter setting changes are not executed immediately but delayed until the next Preset, Search, Check or Jump tuning action.

Note: The mode parameter current output level selection settings allow for alternative values of output current for BCK, WS and data pin signals:

mode [15:12] = 11 / 12 / 13 / 14 / 15 = BCK pin output current 6 / 10 / 15 / 20 / 31 * I_0
mode [11:8] = 11 / 12 / 13 / 14 / 15 = WS pin output current 6 / 10 / 15 / 20 / 31 * I_0
mode [7:0] = 11 / 12 / 13 / 14 / 15 = Data pin output current 6 / 10 / 15 / 20 / 31 * I_0
(typical current unit value I_0 = 22 uA).

The standard current value of 20 * I_0 may drive up to three virtual ground inputs in parallel with at least 6* I_0 input current each (employing resistors for current splitting). For applications where signal lines drive one or two virtual ground inputs lower current settings are advised for reduced crosstalk.

Note: For (digital radio) audio I/O see 3.53 AUDIO cmd 22 Set_Dig_IO; signal = 32.

For FM operation see chapter 3.25 FM cmd 84 Set_DR_Options.

3.47 AM cmd 85 Set_Specials

Special radio options for evaluation and extended application use.

module	33	AM	
cmd	**85**	**Set_Specials**	ana_out
index	1	ana_out [15:0]	audio output use
			0 = normal operation (default)
			2 = L : digital radio left channel / R : analog radio left channel

Application example	AM_Set_Specials (1, 2)	AM digital radio time alignment test
I²C example (hex)	`[ w 21 55 01 0002 ]`	AM digital radio time alignment test

Note: setting ana_out = 2 requires an audio input selection of ‘radio’ and 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 for the respective output pins.

(Note: previous version limitations are resolved and digital radio gain scaling is included.)

For FM operation see chapter 3.26 FM cmd 85 Set_Specials.

3.48 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: 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.

3.49 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

3.50 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 with DR blend (default) (analog radio or digital radio when enabled and DR blend active)
			32 = I²S digital audio input I2S_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

Note: The DR blend function for input source = 0 (radio) is available when digital radio is enabled.

3.51 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 I2S_SD_1
			128 = DAC L/R output
	2	source [15:0]	source
			4 = analog radio
			32 = I²S digital audio input I2S_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 0021 0004]	Select analog radio on I²S output

By default both the DAC output and the I2S_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.

3.52 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
I²C example (hex)	[w 30 **15** 01 0080 0000]	Disable DAC output

3.53 AUDIO cmd 22 Set_Dig_IO

Definition of digital audio input and digital audio output signals.

module	48	AUDIO	
cmd	**22**	**Set_Dig_IO**	signal, mode, format, operation, samplerate
index	1	signal [15:0]	digital audio input / output
			32 = I²S digital audio I2S_SD_0 (input)
			33 = I²S digital audio I2S_SD_1 (output)
	2	mode [15:0]	I/O mode
			0 = off (default)
			1 = current input (only available for signal = 32)
			2 = voltage output (only available for signal = 33)
			3 = current output (only available for signal = 33)) 6 * I_0
			11 … 15 = current output level selection 6 … 31 * I_0
	3	format [15:0]	digital audio format select
			16 = I²S 16 bits (f_{I2S_BCK} = 32 * samplerate)
			32 = I²S 32 bits (f_{I2S_BCK} = 64 * samplerate) (default)
			272 = lsb aligned 16 bit (f_{I2S_BCK} = 64 * samplerate)
			274 = lsb aligned 18 bit (f_{I2S_BCK} = 64 * samplerate)
			276 = lsb aligned 20 bit (f_{I2S_BCK} = 64 * samplerate)
			280 = lsb aligned 24 bit (f_{I2S_BCK} = 64 * samplerate)
	4	operation [15:0]	operation mode
			0 = audio slave mode; I2S_BCK and I2S_WS input signals defined by external signal source (default)
			256 = audio master mode; I2S_BCK and I2S_WS voltage output
			273 = audio master mode; I2S_BCK and I2S_WS current output 6 * I_0
			443 … 511 = audio master mode; current output level selection: [15:8] = 1, [7:4] = 11 … 15 = I2S_BCK 6 … 31 * I_0 [15:8] = 1, [3:0] = 11 … 15 = I2S_WS 6 … 31 * I_0
	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) 32 bit I²S, master all voltage, 48 kHz.
AUDIO_Set_Dig_IO (1, 33, 3, 32, 273, 4410) 32 bit I²S, master all current, 44.1 kHz.

I²C example (hex)
[w 30 **16** 01 0021 0002 0020 0100 12C0] 32 bit I²S, master all voltage, 48 kHz.
[w 30 **16** 01 0021 0003 0020 0111 12C0] 32 bit I²S, master all current, 44.1 kHz.

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

Note: A TEF668XA 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. In case of conflicting control settings the setting of the signal with the lowest enumeration value is used.

Note: f_{I2S_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.

Note: Output pin signals can be selected either voltage output or current output by means of parameter 2 (mode; for output SD) and 4 (operation; for outputs BCK and WS). Voltage output settings are compatible with previous versions V101 and V102, however wherever possible the use of 'audio slave mode' and/or 'virtual ground' current output mode is advised to prevent signal crosstalk towards the sensitive (AM) radio input.

Note: The standard current output value of 6 * I_0 is suited to drive one virtual ground input. For applications with non-standard input circuitry or disturbed current signal lines higher current settings are available from the mode parameter and operation parameter current output level selection. The settings allow for alternative output current values for the SD pin signal and for the master mode BCK and WS pin signals separately:

mode [15:0] = 11 / 12 / 13 / 14 / 15 = SD pin output current 6 / 10 / 15 / 20 / 31 * I_0
operation [7:4] =11 / 12 / 13 / 14 / 15 = BCK pin output current 6 / 10 / 15 / 20 / 31 * I_0
operation [3:0] =11 / 12 / 13 / 14 / 15 = WS pin output current 6 / 10 / 15 / 20 / 31 * I_0
(typical current unit value I_0 = 22 µA).

3.54 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 3.50 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 : I2S_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 I2S_SD_0 is defined by FM and AM radio control 3.24 FM cmd 83 Set_DR_Blend and 3.45 AM cmd 83 Set_DR_Blend.

3.55 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 3.50 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 present 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.

3.56 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 function) (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.

Setting mode = ‘normal operation’ will return to the radio operation as used before standby (unless other selections were made during radio standby mode).
Alternatively a radio tuning action of Preset or Search (see 3.1 FM cmd 1 Tune_To and 3.29 AM cmd 1 Tune_To) will enable normal operation.

3.57 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 … 3 = 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: GPIO 1 and GPIO 2 levels are critical during startup for correct I²C address and crystal definition, general purpose input use is therefore not suggested for these pins.

Note: Use of GPIO 3 (pin 20) is incompatible with pin 19 I2S_SD_1 voltage output mode because of signal crosstalk to the (AM) radio antenna circuit. I2S_SD_1 modes ‘off’ and ‘current output’ from AUDIO cmd 22 Set_Dig_IO however do allow for GPIO 3 use.

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 DAVN, QSI and AGC are all ‘active low’.

Note: Definition and required enabling of assigned features is available from:
‘DAVN’, ‘RDDA’ and ‘RDCL’: 3.22 FM cmd 81 Set_RDS
‘QSI’: 3.23 FM cmd 82 Set_QualityStatus and 3.44 AM cmd 82 Set_QualityStatus
‘AGC’: 3.4 FM cmd 11 Set_RFAGC

3.58 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
APPL_Set_ReferenceClock (1, 846, 23214, 0)	Set crystal reference 55.46667 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
[w 40 **04** 01 034E 5AAE 0000]	Set crystal reference 55.46667 MHz

TEF668XA supported frequencies: 4.000 MHz, 9.216 MHz, 12.000 MHz, 55.46667 MHz.

Note: 55.46667 MHz crystal operation requires a pull-up resistor at pin 27 'GPIO_1', all other use cases (including 55.46667 MHz external reference) require pull-down.

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

3.59 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 TEF668XA offering read data are 32 'FM' for FM radio, 33 'AM' for AM radio and 64 'APPL' for application and system information. Module 'AUDIO' offers no read data currently.

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

The index value allows for reading of a certain specific data range out of the available command read data.

Device version V205 supports the use of index read data addressing.
(Note previous versions V102 and V101 required index = 1)

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 'APPL' module.
- active state = FM: valid read data from 'FM' and 'APPL'.
- active state = AM: valid read data from 'AM' and 'APPL'.

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

4.1 FM cmd 128 / 129 Get_Quality

Read status of the tuner reception quality information

Get_Quality_Status
returns quality status and possibly data with 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
returns quality status and quality 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	FM		
cmd	**128**	**Get_Quality_Status**	| status, level, usn, wam, offset, bandwidth, modulation	
	129	**Get_Quality_Data**		
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 [15:0]	FM noise detector	
			ultrasonic noise detector	
			0 … 1000 (*0.1 %) = 0 … 100% relative usn detector result	
	4	wam [15:0]	FM multipath detector	
			‘wideband-AM’ multipath detector	
			0 … 1000 (*0.1 %) = 0 … 100% relative wam detector result	
	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	
			560 … 3110 [*0.1 kHz] = IF bandwidth 56 … 311 kHz; narrow … wide	
	7		modulation detector	

modulation [15:0]	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.)

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

The AF_update flag bit 15 informs about available AF sampled data.
AF sampled data is not affected and remains after command _Status (cmd 128) read,
AF sampled data is flushed and replaced by continuous data after _Data (cmd 129) read.

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 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).

For AM operation see chapter 4.7 AM cmd 128 / 129 _Get_Quality.

4.1.1 Quality status and detector application use

To assist the use of radio quality detectors status information is available including the time passed since radio station tuning was established. Because of the settling time involved in the different detectors the quality time stamp can be important information to judge the reliability of the different quality data.

Detector settling time of signal strength (level), noise (usn) and multipath (wam) is 1 ms. for > 90% signal settling and first ‘not OK’ judgement is possible after this time. Fluctuating noise and multipath signals will effectively increase detector settling times so a final ‘OK’ judgement is suggested at a later time, e.g. 10 ms.

Detector settling time of frequency offset and modulation is 10 ms for > 90% signal settling. It is to be noted however that by definition the frequency offset measurement is influenced by low frequency audio modulation, a longer test time like e.g. 32 ms is therefore suggested for final judgement.

Modulation is intended for evaluation use only, settling time is 10 ms for > 90%.

AF_update tuning actions employ a short quality measurement time of (default) 2 ms for which the frequency offset detector shows 75% signal settling. Modulation detection is not supported by AF_update and available modulation read values shall be ignored.

In case of dynamic IF bandwidth control the noise detector is less effective but instead the bandwidth may be considered a quality indicator. Indicative bandwidth results are available within 2 ms but longer times, e.g. 10 ms, are suggested for final judgement.

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 operation 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.

Decoder mode FULL SEARCH (mode = 3) enables a special optimized RDS channel decoder system utilizing a combination of soft decision and soft error detection techniques for improved RDS sensitivity at equal or better quality of output data compared to conventional RDS decoder systems. Decoder mode FULL SEARCH read data is compatible with standard decoder mode read data.

RDS decoder mode 'FULL SEARCH' is available for TEF6687A and TEF6689A only.

In all 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

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 found; block data is received with matching data and syndrome 1 : small error; probable 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)) FM_Get_RDS_Data (1, (status … dec_error))	Poll status 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 3.22 FM cmd 81 Set_RDS to enable this option (interface = 2) and 3.57 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.

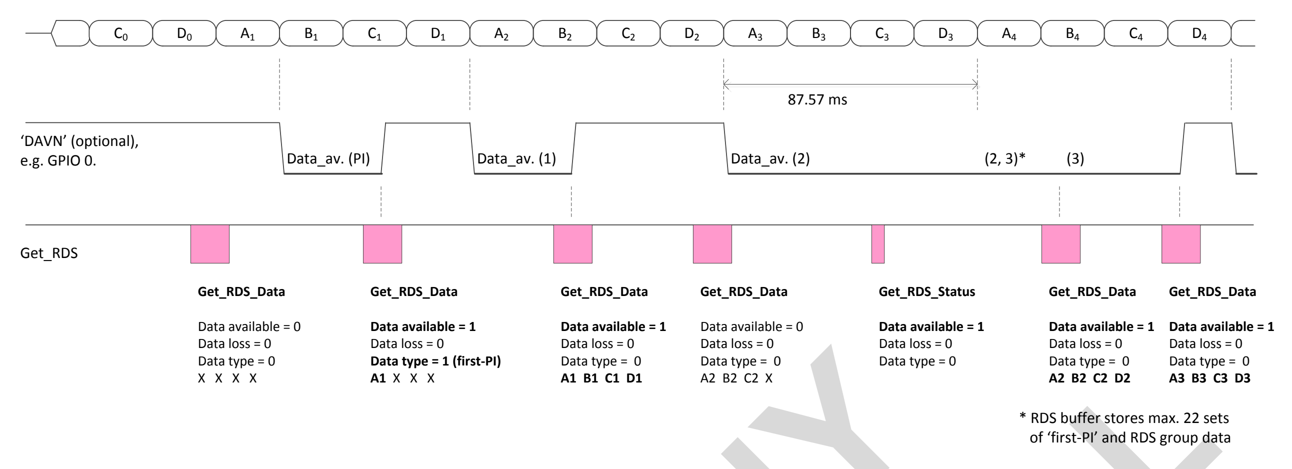


Fig 2. Example of RDS decoder status and data by I²C bus read and optional GPIO 'DAVN' interrupt use.

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)) FM_Get_RDS_Data (1, (status, raw_data))	Poll status Read status and available data
I²C example	`[ w 20 82 01 [ r 8000 ]` `[ w 20 83 01 [ r ???? ???? ???? ]`	Poll status *(RDS raw data available)* 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 3.22 FM cmd 81 Set_RDS to enable this option (interface = 2) and 3.57 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.

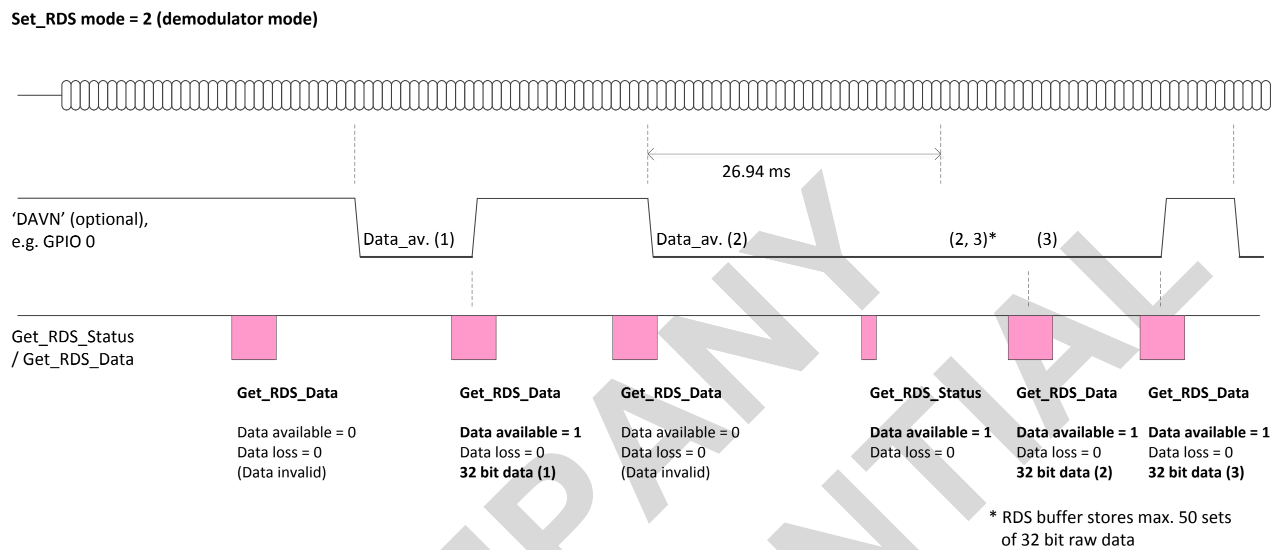


Fig 3. Example of RDS demodulator status and data by I²C bus read and optional GPIO 'DAVN' interrupt use.

4.3 FM 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	FM	
cmd	**132**	**Get_AGC**	| input_att, feedback_att
index	1	input_att [15:0]	RF AGC input attenuation
			0 … 420 (0.1* dB) = 0 … 42 dB attenuation
	2	feedback_att [15:0]	RF AGC feedback attenuation
			0 … 60 (0.1* dB) = 0 … 6 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 TEF668XA 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 cmd 11 Set_RFAG).

For AM processing see chapter 4.8 AM cmd 132 Get_AGC.

4.4 FM cmd 133 Get_Signal_Status

Read information about the received radio signal.

module	32	FM	
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) (TEF6688A and TEF6689A 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*

For AM processing see chapter 4.9 AM cmd 133 Get_Signal_Status.

4.5 FM 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	FM		
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 (TEF6687A and TEF6689A 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 (TEF6687A and TEF6689A 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.

For AM processing see chapter 4.10 AM cmd 134 Get_Processing_Status.

4.6 FM cmd 135 Get_Interface_Status

Available for TEF6688A and TEF6689A only.

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

module	32	FM	
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))	DR sample rate
I²C example (hex)	[w 20 **87** 01 [r *1A5E*]	DR sample rate = *675 kHz*

For AM processing see chapter 4.11 AM cmd 135 Get_Interface_Status.

Radio sample rate is also available from 4.16 APPL cmd 135 Get_Interface_Status.

4.7 AM cmd 128 / 129 Get_Quality

Read status of the tuner reception quality information.

Get_Quality_Status
returns quality status and possibly data. Get_Quality_Status is intended for status read only (i.e. status polling) but data may be read also when desired.

Get_Quality_Data
returns quality status and quality data. Get_Quality_Data is intended for data reading with the status informing about data content and validity.

The availability of two commands is a reservation for possible future use. Because no sampled data functions are present currently the commands are equal in function.

module	33	AM		
cmd	**128**	**Get_Quality_Status**	| status, level, noise, co_channel, offset, bandwidth, modulation	
	129	**Get_Quality_Data**		
index	1	status [15:0]	quality detector status	
			[15:10] =	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	noise [15:0]	AM noise detector	
			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	co_channel [15:0]	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	
			30 … 80 [*0.1 kHz] = IF bandwidth 3 … 8 kHz; narrow … wide	
	7	modulation [15:0]	modulation detector	
			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	AM_Get_Quality_Status (1, (status)) AM_Get_Quality_Data (1, (status .. modulation))	Poll status Read status and all available data
I²C example (hex)	`[ w 21 80 01 [ r 0014]` `[ w 21 81 01 [ r ???? ???? … ???? ]`	Poll status *(2 ms after tuning)* Read status and all available data

The status quality time stamp starts updating as soon as tuning is established and new continuous data becomes available for Preset or Search tuning actions (mode = 1 or 2).

The AM co-channel criteria can be defined from 3.33 AM cmd 14 Set_CoChannelDet.

For FM operation see chapter 4.1 FM cmd 128 / 129 Get_Quality.

4.7.1 Quality status and detector application use

To assist the use of radio quality detectors status information is available including the time passed since radio station tuning was established. Because of the settling time involved in the different detectors the quality time stamp can be important information to judge the reliability of the different quality data.

The initial detector settling time of signal strength (level) is 1 ms for > 90% signal settling allowing fast detection of ‘not OK’ conditions. It is to be noted however that by definition the AM level measurement is influenced by low frequency audio modulation, a longer test time like e.g. 32 ms is therefore suggested for final judgement.

The noise detector (noise) settling time is approx. 10 ms for real-life signals but a longer test time is suggested for final judgement.

Detector settling of the 'co-channel' detector is defined by the co-channel frequency offset condition present. Long wait times of approx. 200 ms are therefore required and detection may fail altogether.

Detector settling time of frequency offset is 1 ms for > 90% signal settling.

Modulation is intended for evaluation use only, settling time is approx. 25 ms for 90%.

4.8 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	33	AM	
cmd	**132**	**Get_AGC**	| input_att, feedback_att
index	1	input_att [15:0]	RF AGC input attenuation 0 … 420 (0.1* dB) = 0 … 42 dB attenuation
	2	feedback_att [15:0]	RF AGC feedback attenuation 0 … 180 (0.1* dB) = 0 … 18 dB attenuation

Application example	AM_Get_AGC (1, (input_att, feedback_att))	Read AGC attenuation settings
I²C example	`[ w 21 84 01 [ r 0078 00B4 ]`	Read AGC attenuation settings *= 12 dB + 18 dB RF attenuation*

Note: The TEF668XA RF AGC employs 6 dB step size, i.e. read values of 0, 60, 120…

For FM operation see chapter 4.3 FM cmd 132 Get_AGC.

4.9 AM cmd 133 Get_Signal_Status

Read information about the received radio signal.

module	33	AM	
cmd	**133**	**Get_Signal_Status**	| status
index	1	status [15:0]	Radio signal information [14] = 0 : analog signal [14] = 1 : digital signal (blend input activated by digital processor or control) (TEF6688A and TEF6689A only)

Application example	AM_Get_Signal_Status (1, (status))	Read availability of digital radio
I²C example	[w 21 **85** 01 [r *4000*]	Read availability of digital radio *= digital radio blend active*

For FM operation see chapter 4.4 FM cmd 133 Get_Signal_Status.

4.10 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	33	AM	
cmd	**134**	**Get_Processing_Status**	| softmute, highcut
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

Application example	AM_Get_Processing_Status (1, (softmute, …))	Read weak signal processing status
I²C example	[w 21 **86** 01 [r *0000 019A*]	Read weak signal processing status = *softmute 0%, highcut 41%*

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.

For FM processing see chapter 4.5 FM cmd 134 Get_Processing_Status.

4.11 AM cmd 135 Get_Interface_Status

Available for TEF6688A and TEF6689A only.

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

module	33	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	AM_Get_Interface_Status (1, (samplerate))	DR sample rate
I²C example (hex)	[w 21 **87** 01 [r *1A5E*]	DR sample rate = *675 kHz*

For FM processing see chapter 4.6 FM cmd 135 Get_Interface_Status.

Radio sample rate is also available from 4.16 APPL cmd 135 Get_Interface_Status.

4.12 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.

4.13 APPL cmd 129 Get_GPIO_Status

Read information about the input state of assigned general purpose input pins (see 3.57 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)	
			[3] = input state of GPIO_3 (0 = low, 1 = high)	
			[2] = input state of GPIO_2 (no input use suggested)	
			[1] = input state of GPIO_1 (no input use suggested)	
			[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 TEF668XA designated input use of GPIO_1 and GPIO_2 during power-up only pins GPIO_0 and GPIO_3 are suggested for application as a general purpose input.

Note: GPIO_3 use is incompatible with audio I²S data output (I2S_SD_1) voltage mode operation. The audio I²S output shall be either disabled or set to current output mode.

4.14 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 = TEF668XA and TEF669XA 'Lithio' and 'Lithio PD' series
			[7:0]	variant identifier
				14 = TEF6686A 'Lithio'
				1 = TEF6687A 'Lithio FMSI'
				9 = TEF6688A 'Lithio DR'
				3 = TEF6689A 'Lithio FMSI DR'
	2	hw_version [15:0]	hardware version	
			[15:8]	major number
				2 = '2'
			[7:0]	minor number
				2 = '.2'
	3	sw_version [15:0]	firmware version	
			[15:8]	major number
				5 = '5'
			[7:0]	minor number
				0 = '.00'

Application example	APPL_Get_Identification (1, (device..))	Read device identification
I²C example	[w 40 82 01 [r 090E 0202 0500]	*(TEF6688A, hw 2.2, sw 5.00)*

Note: The type number version designation '/V205' is derived from the major hw_version and the major sw_version number.

4.15 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 0121 1E01 0001 0000…0000 ]`	Read back last write transmission *(AM_Set_DigitalRadio = ‘on’)*

4.16 APPL cmd 135 Get_Interface_Status

Information about internal radio processing and DR I²S sample rate where applicable.

module	64	APPL	
cmd	**135**	**Get_Interface_Status**	| samplerate
index	1	samplerate [15:0]	Internal radio baseband sample rate
			6500 = 650 kHz
			6750 = 675 kHz

Application example APPL_Get_Interface_Status (1, (samplerate)) radio baseband sample rate

I²C example (hex) `[ w 40 87 01 [ r 1A5E ]` radio baseband sample rate *(675 kHz)*

5. I²C bus protocol

5.1 I²C protocol

TEF668XA 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 8 bit I²C device address for TEF668XA 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_2 shall be pulled either low or high (10 kΩ) during power-on and activation for a defined I²C address. Pin open is not a defined state.

Note: GPIO_1 requires a similar pulled low or high pin definition at startup for the definition of clock reference. GPIO_1 pulled high (10 kΩ to Vdd) during power-on ensures proper operation with a 55.46667 MHz crystal. Instead GPIO_1 shall be pulled low (10 kΩ to ground) during power-on to ensure proper operation with 55.46667 MHz external reference source and with 4 MHz, 9.216 MHz or 12 MHz crystal.

5.2 Write control

Standard write transmissions to the TEF668XA 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.

*Device version V205 fully supports the use of index parameter addressing.
(Previous versions V102 and V101 instead were restricted to use of index = 1 only and required all documented command parameters to be transmitted.)*

In Fig 4 examples of these transmissions are shown.

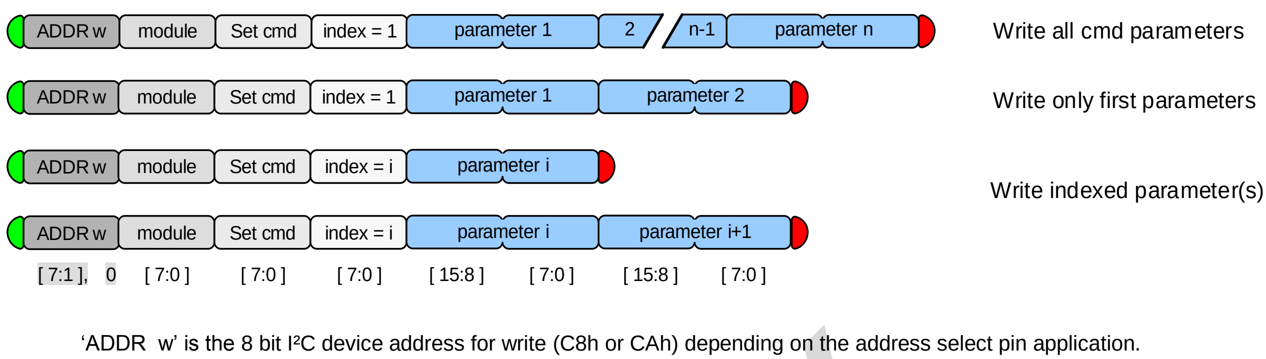


Fig 4. Examples of I²C write control; set command

TEF668XA 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.

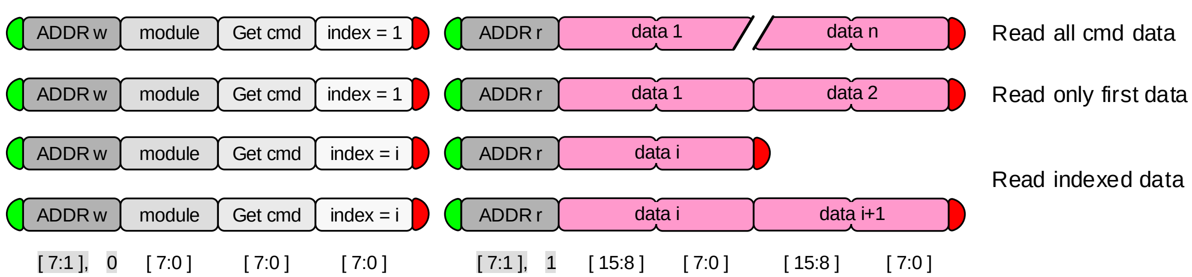
5.3 Read control

Standard reading from the TEF668XA 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.

Device version V205 supports the use of index read data addressing.
(Previous versions V102 and V101 instead were restricted to use of index = 1 only).



'ADDR r' is the 8 bit 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 TEF668XA read control; see chapter 5.6 for details.

TEF668XA 'Get' commands as published in this user manual are without parameter use. For future extensions the protocol however allows for 'Get' commands with parameters.

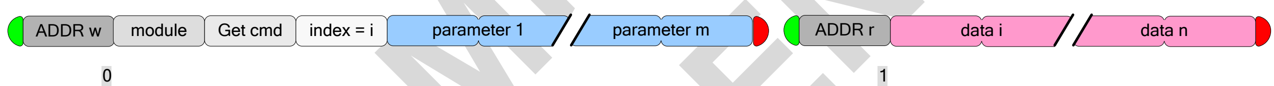


Fig 6. Example of a possible get command with parameter(s)

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).

TEF668XA supports the use of I²C 'repeated start' without restriction. This means TEF668XA 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.

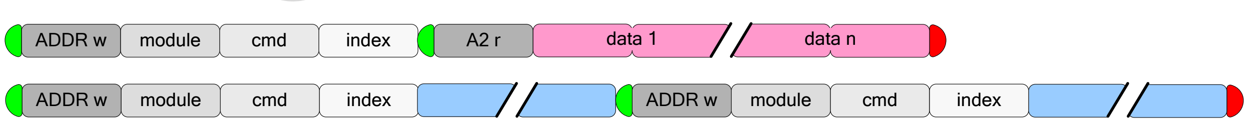


Fig 7. Examples of I²C transmissions with repeated start

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 TEF668XA supports I²C clock speeds up to 400 kHz in accordance with the I²C 'fast mode' specification. TEF668XA 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.

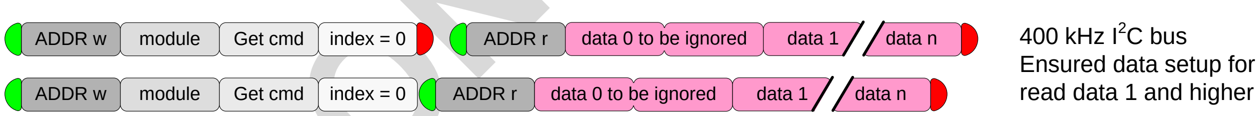


Fig 9. Example of I²C read control with guaranteed 400 kHz operation; get command index = 0

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 which will guarantee the required read data setup time.

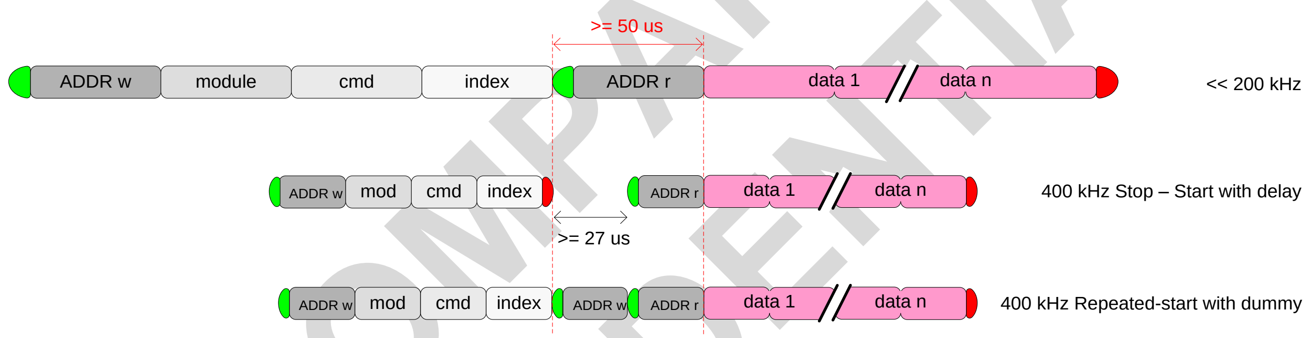


Fig 10. Examples of alternative I²C read control with guaranteed read data setup

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 TEF668XA puts the requested data in its output registers after reception and evaluation of a valid ‘get’ command. TEF668XA 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
Invalid parameter value	FF FCh

- note: only available for special cases, most commands do not test the parameter value.

Invalid parameter write attempt	FF FBh

- attempt to write a non-existent parameter.

Invalid state	FF FAh

- command exists but not available in the current state.

In case of the above listed invalid conditions the command is ignored in full and no command part is executed.

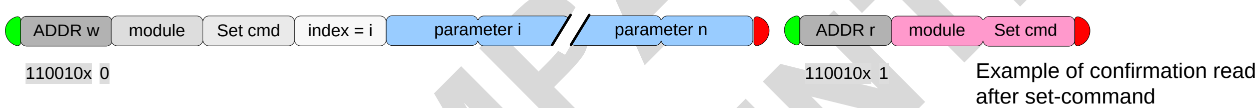


Fig 11. Example of write command with evaluation data read

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 for 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
Invalid state	FF FAh

- command exists but not available in the current state.

* All TEF668XA read commands show ‘instant’ data delivery, an error value of FF F8h shall therefore 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 either error value 00 00h or error value FF F8h may be found occasionally, indicating an erroneous read result.

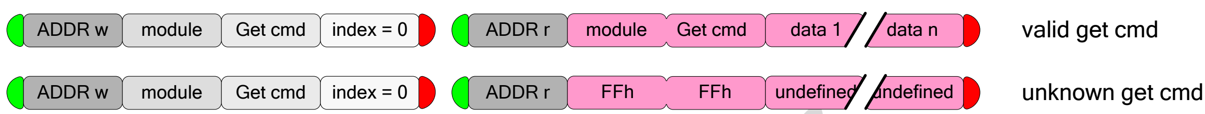


Fig 12. Examples of I²C read control with confirmation; get command index = 0

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

6. Device start-up

6.1 Introduction

The TEF668XA 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 from boot state into idle state and then into active state to realize the desired user operation mode, function and performance.

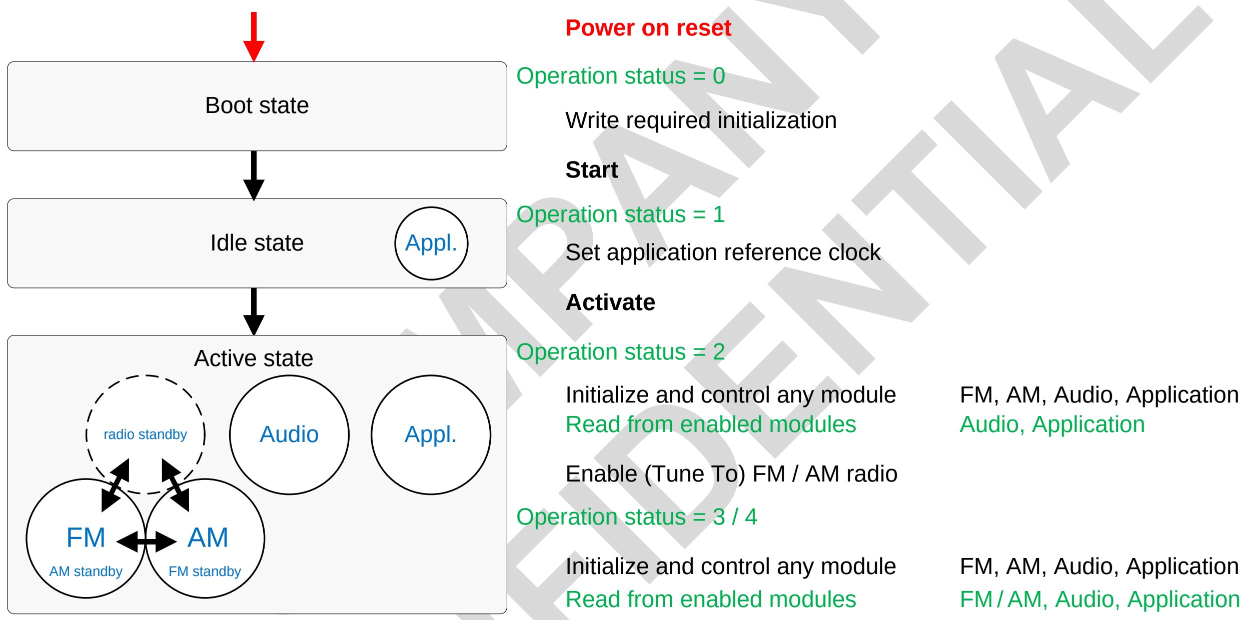


Fig 13. Block diagram of device start-up control sequence

Boot state and idle state have no function other than offering the minimum set of controls required for proper preparation of 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^2C read until the new state is found.

TEF668XA 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. = 4000000 … 55466670, type = 0/1.
    `[ w 40 04 01 034E 5AAE 0000 ]` *: example 55.46667 MHz crystal.*
    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 **APPL_** 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 ]` *: start radio operation*

6.2.1 Required initialization I²C transmission – I²C example

The following I²C transmissions (version p5.10) are a required part of the V205 boot state device initialization. Use of these I²C transmissions is required for proper and full function and performance as described in this user manual.

Note: The indicated set of required initialization transmissions is for use with V205 only.

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

```
▪ [ w 1C 0000 ]
  [ w 1C 0074 ]

▪ [ w 1B F000 6034 D080 2087 603E D080 9000 6040 D080 2202 0055 6004 ]
  [ w 1B F000 6052 DF80 2090 6068 D080 3140 606C D080 9EB9 6075 D080 ]
  [ w 1B F000 6077 D080 F000 6080 D080 9001 6085 D080 9101 6086 D080 ]
  [ w 1B F000 6087 D080 A264 7000 F000 31A0 60AF D080 2013 62A7 D080 ]
  [ w 1B F000 60EA D080 F000 60F8 D280 F000 6103 D080 4FD0 6101 D180 ]
  [ w 1B 9E73 6132 D080 F000 613D D080 F000 6145 D080 F000 615A D080 ]
  [ w 1B 2C87 6166 D080 F000 616A D080 F000 616D D280 F000 7000 F000 ]
  [ w 1B F000 6199 D280 57F2 619B D580 A880 7000 F000 F000 619E D080 ]
  [ w 1B F000 61A5 D280 4FA0 6101 D280 4FC0 6101 D280 F000 61B8 D280 ]
  [ w 1B 4120 14F6 D280 F000 6202 D080 F000 6212 D080 F000 621B D080 ]
  [ w 1B F000 622F D080 F000 6235 D080 F000 6239 D080 F000 6246 D080 ]
  [ w 1B 2DC5 18FF 6006 F000 6272 D080 F000 6274 D080 8209 0DA2 600D ]
  [ w 1B F000 6286 D280 F000 6286 D280 F000 6285 D580 F000 62A9 D280 ]
  [ w 1B 8200 7000 A010 8200 7000 A02B 8200 7000 A069 8200 7000 A0AA ]
  [ w 1B 8200 7000 A26E 8200 7000 A17A 8200 7000 A184 8200 7000 A20D ]
  [ w 1B 8200 7000 A26A F000 27AA D080 F000 01A9 D580 8C79 0046 D080 ]
  [ w 1B F000 7000 D409 F000 0097 D080 4011 0E72 6009 D07F 7000 F000 ]
  [ w 1B C5C9 01B6 D080 0544 6008 A261 F000 3080 D008 F000 0769 6008 ]
  [ w 1B F000 0519 6009 F000 2000 F000 2692 54A3 6001 A200 7000 F000 ]
  [ w 1B A208 7000 F000 A210 7000 F000 D840 7000 F000 F000 3490 F000 ]
  [ w 1B F000 3590 F000 F000 3690 D008 4015 2053 A254 A0E8 5806 A253 ]
  [ w 1B A072 2064 F000 A861 7000 F000 A128 7000 F000 A0B2 7000 F000 ]
  [ w 1B A862 7000 D008 0579 6008 824E F000 1068 6001 F000 6003 8002 ]
  [ w 1B F000 0834 6001 F800 6003 8000 1831 6008 A248 F000 3001 F000 ]
  [ w 1B F000 3103 D008 F000 1D10 6009 4011 7FFF 6002 F000 3010 F000 ]
  [ w 1B F000 3092 F000 F000 3111 F000 1D0F 6008 A241 F000 7000 823F ]
  [ w 1B 9A62 1D0F 600A 8292 7000 9401 908A 0000 6001 3022 080C D080 ]
  [ w 1B F000 0944 D280 F000 07FD D280 F000 0811 D080 F000 1872 6008 ]
  [ w 1B F000 1D0F 6009 F000 2D80 A235 9A02 2011 F000 908A 7000 D009 ]
  [ w 1B 9041 7000 D008 90C1 08EC D180 F000 08DC D080 F000 1D0F 600A ]
  [ w 1B F000 7000 F000 2023 7000 A22D 8059 0949 D080 F000 0313 6006 ]
  [ w 1B F000 7000 8001 F000 FCED 6006 1D10 600E A228 F000 3066 D008 ]
  [ w 1B 1D0F 600B A226 F000 2037 A225 91C7 2191 F000 90C3 0B0B D180 ]
  [ w 1B 8249 0B14 D080 3191 0B14 D080 3191 0B14 D080 1D10 600D A21F ]
  [ w 1B F000 2157 A21E 91C7 3150 F000 9000 7000 9402 F000 7000 9001 ]
  [ w 1B F000 7000 AFEE F000 7FFF 6004 8200 2057 A218 91C7 20D3 A217 ]
  [ w 1B 80FB 7000 9006 82E2 30D3 9801 F000 7000 9804 91C7 3050 F000 ]
  [ w 1B 9100 7000 E1C0 30D0 7000 F000 9003 7000 F000 A2ED 7000 F000 ]
  [ w 1B A2F6 3105 F000 F000 0B22 D080 F000 0BFD D280 F000 7000 98B7 ]
  [ w 1B F000 7000 80B9 F000 2DBB D080 F000 7000 80E2 F000 7000 80E5 ]
  [ w 1B 83FF 1D13 6008 F000 1D15 6009 1007 0000 6002 1007 01F4 6003 ]
  [ w 1B 1012 03E8 6004 1013 0000 6005 1014 003C 6006 1015 0000 6007 ]
  [ w 1B 1016 01F4 6000 1017 03E8 6001 1010 0000 6000 1011 003C 6001 ]
  [ w 1B 1010 7000 F000 1011 7000 A1F9 F000 7000 801B 2FA0 178D 6009 ]
  [ w 1B 2021 1D13 6006 D202 0013 4FF0 C48A 7000 F000 90C3 4005 F000 ]
  [ w 1B 82D3 0013 9013 9008 7000 97FD F000 2E24 4015 3220 609D 6007 ]
```

```
[ w  1B  32A5 0CFA D280 9003 0CA8 D580 D098 1791 6006 8020 0CFA D280 ]
[ w  1B  90C0 0CCE D180 F000 0D92 6009 D042 1792 6006 2021 007F 6003 ]
[ w  1B  8196 7000 F000 825B 3016 770C 82DB 0C7F DD80 C051 2019 A1E3 ]
[ w  1B  2012 7000 F000 2098 7000 F000 2099 0D23 D280 F000 0C7F D080 ]
[ w  1B  21A0 0ED3 6001 32A5 0C70 D080 F000 050A 6000 07E9 6008 A1DC ]
[ w  1B  F000 0063 6000 07E8 6008 81DA F000 0D9A 600C F000 082E 600F ]
[ w  1B  F000 2048 4017 F000 20C9 5806 F000 21CA F000 F000 224B F000 ]
[ w  1B  F000 2011 F000 F000 2000 F000 A1C8 2142 F000 A182 2033 F000 ]
[ w  1B  AE88 2022 F000 A1D8 22C4 F000 A192 60CE 6007 AF0B 3340 F000 ]
[ w  1B  F000 33C3 F000 F000 3077 D008 006E 600C A1C8 F000 2147 A1C7 ]
[ w  1B  C3C7 7000 D008 F000 14D7 D080 44D0 1D1F 6008 F000 45F2 4551 ]
[ w  1B  3000 4693 F000 3081 47F4 F000 3102 0569 6001 3183 7000 F000 ]
[ w  1B  3204 7000 F000 3281 7000 805D F000 4FA0 A016 F000 4FB0 A015 ]
[ w  1B  F000 4FC0 A014 F000 4FD0 A013 F000 4FE0 A012 F000 4FF0 A011 ]
[ w  1B  F000 4020 A010 F000 4040 A00F F000 4050 A00E F000 4060 A00D ]
[ w  1B  4000 1535 D280 4010 1535 D280 4030 1535 D280 F000 152D D080 ]
[ w  1B  9AD9 1535 6001 60FC 6001 EE00 9ADB 7000 E1C0 8059 7000 81AB ]
[ w  1B  1D1F 6009 8005 1D20 6009 8004 1D21 6009 8003 1D22 6009 8002 ]
[ w  1B  1D23 6009 8001 1D24 6009 8000 F000 154A D080 9FB9 41A0 40F3 ]
[ w  1B  9FB1 41A1 9004 0000 6002 9018 F000 3220 F000 F000 32A1 F000 ]
[ w  1B  F000 3422 8017 D621 7000 F000 C259 1000 6003 9E72 41A0 F000 ]
[ w  1B  9E6A 40E0 E200 9C6A 4120 E200 F000 7000 F000 9250 7000 E1C0 ]
[ w  1B  C35B 7000 F000 D522 7000 9006 9EB3 41A1 F000 9EAB 40E1 E200 ]
[ w  1B  9CAB 4121 E200 F000 7000 F000 9291 7000 E1C0 0001 6002 8FEE ]
[ w  1B  9EB3 41A1 F000 9EAB 4111 E200 9CAB 4121 E200 F000 7000 F000 ]
[ w  1B  9291 7000 E1C0 000B 6002 8FE8 F000 40D1 40D0 001F 6002 8FE6 ]
[ w  1B  9FF9 41A0 40F3 F000 41A1 9001 0006 6002 800B C319 1000 6003 ]
[ w  1B  9E72 41A0 F000 9E6A 40E0 E200 9E62 4120 E200 9C6A 4100 E200 ]
[ w  1B  F000 7000 F000 9250 7000 E1C0 C35B 7000 F000 41A1 0017 6002 ]
[ w  1B  0037 6002 E600 9001 7000 E0C0 4403 20A7 A178 91C4 7000 F000 ]
[ w  1B  41A1 41A0 E240 F000 1593 D080 F000 7000 9805 9E6B 7000 9005 ]
[ w  1B  9C43 7000 9005 9C6B 7000 9C02 F000 7000 9C04 F000 7000 8000 ]
[ w  1B  41A3 7000 8003 4083 7000 8002 4153 7000 8001 94EB 7000 8000 ]
[ w  1B  4FE0 1532 D080 F000 4FF0 A002 D712 4FB0 A001 F000 15C5 D080 ]
[ w  1B  F000 40F3 A166 C29B 7000 F000 9CEB 7000 F000 82DB 7000 E140 ]
[ w  1B  94EB 1532 D080 4FB0 7000 AFBB 4FF0 7000 8FBA F000 08CC 6009 ]
[ w  1B  F000 614D 6001 F000 6150 6002 3591 7000 F000 3612 087F 6000 ]
[ w  1B  08C3 6008 815B F000 1695 D280 0544 6003 F000 0E21 6009 8F91 ]
[ w  1B  F000 169B D280 F000 24B3 F000 0E21 6009 8F8E 0026 6000 A005 ]
[ w  1B  8012 6003 F000 0E20 6009 8F8B 0030 6000 A002 8003 6003 F000 ]
[ w  1B  0E20 6009 8F88 F000 16CB D080 0A15 6008 F000 F000 215B D280 ]
[ w  1B  F000 1BCD 6008 2210 7000 F000 2C87 7000 F000 2291 7FFF 6006 ]
[ w  1B  91C7 2D0C F000 2E0A 17CE D580 F000 3306 F000 F000 3386 F000 ]
[ w  1B  F000 3406 F000 3486 17CE D080 F000 3294 F000 91C7 7000 F000 ]
[ w  1B  F000 17F7 D580 F000 7000 D008 9EB7 3912 E200 838F 3912 E200 ]
[ w  1B  F000 188F D080 8200 03E0 6008 0C1D 6009 C010 F000 1000 F000 ]
[ w  1B  3310 1AA2 D080 8200 7000 F000 095D 6008 A134 F000 3480 F000 ]
[ w  1B  F000 3400 D008 8200 04A8 600A F000 0698 6001 09E2 6008 C008 ]
[ w  1B  F000 1021 F000 F000 3180 D008 F000 1893 D280 0846 6008 A12B ]
[ w  1B  F000 2900 A12A 9E30 7000 F000 0997 6008 D409 096E 6000 A127 ]
[ w  1B  F000 3080 D008 0A66 6008 F000 0A87 6009 A00D F000 0F84 D280 ]
[ w  1B  83FF 1D3E D080 0A6D 6008 F000 0A87 6009 A009 F000 0F84 D280 ]
[ w  1B  3190 03E8 6000 3211 0FBE D280 9007 7000 F000 8098 0FBE D280 ]
[ w  1B  8BC7 7000 F000 9004 3187 4007 9080 0FBE D280 3100 1D67 D080 ]
[ w  1B  5807 2225 F000 9104 0387 6000 7FFC 6006 D009 822A 0F9C D280 ]
[ w  1B  80B8 2714 A112 8139 0FE7 D280 A276 2021 F000 F000 20A2 F000 ]
[ w  1B  F000 2123 D008 F7CF 6003 F000 2800 6000 D008 F000 7000 C008 ]
[ w  1B  F000 1032 F000 F000 7000 D008 233E 6005 A108 8E2D 2343 6006 ]
[ w  1B  91C1 22F1 D580 8F86 3E6C 6003 91C1 22F1 D580 8018 7000 F000 ]
[ w  1B  91C1 22F1 D080 0C78 6008 A001 4011 4094 8100 9000 FFEF 6006 ]
[ w  1B  F000 23B8 D180 4106 23B6 D080 0002 6003 8005 0004 6003 8004 ]
[ w  1B  0006 6003 8003 F000 2318 D080 F000 2318 D080 0010 6003 8000 ]
[ w  1B  F000 2084 A0F6 C2E3 7000 F000 9041 238C D180 F000 2377 D080 ]
[ w  1B  40C0 0C95 6008 4081 0C92 6009 F000 3000 F000 F000 3011 D008 ]
[ w  1B  2002 5801 80EE F000 1C8D 6009 61BE 6001 A0EC 3111 1C91 600A ]
[ w  1B  018E 6002 A0EA 30A2 7000 D008 4000 230D D080 F000 1CAF 600E ]
[ w  1B  622D 6006 A0E6 3066 1CA2 600F 622B 6007 A0E4 3077 1CD8 6008 ]
[ w  1B  F000 61DC 6000 F000 61DA 6001 3180 1CBA 6009 3081 6210 6002 ]
```

```
[ w 1B F000 620B 6003 3312 6227 6004 3293 1C94 600A 3594 61EB 6005 ]
[ w 1B F000 61E9 6006 30A5 61F1 6007 3026 1CEA 600B 34A7 61E2 6000 ]
[ w 1B F000 61E5 6001 31B0 61E7 6002 3231 1CD0 600C 32B2 61F3 6003 ]
[ w 1B F000 61FA 6004 30C3 61FE 6005 31C4 61FC 6006 32C5 7000 F000 ]
[ w 1B 3246 7000 8FE0 F000 2870 D080 8200 7000 AE7E F000 2946 D080 ]
[ w 1B F000 31E4 D280 F000 7000 A002 F000 7000 A0AB F000 2961 D080 ]
[ w 1B F000 7000 9279 F000 7000 8E7A F000 7000 AE64 F000 23BD D280 ]
[ w 1B F000 29B4 D080 F000 23D7 D280 F000 29BA D080 F000 23D5 D280 ]
[ w 1B F000 29BE D080 F000 7000 AF90 F000 29E7 D080 4012 2876 D280 ]
[ w 1B F000 29F4 D180 0040 6000 AEF0 0040 6000 F000 F000 2C7A D780 ]
[ w 1B F000 117C D080 F000 7000 AF7F F000 2A35 D080 0CB2 600D F000 ]
[ w 1B F000 286A D280 F000 1905 D280 F000 0BE9 D280 F000 0BF7 D280 ]
[ w 1B F000 01F1 D280 F000 2A7B D080 F000 23BD D280 F000 2A8A D080 ]
[ w 1B F000 187C D280 F000 2A91 D080 F000 0BF8 D280 F000 0BEC D280 ]
[ w 1B F000 01F5 D280 F000 2A9B D080 6204 6000 F000 4021 2889 D080 ]
[ w 1B F000 2892 D280 F000 7000 A032 6208 6000 F000 4021 2889 D080 ]
[ w 1B F000 7000 A09C F000 117C D280 2B03 6000 8FCE F000 2B0D D280 ]
[ w 1B 620E 6000 F000 4051 2889 D080 F000 7000 AF66 F000 2B14 D080 ]
[ w 1B F000 7000 AE89 F000 2B19 D080 6214 6000 F000 4021 2889 D080 ]
[ w 1B F000 2890 D280 F000 7000 A021 6218 6000 F000 4021 2889 D080 ]
[ w 1B F000 7000 A08C F000 117C D280 2B21 6000 8FBE F000 191F D280 ]
[ w 1B 4001 26EE D280 4011 26F0 D280 4011 26F2 D280 F000 0BF1 D280 ]
[ w 1B F000 0BEC D280 F000 0C00 D280 0080 6000 F000 F000 2C7B D280 ]
[ w 1B 4011 0B90 D780 2B4F 6000 F000 F000 2B4E D080 4021 0B90 D280 ]
[ w 1B F000 1B32 D280 F000 1921 D280 F000 2B58 D080 F000 7000 AF4E ]
[ w 1B F000 2B7A D080 F000 7000 AF4C F000 2BE7 D080 F000 2873 D280 ]
[ w 1B 9C2F 4001 F000 9C0F 0AA7 D180 9A1F 0AA7 D180 F000 0AA7 D180 ]
[ w 1B F000 0A91 D080 0CC4 6008 F000 F000 2C8A D080 4002 4001 802C ]
[ w 1B 4012 4001 802B F000 272E D280 9E38 7000 F000 4131 7000 9404 ]
[ w 1B F000 7000 AE32 4131 7000 9002 F000 7000 AE3E 43E1 7000 8000 ]
[ w 1B F000 6243 6002 4010 2D5D D280 F000 2DB2 D080 F000 2641 D280 ]
[ w 1B F000 2FC2 D280 F000 285A D080 F000 7000 AE34 F000 4010 F000 ]
[ w 1B F000 3214 D080 F000 0D15 6008 F000 1798 6000 F000 1798 6001 ]
[ w 1B 3F80 0DAA 6009 3001 56A5 6002 F000 5E86 6003 1012 5989 6004 ]
[ w 1B 1013 61AD 6005 1014 5C6C 6006 1015 64D3 6007 1016 552D 6000 ]
[ w 1B 1017 5CEB 6001 1010 5804 6002 1011 6004 6003 1012 5ADB 6004 ]
[ w 1B 1013 631D 6005 1014 0DA2 600A 1015 02E1 6006 F000 4314 6007 ]
[ w 1B 1026 045B 6000 1027 4495 6001 1020 05D5 6002 1021 4616 6003 ]
[ w 1B 1022 06AE 6004 1023 0000 6005 1024 7000 F000 1025 7000 D008 ]
[ w 1B 4005 0D4F 600C F000 0209 6003 35C2 08FB 6006 8F4D 3140 F000 ]
[ w 1B 8EC4 2047 9006 8165 7000 F000 8F84 4012 F000 8165 08FB 6003 ]
[ w 1B 8EA9 7000 F000 8EC2 7000 F000 C251 7000 F000 F000 3641 F000 ]
[ w 1B F000 3045 F000 F000 30C7 8030 820A 0061 9009 F000 30E3 D080 ]
[ w 1B 17B1 6008 A032 F000 0002 A031 9082 7000 F000 828A 7000 9003 ]
[ w 1B 908A 7000 9001 F000 7000 8FFB 82BF 7000 F000 F000 01B7 D080 ]
[ w 1B 17A9 600E A02A 4FF6 0061 A029 9041 7000 F000 820A 0061 9004 ]
[ w 1B 918E 7000 97FD 3746 7000 F000 D7B1 17AF 6000 F000 30F3 D080 ]
[ w 1B F000 30E7 D080 2140 3191 D080 F000 2C86 D280 F000 7000 D409 ]
[ w 1B F000 272E D280 9000 7000 D008 0D4F 600C A01C 2642 41D7 A01B ]
[ w 1B 9082 7000 F000 F000 6042 D180 F000 31FE D280 F000 7000 F000 ]
[ w 1B 9000 0DAA 6008 0DB0 6008 E600 F000 306F D280 83FF 00FF 6004 ]
[ w 1B 7FFF 6002 CA86 F000 0001 A011 A209 0080 6003 C261 0DB7 600B ]
[ w 1B 8259 0DB6 600A 8909 7000 F000 8E55 7000 F000 D1CB 4015 9002 ]
[ w 1B 9042 3033 F000 91C6 3027 F000 91CF 7000 F000 C3AF 01B7 D280 ]
[ w 1B D7F3 7000 F000 96EF 7000 8DA0 4010 2FB7 D280 F000 2E60 D280 ]
[ w 1B F000 31BE D080 0D4F 6008 A001 2F00 31F7 D080 F000 7000 D008 ]
[ w 1B F000 3357 D080 F000 3395 D280 F000 62AB D080 F000 178D 6008 ]
[ w 1B F000 4087 6000 F000 202B 6000 1000 202C 6000 1000 0000 6000 ]
[ w 1B F000 1000 F000 F000 1000 F000 F000 1791 6008 F000 0EEE 6000 ]
[ w 1B F000 7000 F000 F000 1000 F000 F000 1792 6008 F000 0000 6000 ]
[ w 1B F000 0D92 6000 1000 0005 6000 1000 1D15 6000 1000 0005 6000 ]
[ w 1B 1000 1D1A 6000 F000 1000 F000 F000 1000 F000 F000 1798 6008 ]
[ w 1B F000 1904 6000 F000 0060 6000 1000 191C 6000 1000 0060 6000 ]
[ w 1B 1000 191F 6000 1000 C05E 6000 1000 1925 6000 1000 C05E 6000 ]
[ w 1B 1000 1E28 6000 1000 C052 6000 1000 1E2D 6000 1000 C052 6000 ]
[ w 1B 1000 2918 6000 1000 C03A 6000 1000 2918 6000 1000 8038 6000 ]
[ w 1B 1000 0000 6000 F000 1000 F000 F000 1000 F000 F000 17A9 6008 ]
[ w 1B F000 02A8 6000 F000 035C 6000 1000 0699 6000 1000 103B 6000 ]
```

```
[ w  1B  1000 1506 6000 1000 0000 6000 F000 1000 F000 F000 1000 F000 ]
[ w  1B  F000 17AF 6008 F000 5504 6000 F000 0003 6000 F000 1000 F000 ]
[ w  1B  F000 1000 F000 F000 17B1 6008 F000 0000 6000 F000 7000 F000 ]
[ w  1B  F000 1000 F000 F000 7000 D008 ]
```

- ```
  [ w  1C  0000 ]
  [ w  1C  0075 ]
  ```
- ```
  [ w  1B  8017 8045 8096 815B 82D6 880B 8810 88DB 8948 8B0A 8B12 8B13 ]
  [ w  1B  8B21 8B26 8C6F 94D0 9520 9533 956F 95A8 95AC 95C3 95E1 97C9 ]
  [ w  1B  97F6 988D 9900 9A00 9E73 A012 A103 A2F0 A30D A34C A352 A3ED ]
  [ w  1B  A831 AB01 AB1F AB4C AC76 AC88 ADB0 ADB7 B055 B0E2 B101 B10B ]
  [ w  1B  B135 B13B B197 B303 ]
  ```
- ```
  [ w  1C  0000 ]
  ```
  ```

6.2.2 Required initialization I²C transmission – C code include file

The following data set (p5.10) is a required part of the V205 boot state device initialization.

The C code in this chapter can be included in the 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 will also be found as part of the PC GUI control program installation (.../documentation/PATCH.c).

```
/*
* Copyright Catena / NXP semiconductors
*  Creation date:       2016 08 08 16:18:38
*  Version:             5.00 - p5.10
*
* 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 80 17 .... 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, 0x60, 0x34, 0xD0, 0x80, 0x20, 0x87, 0x60, 0x3E, 0xD0, 0x80, 0x90, 0x00, 0x60, 0x40, 0xD0, 0x80, 0x22, 0x02, 0x00, 0x55, 0x60, 0x04,
   0xF0, 0x00, 0x60, 0x52, 0xDF, 0x80, 0x20, 0x90, 0x60, 0x68, 0xD0, 0x80, 0x31, 0x40, 0x60, 0x6C, 0xD0, 0x80, 0x9E, 0xB9, 0x60, 0x75, 0xD0, 0x80,
   0xF0, 0x00, 0x60, 0x77, 0xD0, 0x80, 0xF0, 0x00, 0x60, 0x80, 0xD0, 0x80, 0x90, 0x01, 0x60, 0x85, 0xD0, 0x80, 0x91, 0x01, 0x60, 0x86, 0xD0, 0x80,
   0xF0, 0x00, 0x60, 0x87, 0xD0, 0x80, 0xA2, 0x64, 0x70, 0x00, 0xF0, 0x00, 0x31, 0xA0, 0x60, 0xAF, 0xD0, 0x80, 0x20, 0x13, 0x62, 0xA7, 0xD0, 0x80,
   0xF0, 0x00, 0x60, 0xEA, 0xD0, 0x80, 0xF0, 0x00, 0x60, 0xF8, 0xD2, 0x80, 0xF0, 0x00, 0x61, 0x03, 0xD0, 0x80, 0x4F, 0xD0, 0x61, 0x01, 0xD1, 0x80,
   0x9E, 0x73, 0x61, 0x32, 0xD0, 0x80, 0xF0, 0x00, 0x61, 0x3D, 0xD0, 0x80, 0xF0, 0x00, 0x61, 0x45, 0xD0, 0x80, 0xF0, 0x00, 0x61, 0x5A, 0xD0, 0x80,
   0x2C, 0x87, 0x61, 0x66, 0xD0, 0x80, 0xF0, 0x00, 0x61, 0x6A, 0xD0, 0x80, 0xF0, 0x00, 0x61, 0x6D, 0xD2, 0x80, 0xF0, 0x00, 0x70, 0x00, 0xF0, 0x00,
   0xF0, 0x00, 0x61, 0x99, 0xD2, 0x80, 0x57, 0xF2, 0x61, 0x9B, 0xD5, 0x80, 0xA8, 0x80, 0x70, 0x00, 0xF0, 0x00, 0xF0, 0x00, 0x61, 0x9E, 0xD0, 0x80,
   0xF0, 0x00, 0x61, 0xA5, 0xD2, 0x80, 0x4F, 0xA0, 0x61, 0x01, 0xD2, 0x80, 0x4F, 0xC0, 0x61, 0x01, 0xD2, 0x80, 0xF0, 0x00, 0x61, 0xB8, 0xD2, 0x80,
   0x41, 0x20, 0x14, 0xF6, 0xD2, 0x80, 0xF0, 0x00, 0x62, 0x02, 0xD0, 0x80, 0xF0, 0x00, 0x62, 0x12, 0xD0, 0x80, 0xF0, 0x00, 0x62, 0x1B, 0xD0, 0x80,
   0xF0, 0x00, 0x62, 0x2F, 0xD0, 0x80, 0xF0, 0x00, 0x62, 0x35, 0xD0, 0x80, 0xF0, 0x00, 0x62, 0x39, 0xD0, 0x80, 0xF0, 0x00, 0x62, 0x46, 0xD0, 0x80,
   0x2D, 0xC5, 0x18, 0xFF, 0x60, 0x06, 0xF0, 0x00, 0x62, 0x72, 0xD0, 0x80, 0xF0, 0x00, 0x62, 0x74, 0xD0, 0x80, 0x82, 0x09, 0x0D, 0xA2, 0x60, 0x0D,
   0xF0, 0x00, 0x62, 0x86, 0xD2, 0x80, 0xF0, 0x00, 0x62, 0x86, 0xD2, 0x80, 0xF0, 0x00, 0x62, 0x85, 0xD5, 0x80, 0xF0, 0x00, 0x62, 0xA9, 0xD2, 0x80,
   0x82, 0x00, 0x70, 0x00, 0xA0, 0x10, 0x82, 0x00, 0x70, 0x00, 0xA0, 0x2B, 0x82, 0x00, 0x70, 0x00, 0xA0, 0x69, 0x82, 0x00, 0x70, 0x00, 0xA0, 0xAA,
   0x82, 0x00, 0x70, 0x00, 0xA2, 0x6E, 0x82, 0x00, 0x70, 0x00, 0xA1, 0x7A, 0x82, 0x00, 0x70, 0x00, 0xA1, 0x84, 0x82, 0x00, 0x70, 0x00, 0xA2, 0x0D,
   0x82, 0x00, 0x70, 0x00, 0xA2, 0x6A, 0xF0, 0x00, 0x27, 0xAA, 0xD0, 0x80, 0xF0, 0x00, 0x01, 0xA9, 0xD5, 0x80, 0x8C, 0x79, 0x00, 0x46, 0xD0, 0x80,
   0xF0, 0x00, 0x70, 0x00, 0xD4, 0x09, 0xF0, 0x00, 0x00, 0x97, 0xD0, 0x80, 0x40, 0x11, 0x0E, 0x72, 0x60, 0x09, 0xD0, 0x7F, 0x70, 0x00, 0xF0, 0x00,
   0xC5, 0xC9, 0x01, 0xB6, 0xD0, 0x80, 0x05, 0x44, 0x60, 0x08, 0xA2, 0x61, 0xF0, 0x00, 0x30, 0x80, 0xD0, 0x08, 0xF0, 0x00, 0x07, 0x69, 0x60, 0x08,
   0xF0, 0x00, 0x05, 0x19, 0x60, 0x09, 0xF0, 0x00, 0x20, 0x00, 0xF0, 0x00, 0x26, 0x92, 0x54, 0xA3, 0x60, 0x01, 0xA2, 0x00, 0x70, 0x00, 0xF0, 0x00,
   0xA2, 0x08, 0x70, 0x00, 0xF0, 0x00, 0xA2, 0x10, 0x70, 0x00, 0xF0, 0x00, 0xD8, 0x40, 0x70, 0x00, 0xF0, 0x00, 0xF0, 0x00, 0x34, 0x90, 0xF0, 0x00,
   0xF0, 0x00, 0x35, 0x90, 0xF0, 0x00, 0xF0, 0x00, 0x36, 0x90, 0xD0, 0x08, 0x40, 0x15, 0x20, 0x53, 0xA2, 0x54, 0xA0, 0xE8, 0x58, 0x06, 0xA2, 0x53,
   0xA0, 0x72, 0x20, 0x64, 0xF0, 0x00, 0xA8, 0x61, 0x70, 0x00, 0xF0, 0x00, 0xA1, 0x28, 0x70, 0x00, 0xF0, 0x00, 0xA0, 0xB2, 0x70, 0x00, 0xF0, 0x00,
   0xA8, 0x62, 0x70, 0x00, 0xD0, 0x08, 0x05, 0x79, 0x60, 0x08, 0x82, 0x4E, 0xF0, 0x00, 0x10, 0x68, 0x60, 0x01, 0xF0, 0x00, 0x60, 0x03, 0x80, 0x02,
   0xF0, 0x00, 0x08, 0x34, 0x60, 0x01, 0xF8, 0x00, 0x60, 0x03, 0x80, 0x00, 0x18, 0x31, 0x60, 0x08, 0xA2, 0x48, 0xF0, 0x00, 0x30, 0x01, 0xF0, 0x00,
   0xF0, 0x00, 0x31, 0x03, 0xD0, 0x08, 0xF0, 0x00, 0x1D, 0x10, 0x60, 0x09, 0x40, 0x11, 0x7F, 0xFF, 0x60, 0x02, 0xF0, 0x00, 0x30, 0x10, 0xF0, 0x00,
   0xF0, 0x00, 0x30, 0x92, 0xF0, 0x00, 0xF0, 0x00, 0x31, 0x11, 0xF0, 0x00, 0x1D, 0x0F, 0x60, 0x08, 0xA2, 0x41, 0xF0, 0x00, 0x70, 0x00, 0x82, 0x3F,
   0x9A, 0x62, 0x1D, 0x0F, 0x60, 0x0A, 0x82, 0x92, 0x70, 0x00, 0x94, 0x01, 0x90, 0x8A, 0x00, 0x00, 0x60, 0x01, 0x30, 0x22, 0x08, 0x0C, 0xD0, 0x80,
   0xF0, 0x00, 0x09, 0x44, 0xD2, 0x80, 0xF0, 0x00, 0x07, 0xFD, 0xD2, 0x80, 0xF0, 0x00, 0x08, 0x11, 0xD0, 0x80, 0xF0, 0x00, 0x18, 0x72, 0x60, 0x08,
   0xF0, 0x00, 0x1D, 0x0F, 0x60, 0x09, 0xF0, 0x00, 0x2D, 0x80, 0xA2, 0x35, 0x9A, 0x02, 0x20, 0x11, 0xF0, 0x00, 0x90, 0x8A, 0x70, 0x00, 0xD0, 0x09,
   0x90, 0x41, 0x70, 0x00, 0xD0, 0x08, 0x90, 0xC1, 0x08, 0xEC, 0xD1, 0x80, 0xF0, 0x00, 0x08, 0xDC, 0xD0, 0x80, 0xF0, 0x00, 0x1D, 0x0F, 0x60, 0x0A,
   0xF0, 0x00, 0x70, 0x00, 0xF0, 0x00, 0x20, 0x23, 0x70, 0x00, 0xA2, 0x2D, 0x80, 0x59, 0x09, 0x49, 0xD0, 0x80, 0xF0, 0x00, 0x03, 0x13, 0x60, 0x06,
   0xF0, 0x00, 0x70, 0x00, 0x80, 0x01, 0xF0, 0x00, 0xFC, 0xED, 0x60, 0x06, 0x1D, 0x10, 0x60, 0x0E, 0xA2, 0x28, 0xF0, 0x00, 0x30, 0x66, 0xD0, 0x08,
   0x1D, 0x0F, 0x60, 0x0B, 0xA2, 0x26, 0xF0, 0x00, 0x20, 0x37, 0xA2, 0x25, 0x91, 0xC7, 0x21, 0x91, 0xF0, 0x00, 0x90, 0xC3, 0x0B, 0x0B, 0xD1, 0x80,
   0x82, 0x49, 0x0B, 0x14, 0xD0, 0x80, 0x31, 0x91, 0x0B, 0x14, 0xD0, 0x80, 0x31, 0x91, 0x0B, 0x14, 0xD0, 0x80, 0x1D, 0x10, 0x60, 0x0D, 0xA2, 0x1F,
   0xF0, 0x00, 0x21, 0x57, 0xA2, 0x1E, 0x91, 0xC7, 0x31, 0x50, 0xF0, 0x00, 0x90, 0x00, 0x70, 0x00, 0x94, 0x02, 0xF0, 0x00, 0x70, 0x00, 0x90, 0x01,
   0xF0, 0x00, 0x70, 0x00, 0xAF, 0xEE, 0xF0, 0x00, 0x7F, 0xFF, 0x60, 0x04, 0x82, 0x00, 0x20, 0x57, 0xA2, 0x18, 0x91, 0xC7, 0x20, 0xD3, 0xA2, 0x17,
   0x80, 0xFB, 0x70, 0x00, 0x90, 0x06, 0x82, 0xE2, 0x30, 0xD3, 0x98, 0x01, 0xF0, 0x00, 0x70, 0x00, 0x98, 0x04, 0x91, 0xC7, 0x30, 0x50, 0xF0, 0x00,
   0x91, 0x00, 0x70, 0x00, 0xE1, 0xC0, 0x30, 0xD0, 0x70, 0x00, 0xF0, 0x00, 0x90, 0x03, 0x70, 0x00, 0xF0, 0x00, 0xA2, 0xED, 0x70, 0x00, 0xF0, 0x00,
   0xA2, 0xF6, 0x31, 0x05, 0xF0, 0x00, 0xF0, 0x00, 0x0B, 0x22, 0xD0, 0x80, 0xF0, 0x00, 0x0B, 0xFD, 0xD2, 0x80, 0xF0, 0x00, 0x70, 0x00, 0x98, 0xB7,
   0xF0, 0x00, 0x70, 0x00, 0x80, 0xB9, 0xF0, 0x00, 0x2D, 0xBB, 0xD0, 0x80, 0xF0, 0x00, 0x70, 0x00, 0x80, 0xE2, 0xF0, 0x00, 0x70, 0x00, 0x80, 0xE5,
   0x83, 0xFF, 0x1D, 0x13, 0x60, 0x08, 0xF0, 0x00, 0x1D, 0x15, 0x60, 0x09, 0x10, 0x07, 0x00, 0x00, 0x60, 0x02, 0x10, 0x07, 0x01, 0xF4, 0x60, 0x03,
   0x10, 0x12, 0x03, 0xE8, 0x60, 0x04, 0x10, 0x13, 0x00, 0x00, 0x60, 0x05, 0x10, 0x14, 0x00, 0x3C, 0x60, 0x06, 0x10, 0x15, 0x00, 0x00, 0x60, 0x07,
   0x10, 0x16, 0x01, 0xF4, 0x60, 0x00, 0x10, 0x17, 0x03, 0xE8, 0x60, 0x01, 0x10, 0x10, 0x00, 0x00, 0x60, 0x00, 0x10, 0x11, 0x00, 0x3C, 0x60, 0x01,
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0xF0, 0x00, 0x29, 0xBE, 0xD0, 0x80, 0xF0, 0x00, 0x70, 0x00, 0xAF, 0x90, 0xF0, 0x00, 0x29, 0xE7, 0xD0, 0x80, 0x40, 0x12, 0x28, 0x76, 0xD2, 0x80,
0xF0, 0x00, 0x29, 0xF4, 0xD1, 0x80, 0x00, 0x40, 0x60, 0x00, 0xAE, 0xF0, 0x00, 0x40, 0x60, 0x00, 0xF0, 0x00, 0xF0, 0x00, 0x2C, 0x7A, 0xD7, 0x80,
0xF0, 0x00, 0x11, 0x7C, 0xD0, 0x80, 0xF0, 0x00, 0x70, 0x00, 0xAF, 0x7F, 0xF0, 0x00, 0x2A, 0x35, 0xD0, 0x80, 0x0C, 0xB2, 0x60, 0x0D, 0xF0, 0x00,
0xF0, 0x00, 0x28, 0x6A, 0xD2, 0x80, 0xF0, 0x00, 0x19, 0x05, 0xD2, 0x80, 0xF0, 0x00, 0x0B, 0xE9, 0xD2, 0x80, 0xF0, 0x00, 0x0B, 0xF7, 0xD2, 0x80,
0xF0, 0x00, 0x01, 0xF1, 0xD2, 0x80, 0xF0, 0x00, 0x2A, 0x7B, 0xD0, 0x80, 0xF0, 0x00, 0x23, 0xBD, 0xD2, 0x80, 0xF0, 0x00, 0x2A, 0x8A, 0xD0, 0x80,
0xF0, 0x00, 0x18, 0x7C, 0xD2, 0x80, 0xF0, 0x00, 0x2A, 0x91, 0xD0, 0x80, 0xF0, 0x00, 0x0B, 0xF8, 0xD2, 0x80, 0xF0, 0x00, 0x0B, 0xEC, 0xD2, 0x80,
0xF0, 0x00, 0x01, 0xF5, 0xD2, 0x80, 0xF0, 0x00, 0x2A, 0x9B, 0xD0, 0x80, 0x62, 0x04, 0x60, 0x00, 0xF0, 0x00, 0x40, 0x21, 0x28, 0x89, 0xD0, 0x80,
0xF0, 0x00, 0x28, 0x92, 0xD2, 0x80, 0xF0, 0x00, 0x70, 0x00, 0xA0, 0x32, 0x62, 0x08, 0x60, 0x00, 0xF0, 0x00, 0x40, 0x21, 0x28, 0x89, 0xD0, 0x80,
0xF0, 0x00, 0x70, 0x00, 0xA0, 0x9C, 0xF0, 0x00, 0x11, 0x7C, 0xD2, 0x80, 0x2B, 0x03, 0x60, 0x00, 0x8F, 0xCE, 0xF0, 0x00, 0x2B, 0x0D, 0xD2, 0x80,
0x62, 0x0E, 0x60, 0x00, 0xF0, 0x00, 0x40, 0x51, 0x28, 0x89, 0xD0, 0x80, 0xF0, 0x00, 0x70, 0x00, 0xAF, 0x66, 0xF0, 0x00, 0x2B, 0x14, 0xD0, 0x80,
0xF0, 0x00, 0x70, 0x00, 0xAE, 0x89, 0xF0, 0x00, 0x2B, 0x19, 0xD0, 0x80, 0x62, 0x14, 0x60, 0x00, 0xF0, 0x00, 0x40, 0x21, 0x28, 0x89, 0xD0, 0x80,
0xF0, 0x00, 0x28, 0x90, 0xD2, 0x80, 0xF0, 0x00, 0x70, 0x00, 0xA0, 0x21, 0x62, 0x18, 0x60, 0x00, 0xF0, 0x00, 0x40, 0x21, 0x28, 0x89, 0xD0, 0x80,
0xF0, 0x00, 0x70, 0x00, 0xA0, 0x8C, 0xF0, 0x00, 0x11, 0x7C, 0xD2, 0x80, 0x2B, 0x21, 0x60, 0x00, 0x8F, 0xBE, 0xF0, 0x00, 0x19, 0x1F, 0xD2, 0x80,
0x40, 0x01, 0x26, 0xEE, 0xD2, 0x80, 0x40, 0x11, 0x26, 0xF0, 0xD2, 0x80, 0x40, 0x11, 0x26, 0xF2, 0xD2, 0x80, 0xF0, 0x00, 0x0B, 0xF1, 0xD2, 0x80,
0xF0, 0x00, 0x0B, 0xEC, 0xD2, 0x80, 0xF0, 0x00, 0x0C, 0x00, 0xD2, 0x80, 0x00, 0x80, 0x60, 0x00, 0xF0, 0x00, 0xF0, 0x00, 0x2C, 0x7B, 0xD2, 0x80,
0x40, 0x11, 0x0B, 0x90, 0xD7, 0x80, 0x2B, 0x4F, 0x60, 0x00, 0xF0, 0x00, 0xF0, 0x00, 0x2B, 0x4E, 0xD0, 0x80, 0x40, 0x21, 0x0B, 0x90, 0xD2, 0x80,
0xF0, 0x00, 0x1B, 0x32, 0xD2, 0x80, 0xF0, 0x00, 0x19, 0x21, 0xD2, 0x80, 0xF0, 0x00, 0x2B, 0x58, 0xD0, 0x80, 0xF0, 0x00, 0x70, 0x00, 0xAF, 0x4E,
0xF0, 0x00, 0x2B, 0x7A, 0xD0, 0x80, 0xF0, 0x00, 0x70, 0x00, 0xAF, 0x4C, 0xF0, 0x00, 0x2B, 0xE7, 0xD0, 0x80, 0xF0, 0x00, 0x28, 0x73, 0xD2, 0x80,
0x9C, 0x2F, 0x40, 0x01, 0xF0, 0x00, 0x9C, 0x0F, 0x0A, 0xA7, 0xD1, 0x80, 0x9A, 0x1F, 0x0A, 0xA7, 0xD1, 0x80, 0xF0, 0x00, 0x0A, 0xA7, 0xD1, 0x80,
0xF0, 0x00, 0x0A, 0x91, 0xD0, 0x80, 0x0C, 0xC4, 0x60, 0x08, 0xF0, 0x00, 0xF0, 0x00, 0x2C, 0x8A, 0xD0, 0x80, 0x40, 0x02, 0x40, 0x01, 0x80, 0x2C,
0x40, 0x12, 0x40, 0x01, 0x80, 0x2B, 0xF0, 0x00, 0x27, 0x2E, 0xD2, 0x80, 0x9E, 0x38, 0x70, 0x00, 0xF0, 0x00, 0x41, 0x31, 0x70, 0x00, 0x94, 0x04,
0xF0, 0x00, 0x70, 0x00, 0xAE, 0x32, 0x41, 0x31, 0x70, 0x00, 0x90, 0x02, 0xF0, 0x00, 0x70, 0x00, 0xAE, 0x3E, 0x43, 0xE1, 0x70, 0x00, 0x80, 0x00,
0xF0, 0x00, 0x62, 0x43, 0x60, 0x02, 0x40, 0x10, 0x2D, 0x5D, 0xD2, 0x80, 0xF0, 0x00, 0x2D, 0xB2, 0xD0, 0x80, 0xF0, 0x00, 0x26, 0x41, 0xD2, 0x80,
0xF0, 0x00, 0x2F, 0xC2, 0xD2, 0x80, 0xF0, 0x00, 0x28, 0x5A, 0xD0, 0x80, 0xF0, 0x00, 0x70, 0x00, 0xAE, 0x34, 0xF0, 0x00, 0x40, 0x10, 0xF0, 0x00,
0xF0, 0x00, 0x32, 0x14, 0xD0, 0x80, 0xF0, 0x00, 0x0D, 0x15, 0x60, 0x08, 0xF0, 0x00, 0x17, 0x98, 0x60, 0x00, 0xF0, 0x00, 0x17, 0x98, 0x60, 0x01,
0x3F, 0x80, 0x0D, 0xAA, 0x60, 0x09, 0x30, 0x01, 0x56, 0xA5, 0x60, 0x02, 0xF0, 0x00, 0x5E, 0x86, 0x60, 0x03, 0x10, 0x12, 0x59, 0x89, 0x60, 0x04,
```

```
   0x10, 0x13, 0x61, 0xAD, 0x60, 0x05, 0x10, 0x14, 0x5C, 0x6C, 0x60, 0x06, 0x10, 0x15, 0x64, 0xD3, 0x60, 0x07, 0x10, 0x16, 0x55, 0x2D, 0x60, 0x00,
   0x10, 0x17, 0x5C, 0xEB, 0x60, 0x01, 0x10, 0x10, 0x58, 0x04, 0x60, 0x02, 0x10, 0x11, 0x60, 0x04, 0x60, 0x03, 0x10, 0x12, 0x5A, 0xDB, 0x60, 0x04,
   0x10, 0x13, 0x63, 0x1D, 0x60, 0x05, 0x10, 0x14, 0x0D, 0xA2, 0x60, 0x0A, 0x10, 0x15, 0x02, 0xE1, 0x60, 0x06, 0xF0, 0x00, 0x43, 0x14, 0x60, 0x07,
   0x10, 0x26, 0x04, 0x5B, 0x60, 0x00, 0x10, 0x27, 0x44, 0x95, 0x60, 0x01, 0x10, 0x20, 0x05, 0xD5, 0x60, 0x02, 0x10, 0x21, 0x46, 0x16, 0x60, 0x03,
   0x10, 0x22, 0x06, 0xAE, 0x60, 0x04, 0x10, 0x23, 0x00, 0x00, 0x60, 0x05, 0x10, 0x24, 0x70, 0x00, 0xF0, 0x00, 0x10, 0x25, 0x70, 0x00, 0xD0, 0x08,
   0x40, 0x05, 0x0D, 0x4F, 0x60, 0x0C, 0xF0, 0x00, 0x02, 0x09, 0x60, 0x03, 0x35, 0xC2, 0x08, 0xFB, 0x60, 0x06, 0x8F, 0x4D, 0x31, 0x40, 0xF0, 0x00,
   0x8E, 0xC4, 0x20, 0x47, 0x90, 0x06, 0x81, 0x65, 0x70, 0x00, 0xF0, 0x00, 0x8F, 0x84, 0x40, 0x12, 0xF0, 0x00, 0x81, 0x65, 0x08, 0xFB, 0x60, 0x03,
   0x8E, 0xA9, 0x70, 0x00, 0xF0, 0x00, 0x8E, 0xC2, 0x70, 0x00, 0xF0, 0x00, 0xC2, 0x51, 0x70, 0x00, 0xF0, 0x00, 0xF0, 0x00, 0x36, 0x41, 0xF0, 0x00,
   0xF0, 0x00, 0x30, 0x45, 0xF0, 0x00, 0xF0, 0x00, 0x30, 0xC7, 0x80, 0x30, 0x82, 0x0A, 0x00, 0x61, 0x90, 0x09, 0xF0, 0x00, 0x30, 0xE3, 0xD0, 0x80,
   0x17, 0xB1, 0x60, 0x08, 0xA0, 0x32, 0xF0, 0x00, 0x00, 0x02, 0xA0, 0x31, 0x90, 0x82, 0x70, 0x00, 0xF0, 0x00, 0x82, 0x8A, 0x70, 0x00, 0x90, 0x03,
   0x90, 0x8A, 0x70, 0x00, 0x90, 0x01, 0xF0, 0x00, 0x70, 0x00, 0x8F, 0xFB, 0x82, 0xBF, 0x70, 0x00, 0xF0, 0x00, 0xF0, 0x00, 0x01, 0xB7, 0xD0, 0x80,
   0x17, 0xA9, 0x60, 0x0E, 0xA0, 0x2A, 0x4F, 0xF6, 0x00, 0x61, 0xA0, 0x29, 0x90, 0x41, 0x70, 0x00, 0xF0, 0x00, 0x82, 0x0A, 0x00, 0x61, 0x90, 0x04,
   0x91, 0x8E, 0x70, 0x00, 0x97, 0xFD, 0x37, 0x46, 0x70, 0x00, 0xF0, 0x00, 0xD7, 0xB1, 0x17, 0xAF, 0x60, 0x00, 0xF0, 0x00, 0x30, 0xF3, 0xD0, 0x80,
   0xF0, 0x00, 0x30, 0xE7, 0xD0, 0x80, 0x21, 0x40, 0x31, 0x91, 0xD0, 0x80, 0xF0, 0x00, 0x2C, 0x86, 0xD2, 0x80, 0xF0, 0x00, 0x70, 0x00, 0xD4, 0x09,
   0xF0, 0x00, 0x27, 0x2E, 0xD2, 0x80, 0x90, 0x00, 0x70, 0x00, 0xD0, 0x08, 0x0D, 0x4F, 0x60, 0x0C, 0xA0, 0x1C, 0x26, 0x42, 0x41, 0xD7, 0xA0, 0x1B,
   0x90, 0x82, 0x70, 0x00, 0xF0, 0x00, 0xF0, 0x00, 0x60, 0x42, 0xD1, 0x80, 0xF0, 0x00, 0x31, 0xFE, 0xD2, 0x80, 0xF0, 0x00, 0x70, 0x00, 0xF0, 0x00,
   0x90, 0x00, 0x0D, 0xAA, 0x60, 0x08, 0x0D, 0xB0, 0x60, 0x08, 0xE6, 0x00, 0xF0, 0x00, 0x30, 0x6F, 0xD2, 0x80, 0x83, 0xFF, 0x00, 0xFF, 0x60, 0x04,
   0x7F, 0xFF, 0x60, 0x02, 0xCA, 0x86, 0xF0, 0x00, 0x00, 0x01, 0xA0, 0x11, 0xA2, 0x09, 0x00, 0x80, 0x60, 0x03, 0xC2, 0x61, 0x0D, 0xB7, 0x60, 0x0B,
   0x82, 0x59, 0x0D, 0xB6, 0x60, 0x0A, 0x89, 0x09, 0x70, 0x00, 0xF0, 0x00, 0x8E, 0x55, 0x70, 0x00, 0xF0, 0x00, 0xD1, 0xCB, 0x40, 0x15, 0x90, 0x02,
   0x90, 0x42, 0x30, 0x33, 0xF0, 0x00, 0x91, 0xC6, 0x30, 0x27, 0xF0, 0x00, 0x91, 0xCF, 0x70, 0x00, 0xF0, 0x00, 0xC3, 0xAF, 0x01, 0xB7, 0xD2, 0x80,
   0xD7, 0xF3, 0x70, 0x00, 0xF0, 0x00, 0x96, 0xEF, 0x70, 0x00, 0x8D, 0xA0, 0x40, 0x10, 0x2F, 0xB7, 0xD2, 0x80, 0xF0, 0x00, 0x2E, 0x60, 0xD2, 0x80,
   0xF0, 0x00, 0x31, 0xBE, 0xD0, 0x80, 0x0D, 0x4F, 0x60, 0x08, 0xA0, 0x01, 0x2F, 0x00, 0x31, 0xF7, 0xD0, 0x80, 0xF0, 0x00, 0x70, 0x00, 0xD0, 0x08,
   0xF0, 0x00, 0x33, 0x57, 0xD0, 0x80, 0xF0, 0x00, 0x33, 0x95, 0xD2, 0x80, 0xF0, 0x00, 0x62, 0xAB, 0xD0, 0x80, 0xF0, 0x00, 0x17, 0x8D, 0x60, 0x08,
   0xF0, 0x00, 0x40, 0x87, 0x60, 0x00, 0xF0, 0x00, 0x20, 0x2B, 0x60, 0x00, 0x10, 0x00, 0x20, 0x2C, 0x60, 0x00, 0x10, 0x00, 0x00, 0x00, 0x60, 0x00,
   0xF0, 0x00, 0x10, 0x00, 0xF0, 0x00, 0xF0, 0x00, 0x10, 0x00, 0xF0, 0x00, 0xF0, 0x00, 0x17, 0x91, 0x60, 0x08, 0xF0, 0x00, 0x0E, 0xEE, 0x60, 0x00,
   0xF0, 0x00, 0x70, 0x00, 0xF0, 0x00, 0xF0, 0x00, 0x10, 0x00, 0xF0, 0x00, 0xF0, 0x00, 0x17, 0x92, 0x60, 0x08, 0xF0, 0x00, 0x00, 0x00, 0x60, 0x00,
   0xF0, 0x00, 0x0D, 0x92, 0x60, 0x00, 0x10, 0x00, 0x00, 0x05, 0x60, 0x00, 0x10, 0x00, 0x1D, 0x15, 0x60, 0x00, 0x10, 0x00, 0x00, 0x05, 0x60, 0x00,
   0x10, 0x00, 0x1D, 0x1A, 0x60, 0x00, 0xF0, 0x00, 0x10, 0x00, 0xF0, 0x00, 0xF0, 0x00, 0x10, 0x00, 0xF0, 0x00, 0xF0, 0x00, 0x17, 0x98, 0x60, 0x08,
   0xF0, 0x00, 0x19, 0x04, 0x60, 0x00, 0xF0, 0x00, 0x00, 0x60, 0x60, 0x00, 0x10, 0x00, 0x19, 0x1C, 0x60, 0x00, 0x10, 0x00, 0x00, 0x60, 0x60, 0x00,
   0x10, 0x00, 0x19, 0x1F, 0x60, 0x00, 0x10, 0x00, 0xC0, 0x5E, 0x60, 0x00, 0x10, 0x00, 0x19, 0x25, 0x60, 0x00, 0x10, 0x00, 0xC0, 0x5E, 0x60, 0x00,
   0x10, 0x00, 0x1E, 0x28, 0x60, 0x00, 0x10, 0x00, 0xC0, 0x52, 0x60, 0x00, 0x10, 0x00, 0x1E, 0x2D, 0x60, 0x00, 0x10, 0x00, 0xC0, 0x52, 0x60, 0x00,
   0x10, 0x00, 0x29, 0x18, 0x60, 0x00, 0x10, 0x00, 0xC0, 0x3A, 0x60, 0x00, 0x10, 0x00, 0x29, 0x18, 0x60, 0x00, 0x10, 0x00, 0x80, 0x38, 0x60, 0x00,
   0x10, 0x00, 0x00, 0x00, 0x60, 0x00, 0xF0, 0x00, 0x10, 0x00, 0xF0, 0x00, 0xF0, 0x00, 0x10, 0x00, 0xF0, 0x00, 0xF0, 0x00, 0x17, 0xA9, 0x60, 0x08,
   0xF0, 0x00, 0x02, 0xA8, 0x60, 0x00, 0xF0, 0x00, 0x03, 0x5C, 0x60, 0x00, 0x10, 0x00, 0x06, 0x99, 0x60, 0x00, 0x10, 0x00, 0x10, 0x3B, 0x60, 0x00,
   0x10, 0x00, 0x15, 0x06, 0x60, 0x00, 0x10, 0x00, 0x00, 0x00, 0x60, 0x00, 0xF0, 0x00, 0x10, 0x00, 0xF0, 0x00, 0xF0, 0x00, 0x10, 0x00, 0xF0, 0x00,
   0xF0, 0x00, 0x17, 0xAF, 0x60, 0x08, 0xF0, 0x00, 0x55, 0x04, 0x60, 0x00, 0xF0, 0x00, 0x00, 0x03, 0x60, 0x00, 0xF0, 0x00, 0x10, 0x00, 0xF0, 0x00,
   0xF0, 0x00, 0x10, 0x00, 0xF0, 0x00, 0xF0, 0x00, 0x17, 0xB1, 0x60, 0x08, 0xF0, 0x00, 0x00, 0x00, 0x60, 0x00, 0xF0, 0x00, 0x70, 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[] =
{
   0x80, 0x17, 0x80, 0x45, 0x80, 0x96, 0x81, 0x5B,
   0x82, 0xD6, 0x88, 0x0B, 0x88, 0x10, 0x88, 0xDB,
   0x89, 0x48, 0x8B, 0x0A, 0x8B, 0x12, 0x8B, 0x13,
   0x8B, 0x21, 0x8B, 0x26, 0x8C, 0x6F, 0x94, 0xD0,
   0x95, 0x20, 0x95, 0x33, 0x95, 0x6F, 0x95, 0xA8,
   0x95, 0xAC, 0x95, 0xC3, 0x95, 0xE1, 0x97, 0xC9,
   0x97, 0xF6, 0x98, 0x8D, 0x99, 0x00, 0x9A, 0x00,
   0x9E, 0x73, 0xA0, 0x12, 0xA1, 0x03, 0xA2, 0xF0,
   0xA3, 0x0D, 0xA3, 0x4C, 0xA3, 0x52, 0xA3, 0xED,
   0xA8, 0x31, 0xAB, 0x01, 0xAB, 0x1F, 0xAB, 0x4C,
   0xAC, 0x76, 0xAC, 0x88, 0xAD, 0xB0, 0xAD, 0xB7,
   0xB0, 0x55, 0xB0, 0xE2, 0xB1, 0x01, 0xB1, 0x0B,
   0xB1, 0x35, 0xB1, 0x3B, 0xB1, 0x97, 0xB3, 0x03
};

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

6.2.3 Required initialization I²C transmission – version p5.10

Initialization version p5.10 is a required part of the V205 device startup.
Version p5.10 is for use with V205 only.

Initialization version p5.10 offers the following updates over earlier releases:

Fix

- Resolved issue of possible distorted I²S audio input and output signal after radio tuning.

New feature

- Extension of FM band tuning to 64 MHz.

Version V205 is equivalent to the previous product device version V102 plus p2.24 initialization but including important new features and functions:

- Command parameter index support for single parameter write or range write
- Read data index support for single data word read or data range read
- RDS 'FULL SEARCH' decoder
- RDS buffer flush option
- Digital radio I²S current output option
- Audio I²S current output option
- GPIO 3 option
- 55.46667 MHz crystal option
- Optional fixed highcut and fixed lowcut filter
- FM antenna signal options

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 (clock loss or clock disturbance) the device will be reset and boot state will be available again 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 I/O pins are high impedance.
- 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 V205 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 case of a harmful disruption of the power supply voltage (power dip) or reference clock signal (clock loss or clock disturbance) the idle state operation will be reset and boot state will be available after power supply voltage and reference signal are re-established.

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.
- Pins GPIO_1, GPIO_2 and DR_BL are high impedance.
- Audio I²S pins, digital radio I²S pins and pins GPIO_0 and GPIO_3 are in 'weak pull down' state (50 kΩ internal impedance to ground).
- 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'.

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

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')
- In 'radio standby' operation the GPIO and DR pins are disabled, equal to the idle state condition. Pin states however can be pre-configured for later FM and AM operation use.
- In 'radio standby' operation full AUDIO functionality is available and audio I²S pins can be configured for use.
- In FM / AM operation pins are in their selected FM or AM state or are in their disabled state when not configured.

- In ‘radio standby’ operation after FM or AM operation the GPIO and DR pins return to their disabled state .
- 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.

6.3.4 Overview of digital I/O pin operation modes

An overview of default pin operation modes and available command options can be found from the below table.

pin	boot	idle	active	active state pin modes set by command control options	
11 DR_BL	Z	Z	Z	MF_in	FM/AM 30 Set_DigitalRadio, mode = 1 (on)
12 DR_WS 13 DR_BCK	Z	wpd	wpd	VG_o20 / VG_o6 … 31 / MF_oF	FM/AM 30 Set_DigitalRadio, mode = 1 (on) FM/AM 84 Set_DR_Options, mode[15:8] = 51 / 187…255 / 34
14 DR_Q_DATA	Z	wpd	wpd	VG_o20 / VG_o6 … 31 / MF_oF / od_out	FM/AM 30 Set_DigitalRadio, mode = 1 (on) FM/AM 84 Set_DR_Options, format = 4-wire FM/AM 84 Set_DR_Options. mode[7:0] = 3 / 11…15 / 2 / 4
15 DR_I_DATA	Z	wpd	wpd	VG_o20 / VG_o6 … 31 / MF_oF / od_out	FM/AM 30 Set_DigitalRadio, mode = 1 (on) FM/AM 84 Set_DR_Options. mode[7:0] = 3 / 11…15 / 2 / 4
16 I2S_SD_0	Z	wpd	wpd	VG_in	AUDIO 22 Set_Dig_IO, signal = 32, mode = 1 (current input)
17 I2S_WS 18 I2S_BCK	Z	wpd	wpd	VG_in	AUDIO 22 Set_Dig_IO, operation = 0 (audio slave)
				VG_o6 / VG_o6 … 31 / MF_oM	AUDIO 22 Set_Dig_IO, operation = 273 / 443…511 / 256
19 I2S_SD_1	Z	wpd	wpd	VG_o6 / VG_o6 … 31 / MF_oM	AUDIO 22 Set_Dig_IO, signal = 33, mode = 3 / 11…15 / 2
20 GPIO_3	Z	wpd	wpd	MF_oM	AUDIO 22 Set_Dig_IO, signal = 33, mode = 2
				MF_in / MF_oL	APPL 3 Set_GPIO, pin = 3, feature = 1 / 2…
26 GPIO_2	Z	wpd	wpd	MF_in / MF_oL	APPL 3 Set_GPIO, pin = 2, feature = 1 / 2…
27 GPIO_1	Z	wpd	wpd	MF_in / MF_oL	APPL 3 Set_GPIO, pin = 1, feature = 1 / 2…
28 GPIO_0	Z	wpd	wpd	MF_in / MF_oL	APPL 3 Set_GPIO, pin = 0, feature = 1 / 2…

Depending on the pin function the following pin modes may be available:

Z = high impedance

wpd = weak pull down (50 kΩ internal impedance to ground)

VG_in = current input (virtual ground input)

MF_in = voltage input (high impedance CMOS input)

VG_o6 ... 31 = current output (virtual ground output with optional current value setting)

MF_oL, M, F = voltage output (low impedance CMOS output with controlled slew rate low, medium, fast)

The pin operation mode of the different available I/O pins is defined by default behavior during start-up for ‘boot state’, ‘idle state’ and ‘active state’, as described in the previous chapters 6.3.1, 6.3.2 and 6.3.3. After enabling of ‘active state’ control commands are available to define the functional behavior and operation mode of the available I/O pins.

Digital radio output pins are enabled by 3.10 FM cmd 30 Set_DigitalRadio and 3.36 AM cmd 30 Set_DigitalRadio with additional pin mode control available from commands 3.25 FM cmd 84 Set_DR_Options and 3.46 AM cmd 84 Set_DR_Options.

Command 3.53 AUDIO cmd 22 Set_Dig_IO can be used to control audio I^2S operation and 3.57 APPL cmd 3 Set_GPIO offers general purpose I/O pin mode control.

7. Overview of available commands

Table 1. FM module command overview - write

	module	cmd					
3.1	FM	1	**Tune_To**	mode	frequency [kHz]		
3.2	FM	2	**Set_Tune_Options**	afu_bw_mode	afu_bandw [kHz]	mute_time	sample_time
3.3	FM	10	**Set_Bandwidth**	mode	bandwidth [kHz]	sensitivity [%]	lo_sensitivity [%]
				min_bandwidth	nom. bandwidth	control_attack	
3.4	FM	11	**Set_RFAGC**	start [dBuV]	extension		
3.5	FM	12	**Set_Antenna**	attenuation [dB]	off_mode		
3.6	FM	20	**Set_MphSuppression**	mode			
3.7	FM	22	**Set_ChannelEqualizer**	mode			
3.8	FM	23	**Set_NoiseBlanker**	mode	sensitivity [%]	level_sensitivity	modulation
				offset	attack	decay	
3.9	FM	24	**Set_NoiseBlanker_Options**	blank_time	blank_time2	blank_mod	blank_time_level
3.10	FM	30	**Set_DigitalRadio**	mode			
3.11	FM	31	**Set_Deemphasis**	timeconstant			
3.12	FM	32	**Set_StereoImprovement**	mode			
3.13	FM	33	**Set_Highcut_Fix**	mode	limit [Hz]		
3.14	FM	34	**Set_Lowcut_Fix**	mode	limit [Hz]		
3.15	FM	38	**Set_LevelStep**	step1 [dB]	step2 [dB]	step3 [dB]	step4 [dB]
				step5 [dB]	step6 [dB]	step7 [dB]	
3.16	FM	39	**Set_LevelOffset**	offset [dB]			
3.17	FM	40	**Set_Softmute_Time**	slow_attack [ms]	slow_decay [ms]	fast_attack [ms]	fast_decay [ms]
	FM	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	45	**Set_Softmute_Max**	mode	limit [dB]		
3.18	FM	50	**Set_Highcut_Time**	slow_attack [ms]	slow_decay [ms]	fast_attack [ms]	fast_decay [ms]
	FM	51	**Set_Highcut_Mod**	mode	start [mod %]	slope [mod %]	shift [control %]
	FM	52	**Set_Highcut_Level**	mode	start [dBuV]	slope [dB]	

	module	cmd					
	FM	**53**	**Set_Highcut_Noise**	mode	start [%]	slope [%]	
	FM	**54**	**Set_Highcut_Mph**	mode	start [%]	slope [%]	
	FM	**55**	**Set_Highcut_Max**	mode	limit [Hz]		
	FM	**56**	**Set_Highcut_Min**	mode	limit [Hz]		
	FM	**57**	**Set_Lowcut_Max**	mode	limit [Hz]		
	FM	**58**	**Set_Lowcut_Min**	mode	limit [Hz]		
	FM	**59**	**Set_Highcut_Options**	mode			
3.19	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]		
3.20	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]		
3.21	FM	**80**	**Set_Scaler**	gain [dB]			
3.22	FM	**81**	**Set_RDS**	mode	restart	interface	
3.23	FM	**82**	**Set_QualityStatus**	mode	interface		
3.24	FM	**83**	**Set_DR_Blend**	mode	in_time [ms]	out_time [ms]	gain [dB]
3.25	FM	**84**	**Set_DR_Options**	samplerate	mode	format	
3.26	FM	**85**	**Set_Specials**	ana_out			
3.27	FM	**86**	**Set_Bandwidth_Options**	modulation [%]			
3.28	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

Table 2. AM module command overview - write

	module	cmd					
3.29	AM	1	**Tune_To**	mode	frequency [kHz]		
3.30	AM	10	**Set_Bandwidth**	mode	bandwidth [kHz]		
3.31	AM	11	**Set_RFAGC**	start [dBuV]			
3.32	AM	12	**Set_Antenna**	attenuation [dB]			
3.33	AM	14	**Set_CoChannelDet**	mode	restart	sensitivity	count
3.34	AM	23	**Set_NoiseBlanker**	mode	sensitivity [%]	gain	blank_time
3.35	AM	24	**Set_NoiseBlanker_Audio**	mode	sensitivity [%]		blank_time
3.36	AM	30	**Set_DigitalRadio**	mode			
3.37	AM	33	**Set_Highcut_Fix**	mode	limit [Hz]		
3.38	AM	34	**Set_Lowcut_Fix**	mode	limit [Hz]		
3.39	AM	38	**Set_LevelStep**	step1 [dB]	step2 [dB]	step3 [dB]	step4 [dB]
				step5 [dB]	step6 [dB]	step7 [dB]	
3.40	AM	39	**Set_LevelOffset**	offset [dB]			
3.41	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 %]
	AM	42	**Set_Softmute_Level**	mode	start [dBuV]	slope [dB]	
	AM	45	**Set_Softmute_Max**	mode	limit [dB]		
3.42	AM	50	**Set_Highcut_Time**	slow_attack [ms]	slow_decay [ms]	fast_attack [ms]	fast_decay [ms]
	AM	51	**Set_Highcut_Mod**	mode	start [mod %]	slope [mod %]	shift [control %]
	AM	52	**Set_Highcut_Level**	mode	start [dBuV]	slope [dB]	
	AM	55	**Set_Highcut_Max**	mode	limit [Hz]		
	AM	56	**Set_Highcut_Min**	mode	limit [Hz]		
	AM	57	**Set_Lowcut_Max**	mode	limit [Hz]		
	AM	58	**Set_Lowcut_Min**	mode	limit [Hz]		
3.43	AM	80	**Set_Scaler**	gain [dB]			
3.44	AM	82	**Set_QualityStatus**	mode	interface		
3.45	AM	83	**Set_DR_Blend**	mode	in_time [ms]	out_time [ms]	gain [dB]
3.46	AM	84	**Set_DR_Options**	samplerate	mode	format	
3.47	AM	85	**Set_Specials**	ana_out			

Table 3. AUDIO module command overview - write

	module	cmd					
3.48	AUDIO	**10**	**Set_Volume**	volume [dB]			
3.49	AUDIO	**11**	**Set_Mute**	mode			
3.50	AUDIO	**12**	**Set_Input**	source			
3.51	AUDIO	**13**	**Set_Output_Source**	signal	source		
3.52	AUDIO	**21**	**Set_Ana_Out**	signal	mode		
3.53	AUDIO	**22**	**Set_Dig_IO**	signal	mode	format	operation
				samplerate			
3.54	AUDIO	**23**	**Set_Input_Scaler**	source	gain [dB]		
3.55	AUDIO	**24**	**Set_WaveGen**	mode	offset	amplitude1	frequency1
				amplitude2	frequency2		

Table 4. APPL module command overview - write

	module	cmd				
3.56	APPL	**1**	**Set_OperationMode**	mode		
3.57	APPL	**3**	**Set_GPIO**	pin	module	feature
3.58	APPL	**4**	**Set_ReferenceClock**	frequency_msb	frequency_lsb	type
3.59	APPL	**5**	**Activate**	mode		

Table 5. FM module command overview - read

	module	cmd					
4.1	FM	**128**	**Get_Quality_Status**	status	level	usn	wam
				offset	bandwidth	modulation	
	FM	**129**	**Get_Quality_Data**	status	level	usn	wam
				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	**132**	**Get_AGC**	input_att	feedback_att		
4.4	FM	**133**	**Get_Signal_Status**	status			
4.5	FM	**134**	**Get_Processing_Status**	softmute	highcut	stereo	sthiblend
				stband_1_2	stband_3_4		
4.6	FM	**135**	**Get_Interface_Status**	samplerate			

Table 6. AM module command overview - read

	module	cmd					
4.7	AM	**128**	**Get_Quality_Status**	status	level	noise	co_channel
				offset	bandwidth	modulation	
	AM	**129**	**Get_Quality_Data**	status	level	noise	co_channel
				offset	bandwidth	modulation	
4.8	AM	**132**	**Get_AGC**	input_att	feedback_att		
4.9	AM	**133**	**Get_Signal_Status**	status			
4.10	AM	**134**	**Get_Processing_Status**	softmute	highcut		
4.11	AM	**135**	**Get_Interface_Status**	samplerate			

Table 7. APPL module command overview - read

	module	cmd					
4.12	APPL	**128**	**Get_Operation_Status**	status			
4.13	APPL	**129**	**Get_GPIO_Status**	status			
4.14	APPL	**130**	**Get_Identification**	device	hw_version	sw_version	
4.15	APPL	**131**	**Get_LastWrite**	size / module	cmd / index	parameter	parameter
				parameter	parameter	parameter	parameter
4.16	APPL	**135**	**Get_Interface_Status**	samplerate			

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