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1. DESCRIPTION

The N681386/87, implements a single channel FXS telephone line interface optimized for short loop applications. It integrates SLCC (Subscriber Line Control Circuit) functionality with a programmable CODEC and a DC/DC controller. The SLCC supports internal ringing up to 90 V_{PK} (5 REN at 4k ft) ideal for Customer Premise Equipment (CPE). The CODEC can be configured for μ -law, A-law or 16-bit linear PCM encoding. It also supports a comprehensive set of signaling capabilities required to supervise and control the telephone lines. These include tone generation, ring tones, DTMF detection/ generation as well as FSK generation. An on-chip Pulse Width Modulation (PWM) driver allows control of an inductor based DC/DC converter. Programmable impedance and trans-hybrid balancing allow for worldwide deployment.

2. FEATURES

- ◆ Complete BORSCHT functions
- ◆ Internal balanced and unbalanced ringing up to 90 V_{PK} (5 REN up to 4k ft)
- ◆ Integrated Power Management Options
 - Integrated DC/DC controller regulates battery voltage to minimize power dissipation in all operating modes
 - Programmable external battery switching
- ◆ Programmable linefeed characteristics
 - Ringing Frequency, Amplitude, and Cadence
 - Trapezoidal and Sinusoidal waveforms
 - Two wire AC impedance, and trans-hybrid balance
 - Constant Current feed (20 to 41) mA
 - Ring Trip and Loop Closure Thresholds
 - Ground Key Detection
- ◆ Programmable signal generation and detection
 - DTMF generation/ detection and Tone generation
 - Frequency Shift Keying (FSK) Enhanced Caller ID generation (Type I and Type II)
- ◆ Loop test and diagnostics support
 - Integrated loopback modes
 - Real-time linefeed monitoring
 - On-chip temperature sensor
 - Line Card Diagnostics Support
- ◆ Digital interfaces
 - PCM: G.711 μ -Law, A-Law and 16-bit linear
 - GCI and SPI bus
 - Programmable audio path gains
- ◆ Both PCM Master and Slave modes supported
- ◆ On-chip PLL for flexible clocking options including 1.0 MHz and 2.0 MHz BCLK operation
- ◆ Operating voltage: 3.3V

- ◆ Narrowband Codec (N681386)
- ◆ Wideband and Narrowband codec (N681387)
- ◆ Optional integrated (N681622) or discrete Subscriber Line Feed Circuit

APPLICATIONS

- ◆ Residential VoIP Gateways / Routers/ IP-PBX
- ◆ Fiber to the Premise/Home (FTTP/H)
- ◆ Wireless Local Loop
- ◆ Optical Network Terminals (ONT)
- ◆ Analog Telephone Adapter (ATA)
- ◆ Voice enabled DSL/Cable Modems
- ◆ Integrated Access Devices
- ◆ Set Top Boxes

Ordering Information

Part Number	Temp Range (°C)	Package	Package Material
N681386DG N681387DG	-40 to 85	48-LQFP	Pb-Free
N681386YG N681387YG	-40 to 85	48-QFN	Pb-Free
N681622YG	-40 to 85	20-QFN	Pb-Free

! WARNING !

HIGH VOLTAGE WARNING USE EXTREME CAUTION



High voltage sources could cause serious injury or death if not used in accordance with design and/or user specifications, if they are used by untrained or unqualified personnel. Before testing Nuvoton's products read and understand all instructions, and safety procedures as in industry standard safe practices.

3. PIN CONFIGURATION

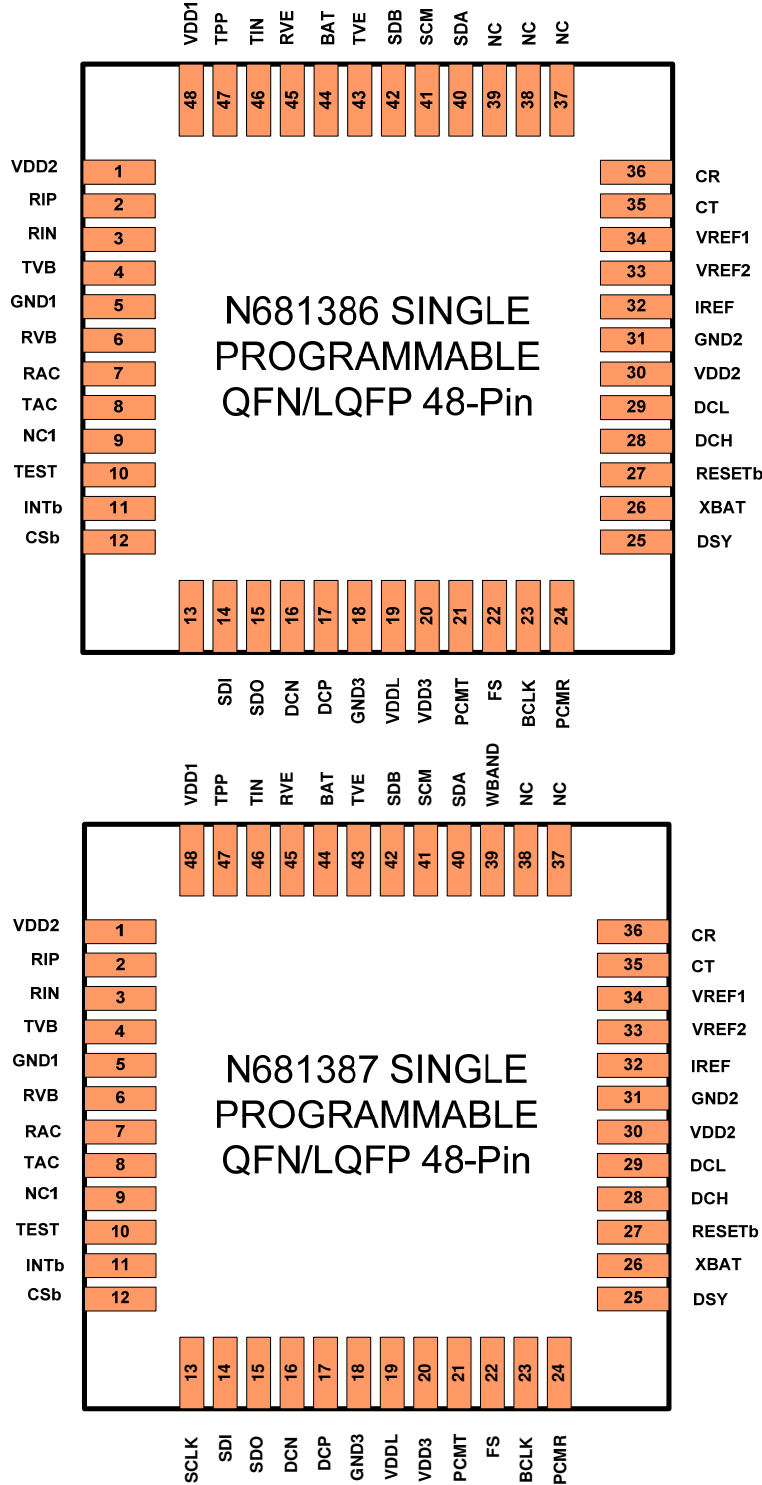


Figure 1: N681386/87 Pin Configuration

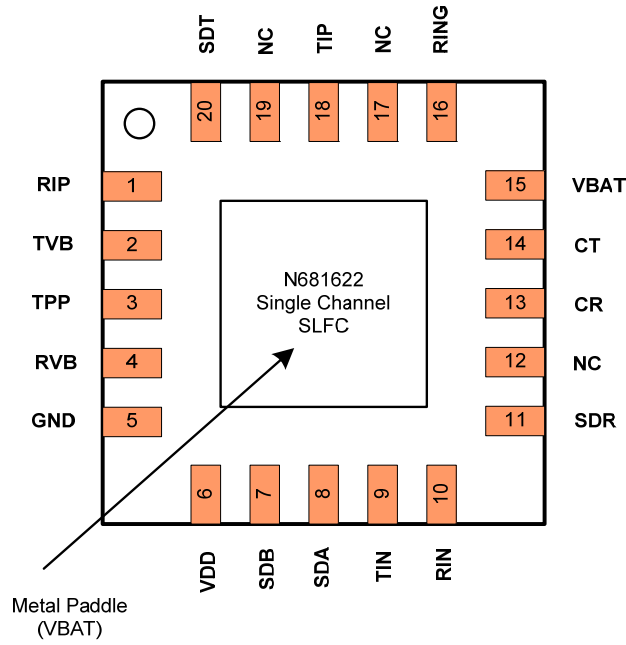


Figure 2: N681622 Subscriber Line Feed Circuit (SLFC) Pin Configuration

4. PIN DESCRIPTION

4.1. N681386/87 Pin Description

Pin Name	Pin No.	Functionality	A/D	Pin Type
VDD1	1	Line-driver 3.3 V supply	A	P
RIP	2	Positive RING Driver current source & Voltage sense	A	I/O
RIN	3	Negative RING Driver current source	A	O
TVB	4	Positive TIP Driver Base Voltage Control	A	O
GND	5	Line-driver ground supply	A	G
RVB	6	Positive RING Driver Base Voltage Control	A	O
RAC	7	RING Voice Band Input	A	I
TAC	8	TIP Voice Band Input	A	I
NC	9	No connect		
TEST	10	For internal testing only. Needs to be tied to ground during normal operation	D	I
INTb	11	Interrupt. Maskable interrupt. Open drain output for wired-or operation	D	O
CSb	12	Chip Select. When inactive, SCLK and SDI are ignored and SDO is high impedance. When active, serial port is operational	D	I
SCLK	13	Serial port bit clock. Controls serial data on SDO and latches data on SDI	D	I
SDI	14	Serial port data in. Serial port control data	D	I
SDO	15	Serial port data out. Serial port control data	D	O
DCN	16	DC/DC converter Control for external NPN BJT	D	O
DCP	17	DC/DC Converter Control for external PNP BJT	D	O
GND3	18	Logic I/O ground supply	D	G
VDDL	19	Logic supply voltage. This pin should not be connected up to an external supply. Use only as shown in application diagram.	D	I/O
VDD3	20	3.3 V Logic I/O supply	D	P
PCMT	21	Serial PCM Transmit data	D	O
FS	22	8 or 16 kHz Frame Sync	D	I/O
BCLK	23	PCM Bit Clock. Also used as internal PLL reference clock	D	I
PCMR	24	Serial PCM Receive data	D	I
DSY	25	SPI Daisy Chain Enable	D	I
XBAT	26	External Battery Supply Enable. Disables DC/DC Controller when set high	D	I
RESETb	27	Reset. Active Low. Hardware reset used to place all control registers in default state.	D	I

Pin Name	Pin No.	Functionality	A/D	Pin Type
DCH	28	DC/DC Converter Current Sense Higher input Voltage	A	I
DCL	29	DC/DC Converter Current Sense Lower input Voltage	A	I
VDD2	30	3.3 V Analog AC path and reference Supply Voltage	A	P
GND2	31	Analog AC path and reference Supply ground	A	P
IREF	32	Current Reference	A	I/O
VREF2	33	Precision Reference Voltage	A	I/O
VREF1	34	Mid Supply Reference Voltage	A	I/O
CT	35	External Capacitor TIP	A	I/O
CR	36	External Capacitor RING	A	I/O
NC	37	No Connect		
NC	38	No Connect		
WBAND	39	Wideband enable (only on N681387)	D	I
SDA	40	Subscriber Loop Differential sense signal A from linefeed circuit	A	I
SCM	41	Subscriber Common Mode sense signal from linefeed circuit	A	I
SDB	42	Subscriber Loop Differential sense signal B from linefeed circuit	A	I
TVE	43	TIP line-driver emitter voltage sense	A	I
BAT	44	Battery voltage monitoring	A	I
RVE	45	RING line-driver emitter voltage sense	A	I
TIN	46	Negative TIP Driver current source	A	O
TPP	47	Positive TIP Driver current source & Voltage sense	A	I/O
VDD1	48	Line-driver 3.3 V supply	A	P

Table 1: N681386/87 Pin Description

A	Analog
D	Digital
G	Ground

O	Output
I	Input
P	Power

4.2. N681622 Pin Description

Pin Name	Pin No.	Functionality	Type	Pin Type
RIP	1	Ring Driver Pull up Current from 34.8 Ohm resistor	LV	I/O
TVB	2	Tip Pull-Up Driver control voltage	LV	I
TPP	3	Tip Driver Pull up Current from 34.8 Ohm resistor	LV	I/O
RVB	4	Ring Pull-Up Driver control voltage	LV	I
GND	5	Supply ground (0V)	LV	G
VDD	6	3.3V Supply	LV	P
SDB	7	Subscriber differential signal B	LV	O
SDA	8	Subscriber differential signal A	LV	O
TIN	9	Tip DC Pull-Down current	LV	I
RIN	10	Ring DC Pull-Down current	LV	I
SDR	11	Subscriber differential Ring input	HV	I/O
NC	12	Not connected		
CR	13	Ring Pull-Down filter capacitor	HV	I/O
CT	14	Tip Pull-Down filter capacitor	HV	I/O
VBAT	15	Battery Supply Voltage	HV	P
RING	16	Ring terminal	HV	O
NC	17	Not connected		
TIP	18	Tip terminal	HV	O
NC	19	Not connected		
SDT	20	Subscriber differential Tip input	HV	I/O

Table 2: N681622 Pin Description

LV	Low Voltage
HV	High Voltage
G	Ground

O	Output
I	Input
P	Power

5. BLOCK DIAGRAM

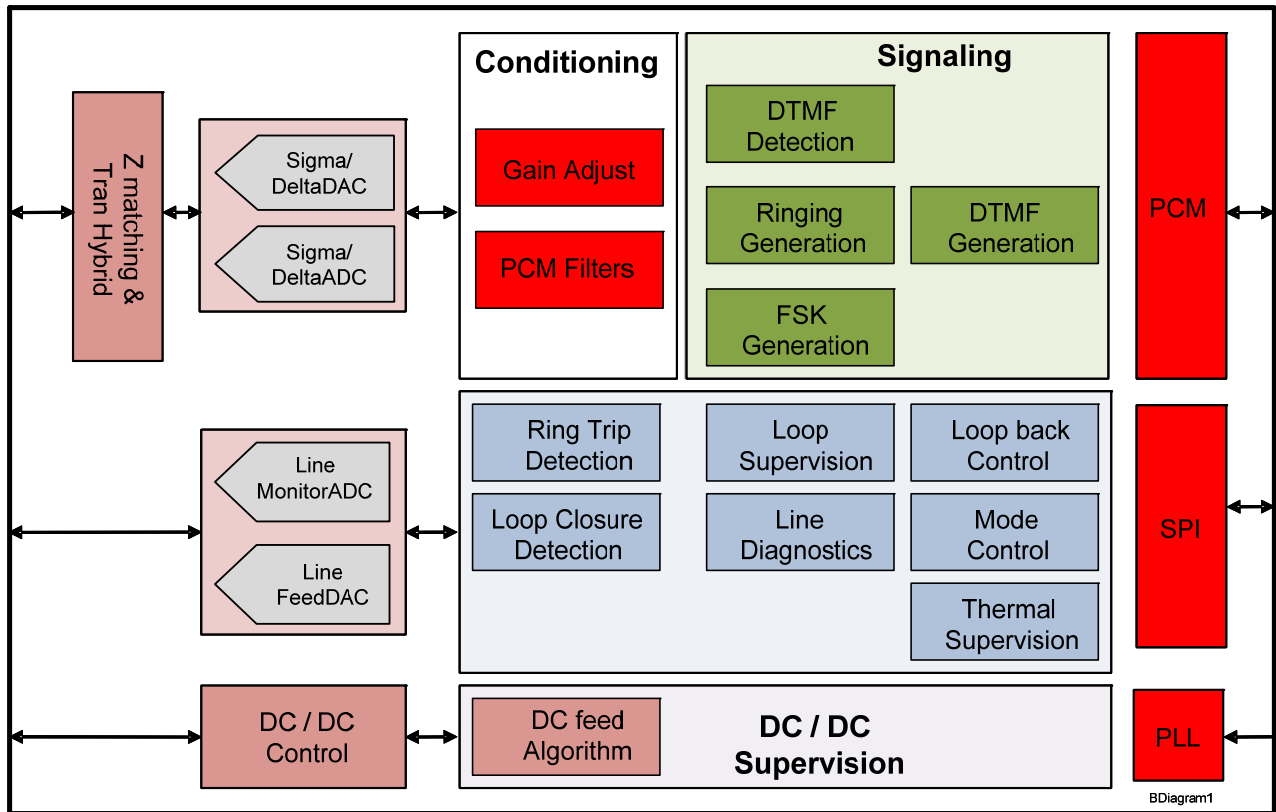


Figure 3: N681386/87 Block Diagram

6. TABLE OF CONTENTS

1.	DESCRIPTION	1
2.	FEATURES	1
3.	PIN CONFIGURATION	2
4.	PIN DESCRIPTION	4
4.1.	N681386/87 PIN DESCRIPTION	4
4.2.	N681622 PIN DESCRIPTION	6
5.	BLOCK DIAGRAM.....	7
6.	TABLE OF CONTENTS	8
7.	LIST OF FIGURES	15
8.	LIST OF TABLES	17
9.	ABSOLUTE MAXIMUM RATINGS	18
9.1.	SINGLE PROGRAMMABLE EXTENDED CODEC/SLCC (N681386/87)	18
9.2.	SUBSCRIBER LINE FEED CIRCUIT (N681622)	18
10.	OPERATING CONDITIONS.....	19
10.1.	SINGLE PROGRAMMABLE EXTENDED CODEC/SLCC (N681386/87)	19
10.2.	SUBSCRIBER LINE FEED CIRCUIT (N681622)	19
11.	ELECTRICAL CHARACTERISTICS.....	20
11.1.	GENERAL PARAMETERS (N681386/87).....	20
11.2.	SUPPLY PARAMETERS DISCRETE SOLUTION (N681386/87 AND DISCRETE LINE DRIVER)	20
11.3.	SUPPLY PARAMETERS SLFC SOLUTION (N681386/87 AND N681622)	21
11.4.	MONITORING A/D PARAMETERS.....	22
11.5.	ANALOG SIGNAL LEVEL AND GAIN PARAMETERS	22
11.6.	2-WIRE TO 4-WIRE CONVERSION PARAMETERS.....	23
11.7.	2-WIRE PARAMETERS	23
11.8.	LINEFEED CHARACTERISTICS	23
11.9.	ANALOG DISTORTION AND NOISE PARAMETERS	24
12.	FUNCTIONAL DESCRIPTION	25
12.1.	BORSCHT FUNCTIONALITY	26
12.1.1.	BATTERY FEED	26
12.1.1.1.	LINEFEED STATES OF OPERATION	28
12.1.1.1.1.	OPEN STATE.....	28
12.1.1.1.2.	ACTIVE, IDLE AND ON-HOOK TRANSMISSION STATES.....	28
12.1.1.1.3.	TIP OPEN STATE	28
12.1.1.1.4.	RING OPEN STATE.....	29
12.1.1.1.5.	RINGING STATE.....	29
12.1.1.1.6.	CALIBRATION STATE	29
12.1.1.2.	OPERATION MODES	29

12.1.1.3.	AUTOMATIC TRANSITIONS	29
12.1.1.3.1.	POWER ALARM AUTOMATIC REACT	29
12.1.1.3.2.	SETTING RING AUTOMATIC	29
12.1.1.3.3.	SETTING LOOP CLOSURE DETECT AUTOMATIC REACT	30
12.1.1.4.	POLARITY REVERSAL.....	32
12.1.1.4.1.	HARD POLARITY REVERSAL	32
12.1.1.4.2.	SOFT POLARITY REVERSAL	32
12.1.1.5.	WINK FUNCTION POLARITY REVERSAL.....	33
12.1.2.	OVER-VOLTAGE PROTECTION.....	33
12.1.2.1.	THERMAL OVERLOAD	34
12.1.2.2.	TEMPERATURE MONITOR	35
12.1.3.	RINGING	35
12.1.3.1.	tone GENERATION.....	36
12.1.3.2.	RING SIGNAL GENERATION.....	39
12.1.3.2.1.	SINUSOIDAL RINGING	41
12.1.3.2.2.	TRAPEZOIDAL RINGING	42
12.1.3.2.3.	RINGING DC OFFSET AND COMMON MODE BIAS.....	43
12.1.3.2.4.	LINEFEED CONSIDERATIONS DURING RINGING	44
12.1.3.3.	INTERNAL UNBALANCED RINGING	44
12.1.3.4.	RING TRIP DETECTION.....	45
12.1.4.	SUPERVISION (SIGNALING).....	47
12.1.4.1.	LOOP CLOSURE DETECTION.....	47
12.1.4.2.	GROUND KEY DETECTION.....	49
12.1.4.3.	CALLER ID AND FSK GENERATION.....	50
12.1.4.4.	DTMF GENERATOR.....	51
12.1.4.5.	DTMF DETECTION.....	53
12.1.5.	CODEC	54
12.1.6.	HYBRID.....	54
12.1.6.1.	AC PATH.....	54
12.1.6.1.1.	NARROWBAND TRANSMIT PATH	54
12.1.6.1.2.	NARROWBAND RECEIVE PATH.....	54
12.1.6.1.3.	ANALOG TRANSHYBRID BALANCING	55
12.1.6.1.4.	IMPEDANCE MATCHING	56
12.1.6.1.5.	DAC/ADC AUTOMUTE	57
12.1.7.	TESTING.....	58
12.1.7.1.	LOOP BACK TESTS	58
12.1.7.2.	DIAGNOSTICS SUPPORT	59
12.1.8.	POWER INTERFACE.....	59

12.1.8.1.	DC/DC CONVERSION (INDUCTOR).....	60
12.1.8.2.	EXTERNAL BATTERY SWITCHING.....	62
12.2.	DIGITAL INTERFACE	63
12.2.1.	CLOCK GENERATION	63
12.2.2.	PCM INTERFACE	64
12.2.2.1.	WIDEBAND AND NARROWBAND OPERATION	65
12.2.2.2.	TOGGLING BETWEEN WIDEBAND AND NARROWBAND	66
12.2.2.3.	PCM INTERFACE IN WIDEBAND OPERATION	66
12.2.2.3.1.	PCM INTERFACE 8KHZ FRAME SYNC.....	66
12.2.2.3.2.	PCM INTERFACE 16KHZ FRAME SYNC.....	67
12.2.2.4.	PLL & PRESCALER IN WIDEBAND OPERATION	67
12.2.3.	SERIAL PERIPHERAL INTERFACE (SPI).....	68
12.2.4.	READ/WRITE SEQUENCE (8-BIT OR 16-BIT).....	69
12.2.5.	SPI DAISY CHAIN.....	71
12.2.6.	SPI BURST MODE.....	72
12.2.7.	SPECIAL READ SEQUENCE FOR 12-BIT WIDE REGISTER	73
12.2.7.1.	12-BIT READ SEQUENCE.....	73
12.3.	POWER-ON RESET	74
12.4.	INTERRUPT HANDLING	75
13.	GENERAL DESCRIPTION FOR N681622 (LINEFEED CIRCUIT).....	76
13.1.	FUNCTIONAL DESCRIPTION FOR N681622 (LINEFEED CIRCUIT).....	76
14.	REGISTER DESCRIPTION.....	77
14.1.	PCM CONTROL REGISTERS	82
14.1.1.	PCM CONTROL REGISTER.....	82
14.1.2.	RECEIVE/TRANSMIT TIMESLOT (WIDEBAND AND NARROWBAND)	82
14.1.3.	PLL STATUS REGISTER.....	83
14.1.4.	PCM FREQUENCY SETTING REGISTER	84
14.1.5.	SILICON VERSION ID REGISTER (READ ONLY)	85
14.1.6.	DEVICE VERSION ID REGISTER (READ ONLY)	85
14.1.7.	TIMESLOT (WIDEBAND).....	85
14.2.	FSK REGISTERS.....	86
14.2.1.	FSK CONTROL REGISTER.....	86
14.2.2.	FSK TRANSMIT REGISTER.....	86
14.2.3.	FSK STATUS REGISTER (READ ONLY)	87
14.2.4.	FSK LCR REGISTER.....	87
14.2.5.	FSK TCR REGISTER.....	88
14.3.	DIAGNOSTIC REGISTERS	89
14.3.1.	DIAGNOSTIC CONTROL 0.....	89

14.3.2.	DIAGNOSTIC CONTROL 1.....	89
14.3.3.	DIAGNOSTIC CONTROL 2, 3, 4. AND 5.....	90
14.3.4.	DIAGNOSTIC CONTROL 6 AND 7 (READ ONLY).....	91
14.3.5.	DIAGNOSTIC CONTROL 8 (READ ONLY).....	92
14.3.6.	DIAGNOSTIC FIFO 0 AND FIFO1 (READ ONLY).....	92
14.4.	SYSTEM REGISTERS.....	93
14.4.1.	PCM HPF (HIGH PASS FILTER).....	93
14.4.2.	LOOP BACK CONTROL REGISTER.....	93
14.4.3.	POWER ON.....	94
14.4.4.	LINEFEED TRIM.....	95
14.5.	INTERRUPT REGISTERS.....	96
14.5.1.	INTERRUPT VECTOR LOW (READ ONLY).....	96
14.5.2.	INTERRUPT STATUS REGISTER 1.....	96
14.5.3.	INTERRUPT ENABLE REGISTER 1.....	97
14.5.4.	INTERRUPT STATUS REGISTER 2.....	97
14.5.5.	INTERRUPT ENABLE REGISTER 2.....	98
14.5.6.	INTERRUPT STATUS REGISTER 3.....	98
14.5.7.	INTERRUPT ENABLE REGISTER 3.....	99
14.6.	DTMF DETECTION REGISTER.....	100
14.6.1.	DTMF CONTROL 1.....	100
14.6.2.	DTMF CONTROL 2.....	101
14.6.3.	DTMF CONTROL 3.....	101
14.6.4.	DTMF STATUS (READ ONLY).....	102
14.6.5.	DTMF THRESHOLD.....	102
14.6.6.	DTMF PRESENT DETECT TIME.....	102
14.6.7.	DTMF ABSENT DETECT TIME.....	103
14.6.8.	DTMF ACCEPT TIME.....	103
14.6.9.	DTMF RECEIVE DATA STATUS.....	104
14.6.10.	DTMF ROW FREQUENCY.....	104
14.6.11.	14/15 DTMF COLUMN FREQUENCY.....	105
14.7.	LINE REGISTERS.....	106
14.7.1.	AC PATH GAIN.....	106
14.7.2.	HYBRID BALANCE.....	106
14.7.3.	COMMON RINGING BIAS ADJUST DURING RINGING.....	107
14.7.4.	LINE AUTOMATIC MANUAL CONTROL.....	107
14.7.5.	LINEFEED STATUS.....	108
14.7.6.	LOOP CURRENT LIMIT.....	108
14.7.7.	RING TRIP DETECT STATUS/ LOOP CLOSURE STATUS (READ ONLY).....	109

14.7.8.	LOOP CLOSURE DEBOUNCE	110
14.7.9.	RING TRIP DEBOUNCE INTERVAL.....	110
14.7.10.	PWM PERIOD	110
14.7.11.	DC/DC CONTROLLER CONTROL	111
14.7.12.	ON-HOOK VOLTAGE	111
14.7.13.	GROUND MARGIN VOLTAGE	112
14.7.14.	HIGH BATTERY VOLTAGE	112
14.7.15.	LOW BATTERY VOLTAGE.....	112
14.7.16.	LOOP CLOSURE DETECT/RING TRIP DETECT COEFFICIENT.....	113
14.7.17.	LOOP CLOSURE DETECT THRESHOLD WITHOUT / WITH HYSTERESIS	113
14.7.18.	RING TRIP DETECT THRESHOLD	114
14.7.19.	OFFSET VOLTAGE	114
14.7.20.	DC/DC TIME ON	114
14.7.21.	DAC/ADC AUTOMUTE FUNCTION.....	115
14.8.	GROUND KEY DETECTION.....	116
14.8.1.	LINEFEED CONTROL	116
14.8.2.	GROUND KEY DETECT HIGH/LOW THRESHOLD	116
14.8.3.	GROUND KEY DETECT DEBOUNCE TIME	117
14.8.4.	GROUND KEY DETECT FILTER COEFFICIENT LOW/ HIGH.....	117
14.8.5.	DC RING TRIP DEBOUNCE FILTER COEFFICIENT LOW.....	117
14.8.6.	DC RING TRIP CURRENT THRESHOLD.....	118
14.8.7.	DC RING TRIP DEBOUNCE TIME	118
14.8.8.	EXTERNAL BATTERY SWITCH OUTPUT CONFIGURATION 1	119
14.8.9.	DC/DC HEAVY CURRENT CONVERTER.....	119
14.8.10.	DC/DC TARGET VOLTAGE (READ ONLY).....	120
14.9.	MONITORING REGISTERS	121
14.9.1.	MONITOR CURRENT FOR RING TRIP AND LOOP CLOSURE.....	121
14.9.2.	MONITOR CURRENT FOR RING TRIP AND LOOP CLOSURE.....	121
14.10.	LINE CONTROL REGISTERS	122
14.10.1.	VOLTAGE REGISTERS.....	122
14.10.1.1.	BATTERY VOLTAGE SENSE (READ ONLY).....	122
14.10.1.2.	TIP/RING VOLTAGE SENSE (READ ONLY).....	122
14.10.1.3.	TIP/RING TRANSISTOR 3 EMITTER VOLTAGE SENSE (READ ONLY)	122
14.11.	TRANSISTOR CURRENT REGISTERS (TIP/RING TRANSISTOR 1/2/3 CURRENT SENSE).....	123
14.12.	LOOP SUPERVISION	124
14.12.1.	LONGITUDINAL CURRENT	124
14.12.2.	LOOP VOLTAGE SENSE (READ ONLY)	124
14.12.3.	TIP, RING, AND LOOP CURRENT (READ ONLY).....	125

14.12.4.	POLARITY.....	125
14.12.5.	COMMON MODE VOLTAGE.....	126
14.12.6.	TIP EMITTER VOLTAGE FOR TRANSISTORS QT1 SENSE (READ ONLY).....	126
14.12.7.	TIP VOLTAGE FOR TRANSISTOR QT1 SENSE (READ ONLY).....	126
14.12.8.	RING EMITTER VOLTAGE FOR TRANSISTOR QT1 SENSE (READ ONLY).....	127
14.12.9.	RING VOLTAGE FOR TRANSISTOR QT1 SENSE (READ ONLY).....	127
14.12.10.	TEMPERATURE SENSE (READ ONLY).....	127
14.12.11.	BAND GAP VOLTAGE.....	127
14.12.12.	PEAK TO PEAK LOOP VOLTAGE (READ ONLY).....	128
14.12.13.	PEAK TO PEAK LOOP CURRENT (READ ONLY).....	128
14.13.	POWER ALARM LPF POLE REGISTERS.....	129
14.13.1.	POWER ALARM COUNTER.....	129
14.13.2.	POWER ALARM LOW PASS FILTER POLE FOR TRANSISTORS 1/2/3.....	129
14.13.3.	POWER ALARM THRESHOLD FOR TRANSISTOR 1-3.....	130
14.14.	IMPEDANCE MATCHING 1/2.....	130
14.14.1.	TEMPERATURE ALARM THRESHOLD.....	131
14.14.2.	LOOP CLOSURE MASK COUNT.....	131
14.14.3.	COARSE CALIBRATION INTERNAL RESISTOR.....	131
14.14.4.	OSCILLATOR 2 RINGING PHASE DELAY.....	131
14.15.	CALIBRATION.....	132
14.16.	DC OFFSET REGISTERS.....	133
14.16.1.	DC OFFSET (RING, TIP, AND VBAT).....	133
14.16.2.	PWM COUNT (READ ONLY).....	133
14.17.	tone GENERATION REGISTERS.....	134
14.17.1.	OSCILLATOR CONTROL.....	134
14.17.2.	RING CONTROL.....	134
14.17.3.	OSCILLATOR 1 AND 2 INITIAL CONDITION LOW/HIGH.....	134
14.17.4.	OSCILLATOR 1 AND 2 COEFFICIENT LOW/HIGH.....	135
14.18.	OSCILLATOR 1 AND 2 ACTIVE/ INACTIVE TIME LOW/HIGH.....	135
14.19.	GENERAL TONE GENERATION.....	136
14.19.1.	RING OFFSET.....	136
14.19.2.	ADC/DAC DIGITAL GAIN.....	136
14.19.3.	PWM DC/DC FINE TUNING.....	137
14.19.4.	PWM DC/DC FINE TUNING SKIP PERIOD.....	137
14.19.5.	PWM DC/DC FINE TUNING.....	138
14.19.6.	IMPEDANCE MATCH REGISTER.....	139
14.19.6.1.	IMPEDANCE MATCHING COEFFICIENT RAM.....	139
14.19.6.2.	IMPEDANCE MATCHING DELAY COUNT.....	139

14.19.6.3.	IMPEDANCE MATCHING COEFFICIENT RAM CONTROL	139
14.19.6.4.	PCM SCALING.....	140
14.19.6.5.	RESERVED REGISTERS	140
14.19.6.6.	FILTER BYPASS.....	140
15.	TIMING DIAGRAM	141
15.1.	PCM TIMING DIAGRAM FOR NON-GCI	141
15.2.	PCM TIMING DIAGRAM FOR GCI	142
15.3.	SPI TIMING DIAGRAM	144
16.	DIGITAL I/O.....	150
16.1.1.	μ-LAW ENCODE DECODE CHARACTERISTICS	150
16.2.	A-LAW ENCODE DECODE CHARACTERISTICS.....	151
16.3.	μ-LAW / A-LAW CODES FOR ZERO AND FULL SCALE	151
16.3.1.	μ-LAW / A-LAW CODES FOR 0DBM0 OUTPUT (DIGITAL MILLIWATT).....	152
16.4.	16-BIT LINEAR PCM CODES FOR ZERO AND FULL SCALE.....	152
16.5.	16-BIT LINEAR PCM CODES FOR 1 KHZ DIGITAL MILLIWATT.....	152
17.	TYPICAL APPLICATION CIRCUITS	153
17.1.	DC/DC APPLICATION	153
17.2.	DISCRETE LINE DRIVER.....	154
17.3.	DC DC	155
17.4.	TRIPLE BATTERY SWITCH APPLICATION.....	156
17.5.	N681386/87 DCDC APPLICATION USE WITH SLFC N681622.....	157
17.6.	N681622 LINEFEED CIRCUIT	158
18.	PACKAGE SPECIFICATION.....	159
18.1.	LQFP-48 (10X10X1.4MM FOOTPRINT 2.0MM)	159
18.2.	QFN-48.....	160
18.3.	QFN 20L 4X4 MM ² , PITCH:0.50 MM.....	161
19.	ORDERING INFORMATION	162
20.	VERSION HISTORY	163

7. LIST OF FIGURES

Figure 1: N681386/87 Pin Configuration2

Figure 2: N681622 Subscriber Line Feed Circuit (SLFC) Pin Configuration3

Figure 3: N681386/87 Block Diagram7

Figure 4: AC signal Path25

Figure 5: DC Feed Regions26

Figure 6: Line Loop Control.....27

Figure 7: Example State Diagram30

Figure 8: Block Diagram Oscillator 1.....38

Figure 9: Zero Crossing for Tone Generation39

Figure 10: Trapezoidal Ringing42

Figure 11: Positive DC offset for Trapezoidal Ringing.....43

Figure 12: Programming V_{CMR} voltage for Trapezoidal Ringing43

Figure 13: Unbalanced Ringing on TIP44

Figure 14: RING Trip Detection Mechanism45

Figure 15: Loop Closure Detector Block Diagram47

Figure 16: Ground Key Detection Circuitry.....49

Figure 17: The Architecture of Linear FSK Waveform Generator.....50

Figure 18: DTMF Detector - Functional Block Diagram.....53

Figure 19: Characteristic Line Impedance.....56

Figure 20: Diagnostics Support Block Diagram.....59

Figure 21: Voltage Tracking in Forward Active State61

Figure 22: Dynamic Battery Target61

Figure 23: Three Voltage External Battery switching62

Figure 24: Two Battery Supply Control Circuit62

Figure 25: Wideband 8kHz Frame Sync PCM interface66

Figure 26: Wideband 16kHz Frame Sync PCM interface67

Figure 27: Register write operation through a 8-bit SPI port70

Figure 28: Register read operation through a 8-bit SPI port.....70

Figure 29: Register write operation through a 16-bit SPI port70

Figure 30: Register read operation through a 16-bit SPI port.....70

Figure 31: Three Chip Daisy Chain connection.....71

Figure 32: Device/Register Address for Three Device Daisy Chain application71

Figure 33: DATA for Three Device Daisy Chain application.....72

Figure 34: Burst mode operation (BST=1)72

Figure 35: SPI 12-bits Read sequence74

Figure 36: N681622 Equivalent Internal diagram.....76

Figure 37: PCM Timing for Non-GCI141

Figure 38: GCI PCM Timing 142

Figure 39: SPI Timing (Non-Daisy Chain Mode) 144

Figure 40: In-band Transmit Frequency Response 145

Figure 41: In-band Receive Frequency Response 145

Figure 42: Transmit Group Delay Distortion 146

Figure 43: Receive Group Delay Distortion 146

Figure 44: 2-Wire to PCM Signal to Distortion Mask (A-Law) 147

Figure 45: 2-Wire to PCM Signal to Distortion Mask (μ -Law) 147

Figure 46: Wideband In-band Transmit Frequency Response 148

Figure 47: Wideband Transmit Group Delay Distortion 148

Figure 48: Wideband Receive Group Delay Distortion 149

Figure 49: Typical Application Block Diagram 153

Figure 50: Discrete Line-driver 154

Figure 51: Inductor based circuit 12V supply 155

Figure 52: Triple Battery based Switch 1 156

Figure 53: N681386/87 Pro-X Application diagram to be used with N681622 157

Figure 54: N681622 Linefeed circuit 158

8. LIST OF TABLES

Table 1: N681386/87 Pin Description.....	5
Table 2: N681622 Pin Description.....	6
Table 3: Programmable Ranges for DC Line Feed	26
Table 4: Linefeed States	28
Table 5: Operation Modes.....	29
Table 6: Associated Registers for Linefeed Control	30
Table 7: TIP and RING Voltage Targets	31
Table 8: Registers Associated with Line Monitoring – Measured.....	31
Table 9: Registers Associated with Line Monitoring – Calculated.....	31
Table 10: Registers for Polarity Reversal.....	33
Table 11: PWM DC/DC Power Alarm Counter.....	34
Table 12: Registers Associated with Thermal Overload.....	34
Table 13: Associated Registers for Oscillator Control (Oscillator 1 Example).....	36
Table 14: Example Register settings for Oscillator m.....	37
Table 15: Registers for RING Generation	40
Table 16: Example Ringer Register settings	41
Table 17: Registers for RING Trip Detection.....	46
Table 18: Recommended RING Trip Values for Ringing.....	46
Table 19: Loop Closure Detection Registers.....	48
Table 20: Ground Key Detection Registers	49
Table 21: Registers for FSK Generation	51
Table 22: DTMF frequency mapping.....	51
Table 23: Digital Gain Adjust Coefficients and Attenuation weightings	55
Table 24: Examples of Resistive Impedance Matching.....	56
Table 25: Examples of Complex Impedance Matching	57
Table 26: Registers for Automute.....	57
Table 27: Registers associated with DC/DC Conversion	60
Table 28: Example Standard Interface modes	64
Table 29: Wideband or Narrowband Hardware Selection	65
Table 30: PLL and Prescaler in Wideband.....	67
Table 31: Device Address Bit pattern.....	68
Table 32: 12-bit byte Selection.....	69
Table 33: Interrupt Registers.....	75

9. ABSOLUTE MAXIMUM RATINGS

9.1. Single Programmable Extended Codec/SLCC (N681386/87)

Condition	Value
Junction temperature	150°C
Storage temperature range	-65°C to +150°C
LQFP-48 Thermal Resistance, typical	76 °C/W
QFN-48 Thermal Resistance, typical	27.1 °C/W
Voltage applied to any pin	(V _{SS} - 0.3V) to (V _{DD} + 0.3V)
Input current applied to any digital input pin	+/- 10 mA
ESD (Human Body Model)	2000 V
V _{DD} - V _{SS}	-0.5V to +3.63V
Power Dissipation	0.7W

1. Stresses above those listed may cause permanent damage to the device. Exposure to the absolute maximum ratings may affect device reliability. Functional operation is not implied at these conditions.

9.2. Subscriber Line Feed Circuit (N681622)

Parameter	Symbol	Value	Unit
VDD Supply Voltage	VDD	-0.5 - 5	V
VBAT Supply Voltage	VBAT	-104	V
Input Voltage HV IO	VINHV	(VBAT-0.3) to (VDD+0.3)	V
Input Voltage LV IO	VINLV	-0.3 to (VDD+0.3)	V
ESD, HBM		JESD22 Class 1C	V
Operating Temperature **	TA	-40 - 100	C
Storage Temperature	TS	-40 - 150	C
Thermal Resistance QFN20	Rthja	45	C/W
Power Dissipation	Pmax	0.9	W

** When the dice temperature reaches over 130°C, the device reliability may be adversely affected.

10. OPERATING CONDITIONS

10.1. Single Programmable Extended Codec/SLCC (N681386/87)

Condition	Symbol	Min	Typ	Max	Unit
Industrial operating temperature	TA	-40		+85	C
Supply voltage (V _{DD})	VDD	3.13		3.47	V
Ground voltage (V _{SS})	VSS		0		V

Note: Exposure to conditions beyond those listed under Absolute Maximum Ratings may adversely affect the life and reliability of the device.

10.2. Subscriber Line Feed Circuit (N681622)

Parameter	Symbol	Min	Typ	Max	Unit
Industrial operating temperature	TA	-40		85	C
Supply voltage (V _{DD})	VDD	3.13	3.3	3.47	V
VBAT Supply Voltage	VBAT	-100	-	-9	V

11. ELECTRICAL CHARACTERISTICS

11.1. GENERAL PARAMETERS (N681386/87)

$V_{DD}=3.13\text{ V to }3.47\text{ V}$; $V_{SS}=0\text{ V}$; $T_A = -40^{\circ}\text{C to }+85^{\circ}\text{C}$;

Symbol	Parameters	Conditions	Min (2)	Typ (1)	Max (2)	Units
V_{IL}	Logic Input LOW Voltage		-0.3	--	0.8	V
V_{IH}	Logic Input HIGH Voltage		2	--	3.6	V
V_T	Threshold point			1.41		V
V_{OL}	Logic Output LOW Voltage	INTB,FS,PCMT,SDO: $I_{OL} = 4\text{ mA}$ DCP, DCN: $I_{OL} = 16\text{ mA}$	--	--	0.4	V
V_{OH}	Logic Output HIGH Voltage	FS,PCMT,SDO: $I_{OH} = 4\text{ mA}$ DCP, DCN: $I_{OH} = 16\text{ mA}$	2.4	--		V
I_{IL}	Input HIGH & LOW Leakage Current	$V_{SS}<V_{IN}<V_{DD}$ No pull-up or pull-down	--	--	+/-10	μA
I_{OZ}	Tri-state Leakage Current	$V_{SS}<V_O<V_{DD}$ High Z State	--	--	+/-10	μA
C_{IN}	Digital Input Capacitance		--	3	--	pF
C_{OUT}	Digital Output Capacitance	V_O High Z	--	3	--	pF

1. Typical values: $T_A = 25^{\circ}\text{C}$, $V_{DD} = 3.3\text{ V}$

2. All min/max limits are guaranteed by Nuvoton via electrical testing or characterization. Not all specifications are 100 percent tested.

11.2. SUPPLY PARAMETERS DISCRETE SOLUTION (N681386/87 AND DISCRETE LINE DRIVER)

$V_{DD}=3.13\text{ V to }3.47\text{ V}$; $V_{SS}=0\text{ V}$; $T_A=-40^{\circ}\text{C to }+85^{\circ}\text{C}$;

Symbol	Parameters	Conditions	Min	Typ (1)	Max (2)	Units
I_{PD}	Total Power Down Supply Current	RESETb = 0V, Vdd1..Vdd3 FS=BCLK=0V		12	100	μA
I_{SB}	Total Standby Supply Current	RESETb = VDD, VDD1 .. VDD3 FS=BCLK=0V, Line state Open		8.0	11.3	mA
I_{VDD}	Total Supply Current for all supplies @3.3V (linefeed states)	Open (ADC and DAC disabled)		21		mA
		Forward/Reverse Active $I_{LIM}=20\text{ mA}$		66		mA
		Forward/Reverse ON-HOOK Transmission		45		mA
		Forward/Reverse Idle (ADC and DAC disabled)		29		mA
		TIP/RING Open		28		mA
		Ringing, Sine wave, REN=1, $V_{PK}=56\text{ V}$		50		mA
I_{VBAT}	Total Battery Supply	Open, VBAT = 72V		0.72		mA

Symbol	Parameters	Conditions	Min	Typ (1)	Max (2)	Units
	Current	Forward/Reverse Active $I_{LIM}=20$ mA,		30		mA
		Forward/Reverse ON-HOOK Transmission, XBTA:XTBOT=0, VBAT = 54V		12		mA
		Forward/Reverse Idle, VBAT = 54V		1.3		mA
		TIP/RING Open, VBAT = 54V		1.0		mA
		Ringling, Sine wave, REN=1, VBAT = 71V		6.0		mA

1. Typical values: $T_A = 25^{\circ}\text{C}$, $V_{DD} = 3.3\text{ V}$
2. All min/max limits are guaranteed by Nuvoton via electrical testing or characterization. Not all specifications are 100 percent tested.
3. The supply current for the DC/DC converter can be calculated by : $IDC/DC=IVBAT*VBAT/(efficiency*VDC/DC)$

11.3. SUPPLY PARAMETERS SLFC SOLUTION (N681386/87 AND N681622)

Parameter	Symbol	Condition	MIN	TYP	Max	Unit
VDD Supply Current	IDDO	Open State		24.0		mA
	IDDI	Low Power Idle State, VBAT=-50V		21.4		mA
	IDDA	Active State		63.3		mA
	IDDR	Ringling, 1REN, 40Vrms		TBD		mA
	IDDOT	On-Hook Transmit		47.9		mA
	IDDTO	Tip/Ring Open		TBD		mA
VBAT Supply Current	IBTO	Open State		0.4		mA
	IBTI	Low Power Idle State, VBAT=-50V	-	0.2	1.2	mA
	IBTA	Active State		29.0		mA
	IBTR	Ringling, 1REN, 40Vrms		TBD		mA
	IBTOT	On-Hook Transmit		14.1		mA
	IBTTO	Tip/Ring Open		TBD		mA

11.4. MONITORING A/D PARAMETERS

$V_{DD}=3.13\text{ V to }3.47\text{ V}$; $V_{SS}=0\text{ V}$; $T_A=-40^{\circ}\text{C to }+85^{\circ}\text{C}$

Symbol	Parameters	Min	Typ	Max	Units
INL	Integral Nonlinearity (8-bit resolution)		+/-0.5		LSB
DNL	Differential Nonlinearity (8-bit resolution)		+/-0.5		LSB
	Gain Error (Current)			20	%
	Gain Error (Voltage)			10	%
	Sample Rate per channel	--	--	800	Hz
	Number of channels	--	16	--	

Typically at 12-bit the INL and DNL is 2 LSB.

11.5. ANALOG SIGNAL LEVEL AND GAIN PARAMETERS

$V_{DD}=3.13\text{ V to }3.47\text{ V}$; $V_{SS}=0\text{ V}$; $T_A=-40^{\circ}\text{C to }+85^{\circ}\text{C}$; Loading $600\ \Omega$

PARAMETER	SYM.	CONDITION	TYP.	TRANSMIT (A/D)		RECEIVE (D/A)		UNIT
				MIN.	MAX.	MIN.	MAX.	
Absolute Level	L_{ABS}	0 dBm0 = 0 dBm @ 600 Ω	1.0954	---	---	---	---	V_{PK}
Max. Transmit Level	T_{XMAX}	3.17 dBm0 for u-Law 3.14 dBm0 for A-Law ⁽¹⁾	1.5779 1.5725	---	---	---	---	V_{PK} V_{PK}
Absolute Gain (0 dBm0 @ 1020 Hz; $T_A=+25^{\circ}\text{C}$)	G_{ABS}	0 dBm0 @ 1020 Hz, $V_{DD}=3.3\text{V}$; $T_A=+25^{\circ}\text{C}$; assuming ideal line impedance matching	0	-0.40	+0.40	-0.40	+0.40	dB
Absolute Gain variation with Temperature	G_{ABST}	$T_A=0^{\circ}\text{C to }T_A=+70^{\circ}\text{C}$ $T_A=-40^{\circ}\text{C to }T_A=+85^{\circ}\text{C}$	0	-0.10 -0.20	+0.10 +0.20	-0.10 -0.20	+0.10 +0.20	dB
Absolute Gain variation with Supply Voltage	G_{ABSS}	$V_{DD}=3.13\text{ V} - 3.47\text{ V}$; 0dBm0 @ 1020 Hz; $T_A=+25^{\circ}\text{C}$	0	-0.10	+0.10	-0.10	+0.10	dB
Frequency Response	G_{RTV}		See Figure					
Gain Variation vs. Level Tone (1020 Hz relative to -10 dBm0)	G_{LT}	+3 to -40 dBm0	---	-0.3	+0.3	-0.3	+0.3	dB
		-40 to -50 dBm0	---	-0.6	+0.6	-0.6	+0.6	
		-50 to -60 dBm0	---	-1.6	+1.6	-1.6	+1.6	
Gain Step Variation	G_{ST}	-6 dB to 6 dB	0	-	+/- 0.025	-	+/-0.025	dB
Absolute Group Delay	T_{ABS}	1200 Hz	---	633	650	286	300	usec
Group Delay Distortion (relative to group delay @ 1200 Hz)	T_D		See Figure					

1. Default Gain Setting

11.6. 2-WIRE TO 4-WIRE CONVERSION PARAMETERS

$V_{DD}=3.13\text{ V to }3.47\text{ V}$; $V_{SS}=0\text{ V}$; $T_A=-40^{\circ}\text{C to }+85^{\circ}\text{C}$; Loading $600\ \Omega$

PARAMETER	SYM.	CONDITION	MIN.	TYP.	MAX.	UNIT
Return Loss	R _L	200 Hz to 3.4 kHz, 600 Ohm	26	40		dB
Trans hybrid Balance	H _B	200 Hz to 3.4 kHz, 600 Ohm	26	40		dB

11.7. 2-WIRE PARAMETERS

$V_{DD}=3.13\text{ V to }3.47\text{ V}$; $V_{SS}=0\text{ V}$; $T_A=-40^{\circ}\text{C to }+85^{\circ}\text{C}$; Loading $600\ \Omega$

PARAMETER	SYM.	CONDITION	MIN	TYP	MAX	UNIT
Longitudinal Conversion Loss	L _{CL}	300 Hz to 600 Hz	40		---	dB
		600 Hz to 3.4 kHz,	46			
Longitudinal to Metallic or PCM Balance	L _{ML}	300 Hz to 600 Hz	40	52	---	dB
	L _{MH}	600 Hz to 3.4 kHz,	46	55	---	dB
Longitudinal Impedance	L _Z	300 Hz to 3.4 kHz	---	18.5		Ohms
Longitudinal Current	L _I	Active OFF-HOOK; 300 Hz to 3.4 kHz	---	6.7		mA

11.8. LINEFEED CHARACTERISTICS

$V_{DD}=3.13\text{ V to }3.47\text{ V}$; $V_{SS}=0\text{ V}$; $T_A=-40^{\circ}\text{C to }+85^{\circ}\text{C}$; Loading $600\ \Omega$

Parameter	Sym.	Condition	MIN	TYP	MAX	Unit
RING amplitude	V _{TR}	5 REN load; sine wave; R _{LOOP} = 160 Ohm; V _{BAT} = -75 V	44	45	---	V _{RMS}
Loop closure / Ground start threshold accuracy	I _{lt}	I _{lt} = 11.43 mA	---	---	+/-20	%
RING trip threshold accuracy	I _{rt}	I _{rt} = 40.64 mA	---	---	+/-20	%
Trapezoidal RING crest factor accuracy		Crest factor = 1.3	---	---	+/-0.05	
Sinusoidal RING crest factor	R _{cf}		1.35	---	1.45	
Ringing frequency accuracy		F = 20 Hz	---	---	+/-1	%
Ringing cadence accuracy		Accuracy of on/off time	---	---	+/-50	ms
DC Loop Current Accuracy		ILIM = 20 mA, R _{LOAD} = 500 ohm		---	+/-20	%
DC Open Circuit Voltage Accuracy		Active Mode; V _{OH} = 48 V, V _{TIP} - V _{RING}		---	+/-4	V
Power alarm threshold accuracy		Power Threshold = 300 mW	---	---	+/-25	%

11.9. ANALOG DISTORTION AND NOISE PARAMETERS

$V_{DD}=3.13\text{ V} - 3.47\text{ V}$; $V_{SS}=0\text{ V}$; $T_A=-40^{\circ}\text{C}$ to $+85^{\circ}\text{C}$; Loading $600\ \Omega$

PARAMETER	SYM.	CONDITION	TRANSMIT (A/D)			RECEIVE (D/A)			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	
Total Distortion vs. Level Tone u-Law	D_{LTu}	1020 Hz, C-Message Weighted	See Figure			See Figure			
Total Distortion vs. Level Tone, A-Law	D_{LTA}	1020 Hz, Psophometric Weighting							
Audio Tone Generator Signal-to-Distortion Ratio	D_{LTT}	0 dBm0, Active OFF-HOOK and OHT, ideal impedance matching	45	---	---	45	---	---	dB
Spurious Out-Of-Band (300 Hz to 3400 Hz @ 0dBm0)	D_{SPO}	4600 Hz to 7600 Hz 7600 Hz to 8400 Hz 8400 Hz to 100000 Hz	NA	NA	NA	---	-70 -70 -65	-30 -40 -30	dB
Spurious In-Band (700 Hz to 1100 Hz @ 0dBm0)	D_{SPI}	300 to 3200 Hz	---	---	-47	---	---	-47	dB
Intermodulation Distortion (300 Hz to 3400 Hz -4 to -21 dBm0)	D_{IM}	Two tones	---	---	-45	---	---	-45	dB
Idle Channel Noise	N_{IDL}	u-Law; C-message A-Law; Psophometric 16-bit Linear	---	13 -74 ---	18 -69	---	1 -90 ---	14 -76	dBrnc0 dBm0p
Power Supply Rejection	$PSRR_A$	V_{DDA} ; DC to 3.4 kHz	40	---	---	40	---	---	dB
Power Supply Rejection	$PSRR_B$	V_{BAT} ; DC to 3.4 kHz	40	---	---	40	---	---	dB

12. FUNCTIONAL DESCRIPTION

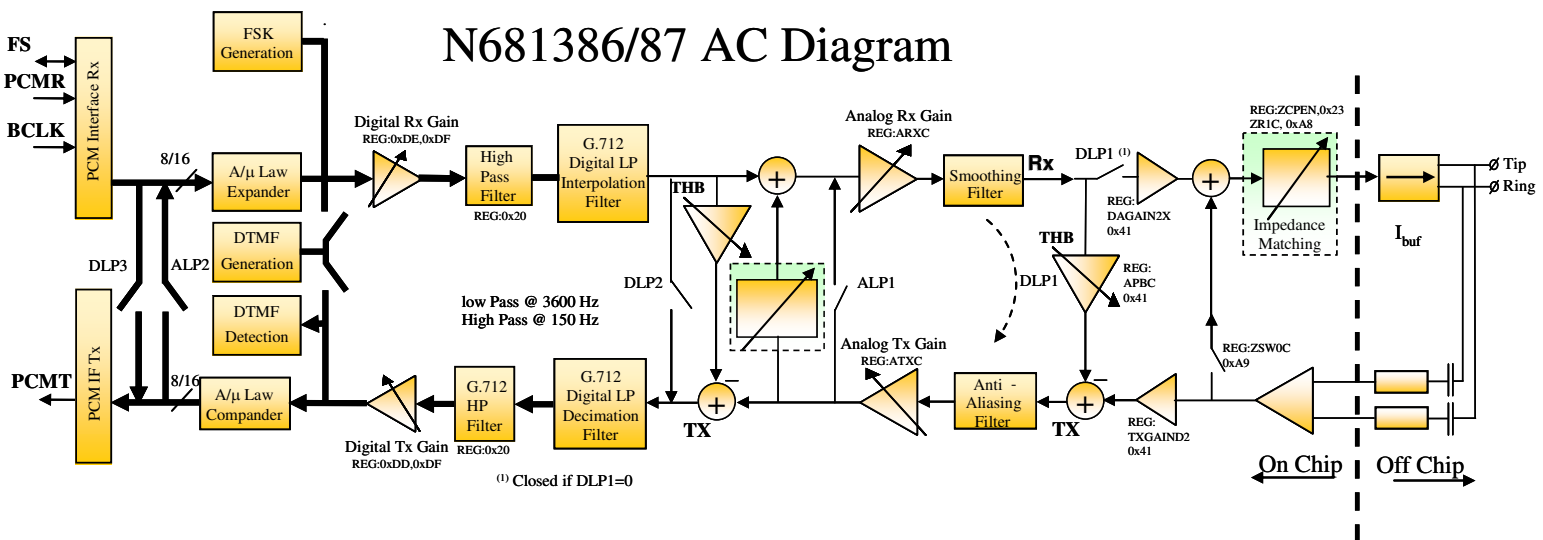


Figure 4: AC signal Path