RE46C420/1/2

Multicriteria Smoke Detector Companion IC with Dual Photoelectric and CO Sensing

Features

- Low Quiescent Current
- Operates Using Two AA Batteries or a Single Lithium Battery
- 4V, 5.2V, 8.5V, 10V, 11.5V or 17V Boost Converter
- Piezoelectric Horn Driver
- 3.3V Regulator
- Dual Independently-Controlled LED Drivers with Programmable Current up to 200 mA
- Dual-Input Programmable Gain Integrating Operational Amplifier with Effective Transimpedance > 20 MΩ at 100 µs
- Internal Operational Amplifier for Interfacing with a Two-Terminal CO or Toxic Gas Sensor:
  - Rail-to-Rail Inputs and Output
  - Unity Gain Stable
  - 10 kHz Gain Bandwidth Product
- Buffered Internal CO Reference
- Analog Buffer for Sensing Multiple Internal Voltages
- Alarm Interconnect
- Watchdog Timer to Monitor Microcontroller Unit (MCU) Communication
- Serial Peripheral Interface (SPI) Controlled
- Packaging:
  - RE46C420 and RE46C421: 4 mm × 4 mm 28-Lead VQFN
  - RE46C422: 5 ,mm × 5 mm 32-Lead VQFN

General Description

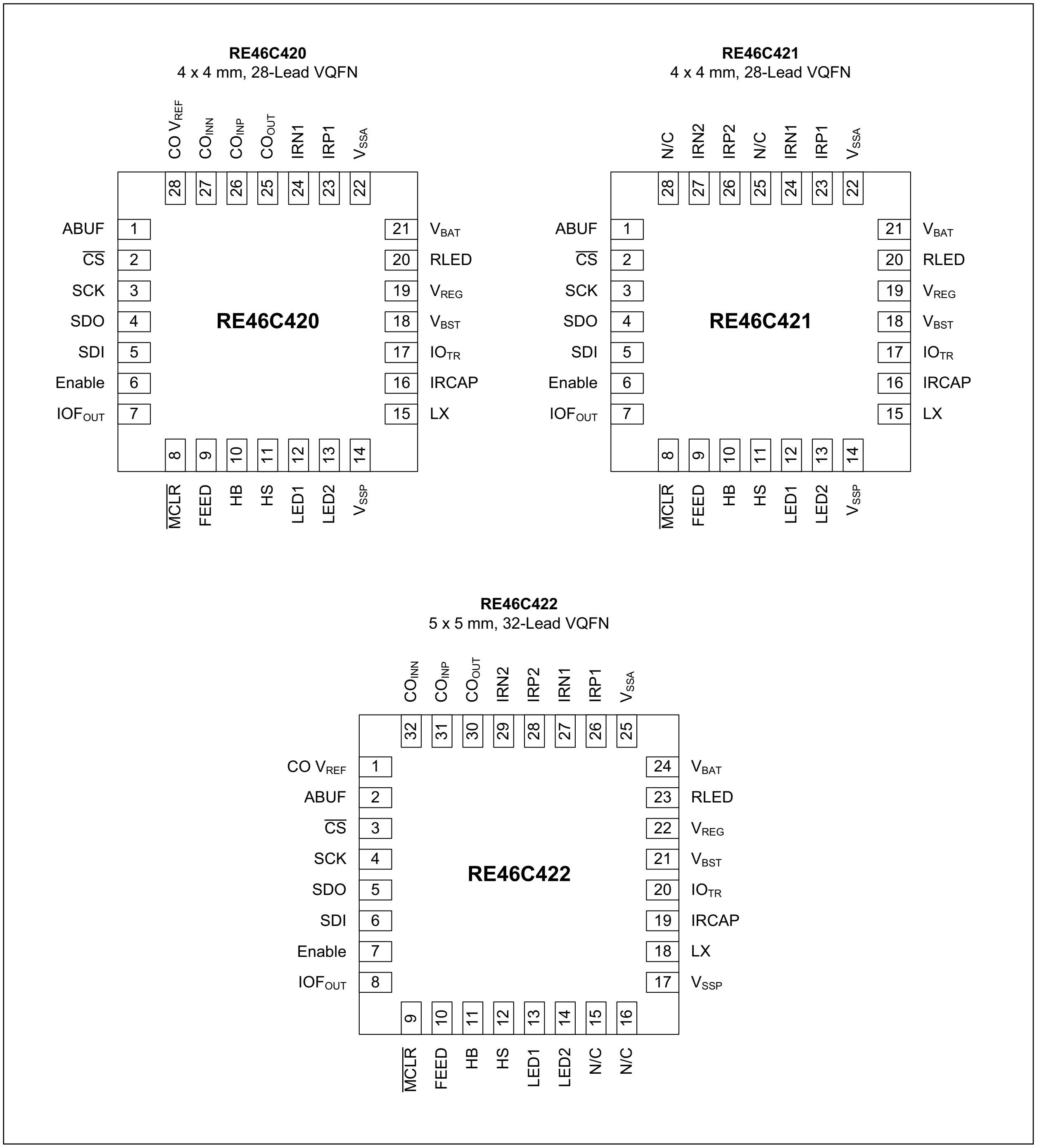
RE46C420/1/2 is a low power companion IC for smoke detectors. It provides all the necessary analog, interface and power regulation functions required for an MCU-based multicriteria smoke detector, making it suitable for use in 3V and 9V battery applications.

Differences between the devices:

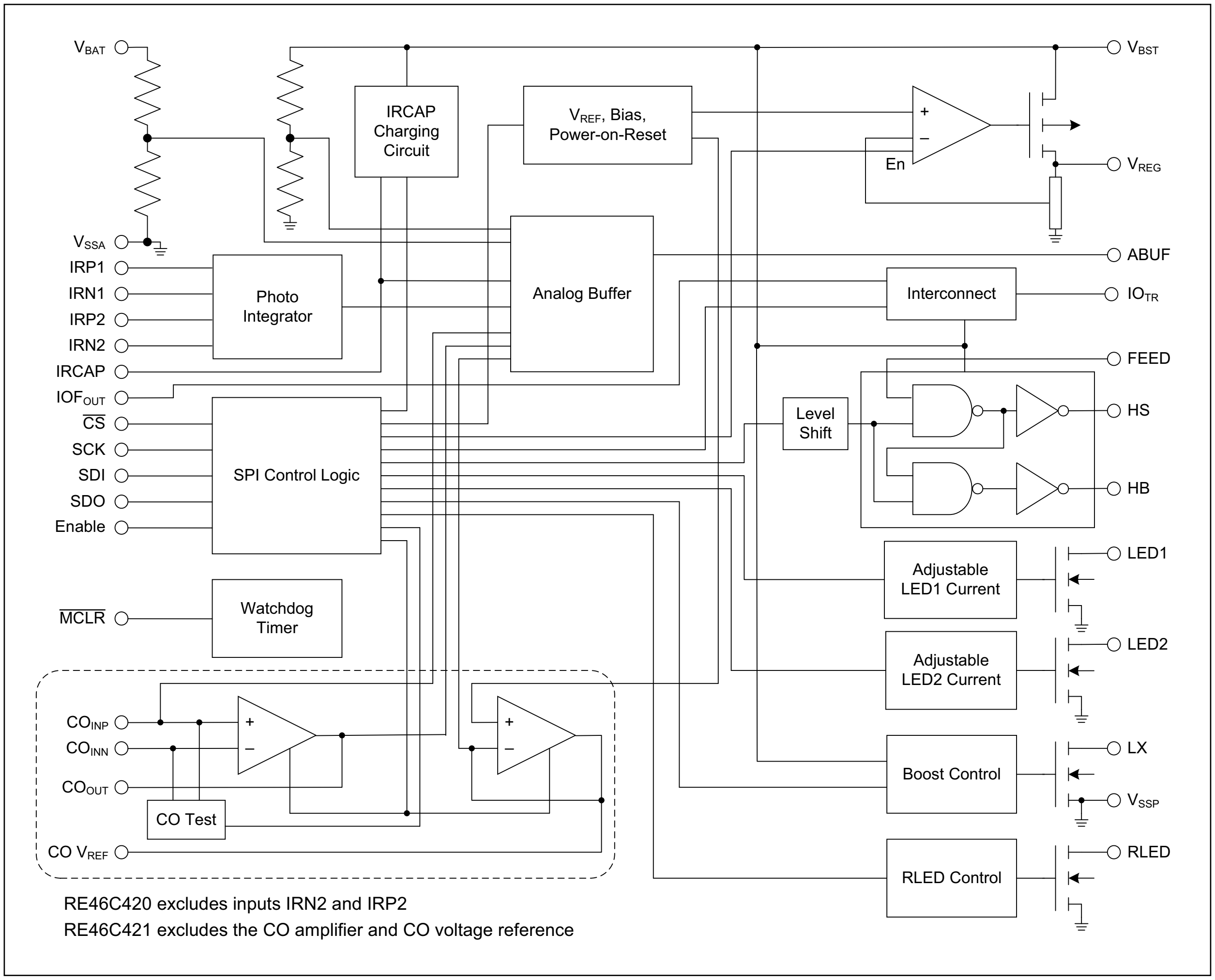
- RE46C420:
  - One integrating photo amplifier
  - CO circuitry
- RE46C421:
  - Dual integrating photo amplifiers
  - No CO circuitry
- RE46C422:
  - Dual integrating photo amplifiers
  - CO circuitry

The RE46C420/1/2 SPI enables the MCU to control device operation and all the parameters that determine the output voltage signal levels of the device, including LED current, amplifier gain and integration time. These parameters, together with the activation of various functions, are configurable through the SPI port.

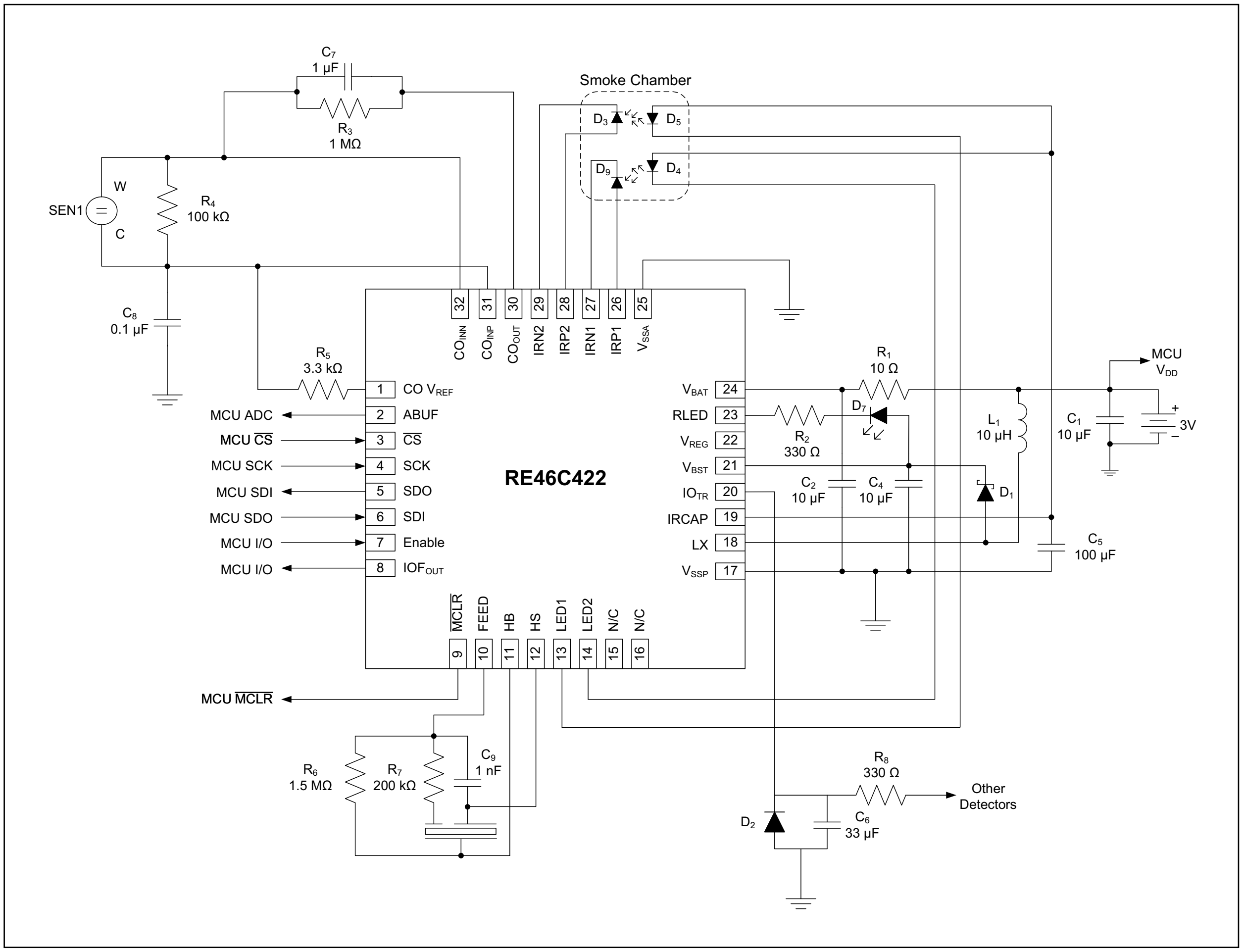
Package Types



Functional Block Diagram



Typical 3V Application (RE46C422)



1.0 ELECTRICAL CHARACTERISTICS

1.1 Absolute Maximum Ratings(†)

V_{BAT}	+4.0V
V_{REG}	+3.5V
V_{BST}	+18V
LX	V_{BST} + 0.6V
IRCAP, LED1, LED2	+5.5V
Input Voltage Range Except FEED, when BatSel = 1, (V_{IN1})	-0.3V to V_{BAT} + 0.3V
Input Voltage Range Except FEED, when RegSel = 1, (V_{IN1})	-0.3V to V_{REG} + 0.3V
FEED Input Voltage Range (V_{INFD})	-15V to +35V
Output Voltage Range, except as noted below (V_{OUT})	-0.3 to +3.6V
$\overline{\text{HB}}$, $\overline{\text{HS}}$, RLED Output Voltage Range	-0.3V to V_{BST}
$\overline{\text{MCLR}}$ Output Voltage Range	-0.3V to +12V
IO_{TR}	-0.3V to +18V
Input Current Except FEED (I_{IN})	+10 mA
Input Current (V_{BAT})	I_{BAT} = +20 mA
Continuous Operating Current (HS, HB, V_{BST}, V_{REG})	I_{O1} = +40 mA
Continuous Operating Current (RLED)	I_{RL} = +30 mA
Continuous Operating Current (ABUF, SDO, IOF_{OUT}, CO_{OUT}, $\overline{\text{MCLR}}$)	I_{O2} = +10 mA
Continuous Operating Current (CO V_{REF})	I_{BAT} = +1 mA
Continuous Operating Current (LED1, LED2)	I_{OIR} = +400 mA
HBM ESD	+1.5 kV
Storage Temperature (T_{STG})	-55°C to +125°C
Operating Temperature Range (T_A)	-20°C to +70°C
Maximum Junction Temperature (T_J)	+150°C

† **Notice:** Stresses above those listed under “Maximum Ratings” may cause permanent damage to the device. This is a stress rating only and functional operation of the device at these, or any other conditions above those indicated in the operation listings of this specification, is not implied. Exposure to maximum rating conditions for extended periods may affect device reliability.

1.2 ELECTRICAL SPECIFICATIONS

TABLE 1-1: ELECTRICAL CHARACTERISTICS

Electrical Characteristics: Unless otherwise indicated, all parameters apply at T_A = -10°C to +60°C, V_{BAT} = 3V, V_{SS} = 0V, V_{BST} = 9V, V_{IRCAP} = 5.5V, C_3 = 22 µF, C_4 = 10 µF, C_5 = 100 µF, BatSel = 1, RegEn = 0, RegSel = 0, LBEn = 0, HBEn = 0 (Note 1), (Note 2), (Note 3), (Note 4)

Parameter	Symbol	Test Pin	Min.	Typical	Max.	Units	Conditions
System Supply							
Supply Voltage	V_{BAT}	V_{BAT}	2.1	—	3.6	V	
	V_{BST}	V_{BST}	4.9	—	17	V	External Supply Powers V_{BST}
Reset Voltage	POR	V_{BAT}	1.2	1.7	2	V	Power-on reset, V_{BAT} rising, V_{BST} floating
		V_{BST}	2	2.4	3.7	V	Power-on reset, V_{BAT} floating, V_{BST} rising
		V_{BAT}	1.1	1.4	1.7	V	Brown-out reset, V_{BAT} falling, BatSel = 1
I_{DD}	I_{DDSTBY}	V_{BAT}	—	300	600	nA	All circuits disabled
	I_{DDrev}	V_{BAT}	—	-20	-175	nA	Reverse I_{DD} leakage, V_{BAT} = 2V, V_{REG} = 3.5V, RegEn = 0, RegSel = 1, BatSel = 0
Boost Regulator (LBEn = 1, LBV = 1, HBEn = 0, HBV[2:1] = 00) (Low-boost enabled, high-boost disabled, low-boost voltage set to 5.2V)							
I_{DD}	I_{DDBST}	V_{BAT}	—	18	—	µA	No load, LBV = 1
I_{POS}	I_{POSBST}	V_{BST}	—	9	—	µA	No load, LBV = 1
Boost Regulator Output Voltage	V_{BST1}	V_{BST}	3.74	4	4.26	V	I_{LOAD} = 10 mA, LBV = 0
	V_{BST2}		4.9	5.2	5.5	V	I_{LOAD} = 10 mA, LBV = 1
	V_{BST3}		8	8.5	9	V	I_{LOAD} = 10 mA, HBEn = 1, HBV[2:1] = 00
	V_{BST4}		9.4	10	10.6	V	I_{LOAD} = 10 mA, HBEn = 1, HBV[2:1] = 0
	V_{BST5}		10.8	11.5	12.2	V	I_{LOAD} = 10 mA, HBEn = 1, HBV[2:1] = 10
	V_{BST6}		15	16	17	V	I_{LOAD} = 10 mA, HBEn = 1, HBV[2:1] = 11

Note 1: Wherever a specific V_{BST} value is listed under test conditions, V_{BST} is externally forced with the inductor disconnected and the Boost converter NOT running. LBEn = 0, HBEn = 0.

2: Typical values are for design information only and apply at T_A = +25°C.

3: Limits shown are 100% tested at T_A = +25°C only. Test limits are guard-banded based on temperature characterization to warrant compliance at temperature extremes.

4: All analog functions are off, unless otherwise noted: ABUF[3:0] = 0000, LBEn = 0, HBEn = 0, IRCEn = 0, PAEn = 0, LED2En = 0, LED1En = 0, HrnEn = 0, IOEn = 0, RLEn = 0, RegEn = 0, COAEn = 0, COREn = 0, COTest = 0, WDEn = 0.

5: Not production-tested.

6: ΔmV = ABUF – 200 mV

TABLE 1-1: ELECTRICAL CHARACTERISTICS (CONTINUED)

Electrical Characteristics: Unless otherwise indicated, all parameters apply at T_A = -10°C to +60°C, V_{BAT} = 3V, V_{SS} = 0V, V_{BST} = 9V, V_{IRCAP} = 5.5V, C_3 = 22 µF, C_4 = 10 µF, C_5 = 100 µF, BatSel = 1, RegEn = 0, RegSel = 0, LBEn = 0, HBEn = 0 (Note 1), (Note 2), (Note 3), (Note 4)

Parameter	Symbol	Test Pin	Min.	Typical	Max.	Units	Conditions
Boost Regulator (continued)							
Soft-Start Time	t_{BST0}	V_{BST}	—	15	—	ms	Initial Startup, V_{BAT} = 0V to 3V
	t_{BST1}		—	2.5	—	ms	HBEn = 0 to 1, HBV[2:1] = 00
	t_{BST2}		—	3.7	—	ms	HBEn = 0 to 1, HBV[2:1] = 01
	t_{BST3}		—	7	—	ms	HBEn = 0 to 1, HBV[2:1] = 11
	t_{BST4}		—	4	—	ms	LBEn = 0 to 1, LBV = 1, RegEn = 1
	t_{BST5}		—	5.5	—	ms	LBEn = 0, HBEn = 0 to 1, HBV[2:1] = 01, RegEn = 1
	t_{BST6}		—	11	—	ms	LBEn = 0, HBEn = 0 to 1, HBV[2:1] = 10, RegEn = 1
V_{BST} Efficiency	V_{EFF}	V_{BST}, V_{BAT}	—	76	—	%	I_{LOAD} = 10 mA, LBV = 1
Output Off Leakage High	I_{IHOZ}	LX	—	—	1	µA	LX = V_{BST} = 18V, LBEn = 0, HBEn = 0
3.3V Regulator (V_{BST} = 5.2V, RegEn = 1, RegSel = 0, LBEn = 0, HBEn = 0) (Enable regulator, power internal circuits from V_{BAT}, boost regulator off)							
I_{POS}	I_{POSREG}	V_{BST}	—	3	6	µA	No load
Startup Time	t_{REG}	V_{REG}	—	0.7	3	ms	No load, V_{REG} = 0.0V to 90% V_{REG}
Regulator Voltage	V_{REG1}	V_{REG}	3.1	3.3	3.5	V	I_{LOAD} = 20 mA
Load Regulation	V_{REGLD}	V_{REG}	—	10	50	mV	I_{LOAD} = 0 to 20 mA, RegSel = 1, BatSel = 0
Short Circuit Current	I_{REGSC}	—	—	52	—	mA	V_{REG} shorted to V_{SS}
Line Regulation	V_{REGLN}	V_{REG}	—	0.02	0.25	%/V	I_{LOAD} =1mA, V_{BST} = 4.9V to 17V

Note 1: Wherever a specific V_{BST} value is listed under test conditions, V_{BST} is externally forced with the inductor disconnected and the Boost converter NOT running. LBEn = 0, HBEn = 0.

2: Typical values are for design information only and apply at T_A = +25°C.

3: Limits shown are 100% tested at T_A = +25°C only. Test limits are guard-banded based on temperature characterization to warrant compliance at temperature extremes.

4: All analog functions are off, unless otherwise noted: ABUF[3:0] = 0000, LBEn = 0, HBEn = 0, IRCEn = 0, PAEn = 0, LED2En = 0, LED1En = 0, HrnEn = 0, IOEn = 0, RLEn = 0, RegEn = 0, COAEn = 0, COREn = 0, COTest = 0, WDEn = 0.

5: Not production-tested.

6: ΔmV = ABUF – 200 mV

TABLE 1-1: ELECTRICAL CHARACTERISTICS (CONTINUED)

Electrical Characteristics: Unless otherwise indicated, all parameters apply at T_A = -10°C to +60°C, V_{BAT} = 3V, V_{SS} = 0V, V_{BST} = 9V, V_{IRCAP} = 5.5V, C_3 = 22 µF, C_4 = 10 µF, C_5 = 100 µF, BatSel = 1, RegEn = 0, RegSel = 0, LBEn = 0, HBEn = 0 (Note 1), (Note 2), (Note 3), (Note 4)

Parameter	Symbol	Test Pin	Min.	Typical	Max.	Units	Conditions
Photo Detection							
Photo Amplifier (PAEn = 1, ABUF[3:0] = 0000, EnBUF = 1, InSel = 0, ITCn = 0, EnCntl = 0, IT[5:4] = 00, Gain[2:0] = 000) (Photo amplifier and ABUF enabled, Inputs = IRN1 and IRP1, fixed integration time = 100 µs, Gain = 1, Status = Reset)							
I_{DD}	I_{DDPA}	V_{BAT}	—	50	120	µA	I_{DD} due to ABUF powering on when photo amplifier powers on
IRCAP Supply Current	$I_{IRCAPPA}$	IRCAP	—	340	410	µA	
Startup Time	t_{SUPA}	ABUF	—	10	110	µs	IRCEn=1, PAEn = 0 to 1 transition
Input Bias Current	I_{BOP1}	IRN1, IRP1	-200	—	200	pA	InSel = 0, Gain[2:0] = 100, IT[5:4] = 01, Enable Pin = 1
	I_{BOP2}	IRN2, IRP2	-200	—	200	pA	InSel = 1, Gain[2:0] = 100, IT[5:4] = 01, Enable Pin = 1
Photo Amplifier Reference	PARef	ABUF	—	200	—	mV	
PAOut1	PAO01	ABUF	620	830	1040	ΔmV(6)	G = 1, I_{PD} = 40 nA
	PAO02		1290	1660	2050	ΔmV(6)	G = 2, Gain[2:0] = 001, I_{PD} = 40 nA
	PAO03		—	830	—	ΔmV(6)	G = 4, Gain[2:0] = 010, I_{PD} = 10 nA
	PAO04		—	1660	—	ΔmV(6)	G = 8, Gain[2:0] = 011, I_{PD} = 10 nA
	PAO05		1200	1560	1920	ΔmV(6)	G = 16, Gain[2:0] = 100, I_{PD} = 5 nA
	PAO06		1000	1400	1800	ΔmV(6)	G = 32, Gain[2:0] = 101, I_{PD} = 2.5 nA
PAOut2	PAO09		620	830	1040	ΔmV(6)	Input2, InSel = 1, G = 1, Gain[2:0] = 000, I_{PD} = 40 nA
PAOut3	PAO10		—	800	—	ΔmV(6)	t_i = 200 µs, IT[5:4] = 01, I_{PD} = 20 nA
	PAO11		—	1200	—	ΔmV(6)	t_i = 300 µs, IT[5:4] = 10, I_{PD} = 20 nA
	PAO12		—	1600	—	ΔmV(6)	t_i = 400 µs, IT[5:4] = 11, I_{PD} = 20 nA
	PAO13		—	2800	—	mV	t_i = 400 µs, IT[5:4] = 11, I_{PD} = 40 nA, Highside Test, V_{IRCAP} = 3.3V

Note 1: Wherever a specific V_{BST} value is listed under test conditions, V_{BST} is externally forced with the inductor disconnected and the Boost converter NOT running. LBEn = 0, HBEn = 0.

2: Typical values are for design information only and apply at T_A = +25°C.

3: Limits shown are 100% tested at T_A = +25°C only. Test limits are guard-banded based on temperature characterization to warrant compliance at temperature extremes.

4: All analog functions are off, unless otherwise noted: ABUF[3:0] = 0000, LBEn = 0, HBEn = 0, IRCEn = 0, PAEn = 0, LED2En = 0, LED1En = 0, HrnEn = 0, IOEn = 0, RLEn = 0, RegEn = 0, COAEn = 0, COREn = 0, COTest = 0, WDEn = 0.

5: Not production-tested.

6: ΔmV = ABUF – 200 mV

TABLE 1-1: ELECTRICAL CHARACTERISTICS (CONTINUED)

Electrical Characteristics: Unless otherwise indicated, all parameters apply at T_A = -10°C to +60°C, V_{BAT} = 3V, V_{SS} = 0V, V_{BST} = 9V, V_{IRCAP} = 5.5V, C_3 = 22 µF, C_4 = 10 µF, C_5 = 100 µF, BatSel = 1, RegEn = 0, RegSel = 0, LBEn = 0, HBEn = 0 (Note 1), (Note 2), (Note 3), (Note 4)

Parameter	Symbol	Test Pin	Min.	Typical	Max.	Units	Conditions
Integration Time (PAEn = 1, ABUF = 0000, EnBUF = 1, InSel = 0, ITCn = 0, EnCntl = 0, Gain[2:0] = 000) (Photo amplifier and ABUF enabled, Inputs IRN1 and IRP1, fixed integration time, Gain = 1)							
PAOut1 t_i = 100 µs	t_{i100}	ABUF	80	100	120	µs	IT[5:4] = 00, I_{PD} = 20 nA
PAOut1 t_i = 200 µs	t_{i200}		160	200	240	µs	IT[5:4] = 01, I_{PD} = 20 nA
PAOut1 t_i = 300 µs	t_{i300}		240	300	360	µs	IT[5:4] = 10, I_{PD} = 20 nA
PAOut1 t_i = 400 µs	t_{i400}		320	400	480	µs	IT[5:4] = 11, I_{PD} = 20 nA
IRCAP LED Supply (V_{BST} = 6V, IRCEn = 1, LBEn = 1, LBV = 1)							
I_{POS}	$I_{POSIRCAP1}$	V_{BST}	—	4	7.2	µA	Not charging (V_{IRCAP} = 5.5V)
	$I_{POSIRCPCHRG}$		—	60	100	µA	Charging (V_{IRCAP} = 3.5V)
I_{DD}	$I_{DDIRCAP}$	V_{BAT}	—	6	10	µA	
Startup Time	t_{IRCAP}	—	—	2	—	µs	R_{IRCAP} = 1 kΩ, V_{IRCAP} = 0V to 1V
IRCAP Voltage	V_{IRCAP}	IRCAP	3.3	—	5.5	V	LEDEn1 = 1 or LEDEn 2 = 1, PAEN = 1
Charging Current	I_{IRCAP}	IRCAP	—	18	—	mA	V_{IRCAP} = 3.5V, LBV = 0,
Turn On Voltage	V_{TIR1}	IRCAP	3.6	4	4.4	V	Falling edge, I_{OUT} = 10 mA, LBV = 0
	V_{TIR2}		4.6	4.85	5.1	V	Falling edge, I_{OUT} = 10 mA, LBV = 1
Turn Off Voltage	V_{TIR3}	IRCAP	4	4.4	4.8	V	Rising edge, I_{OUT} = 1 mA, LBV = 0
	V_{TIR4}		5	5.25	5.5	V	Rising edge, I_{OUT} = 1 mA, LBV = 1

Note 1: Wherever a specific V_{BST} value is listed under test conditions, V_{BST} is externally forced with the inductor disconnected and the Boost converter NOT running. LBEn = 0, HBEn = 0.

2: Typical values are for design information only and apply at T_A = +25°C.

3: Limits shown are 100% tested at T_A = +25°C only. Test limits are guard-banded based on temperature characterization to warrant compliance at temperature extremes.

4: All analog functions are off, unless otherwise noted: ABUF[3:0] = 0000, LBEn = 0, HBEn = 0, IRCEn = 0, PAEn = 0, LED2En = 0, LED1En = 0, HrnEn = 0, IOEn = 0, RLEn = 0, RegEn = 0, COAEn = 0, COREn = 0, COTest = 0, WDEn = 0.

5: Not production-tested.

6: ΔmV = ABUF – 200 mV

TABLE 1-1: ELECTRICAL CHARACTERISTICS (CONTINUED)

Electrical Characteristics: Unless otherwise indicated, all parameters apply at T_A = -10°C to +60°C, V_{BAT} = 3V, V_{SS} = 0V, V_{BST} = 9V, V_{IRCAP} = 5.5V, C_3 = 22 µF, C_4 = 10 µF, C_5 = 100 µF, BatSel = 1, RegEn = 0, RegSel = 0, LBEn = 0, HBEn = 0 (Note 1), (Note 2), (Note 3), (Note 4)

Parameter	Symbol	Test Pin	Min.	Typical	Max.	Units	Conditions
Photo LED Driver (X = 1 or 2) (V_{BST} = 5V, V_{IRCAP} = 4.5V, IRCEn = 0, LEDxEn = 1, PAEn = 1, ITCn = 1, Enable = 1) (IRCAP disabled, photo amplifier enabled, Enable pin controls LED on/off)							
IRCAP LED Supply Current	$I_{IRCAPLED}$	IRCAP	—	1	—	mA	I_{LEDx} = 100 mA, LEDx[2:0] = 101
Startup Time (LEDx)	t_{SULED}	—	—	10	20	µs	PAEn = 1, LEDxEn = 1, from LED select to LED ready to enable
Turn On Time (LEDx)	t_{LED}	LEDx	—	0.4	—	µs	V_{LEDx} = 1V, LEDx[2:0] = 010, from LED enable to ILED at 70% (I_{LEDx} = 35 mA)
LED1 and LED2 Output Current	I_{LEDx20}	LEDx	18	20	22	mA	V_{LEDx} = 0.8V, T_A = +25°C, LEDx[2:0] = 000
	I_{LEDx40}		36	40	44	mA	V_{LEDx} = 0.8V, T_A = +25°C, LEDx[2:0] = 001
	I_{LEDx50}		45	50	55	mA	V_{LEDx} = 0.8V, T_A = +25°C, LEDx[2:0] = 010
	I_{LEDx60}		54	60	66	mA	V_{LEDx} = 0.8V, T_A = +25°C, LEDx[2:0] = 011
	I_{LEDx80}		72	80	88	mA	V_{LEDx} = 1V, T_A = +25°C, LEDx[2:0] = 100
	$I_{LEDx100}$		90	100	110	mA	V_{LEDx} = 1V, T_A = +25°C, LEDx[2:0]= 101
	$I_{LEDx150}$		135	150	165	mA	V_{LEDx} = 1V, T_A = +25°C, LEDx[2:0]= 110
	$I_{LEDx200}$		180	200	220	mA	V_{LEDx} = 1V, T_A = +25°C, LEDx[2:0]= 111
LED Current Temperature Coefficient	TC_{LED0}	LEDx	—	0	—	%/°C	LEDxTC[2:0] = 000; $I_{LEDXXXX}$ (**Note 5**)
	TC_{LED3}		—	0.3	—	%/°C	LEDxTC[2:0] = 001; $I_{LEDXXXX}$ (**Note 5**)
	TC_{LED4}		—	0.4	—	%/°C	LEDxTC[2:0] = 010; $I_{LEDXXXX}$ (**Note 5**)
	TC_{LED5}		—	0.5	—	%/°C	LEDxTC[2:0] = 011; $I_{LEDXXXX}$ (**Note 5**)
	TC_{LED6}		—	0.6	—	%/°C	LEDxTC[2:0] = 1XX; $I_{LEDXXXX}$ (**Note 5**)

Note 1: Wherever a specific V_{BST} value is listed under test conditions, V_{BST} is externally forced with the inductor disconnected and the Boost converter NOT running. LBEn = 0, HBEn = 0.

2: Typical values are for design information only and apply at T_A = +25°C.

3: Limits shown are 100% tested at T_A = +25°C only. Test limits are guard-banded based on temperature characterization to warrant compliance at temperature extremes.

4: All analog functions are off, unless otherwise noted: ABUF[3:0] = 0000, LBEn = 0, HBEn = 0, IRCEn = 0, PAEn = 0, LED2En = 0, LED1En = 0, HrnEn = 0, IOEn = 0, RLEn = 0, RegEn = 0, COAEn = 0, COREn = 0, COTest = 0, WDEn = 0.

5: Not production-tested.

6: ΔmV = ABUF – 200 mV

TABLE 1-1: ELECTRICAL CHARACTERISTICS (CONTINUED)

Electrical Characteristics: Unless otherwise indicated, all parameters apply at T_A = -10°C to +60°C, V_{BAT} = 3V, V_{SS} = 0V, V_{BST} = 9V, V_{IRCAP} = 5.5V, C_3 = 22 µF, C_4 = 10 µF, C_5 = 100 µF, BatSel = 1, RegEn = 0, RegSel = 0, LBEn = 0, HBEn = 0 (Note 1), (Note 2), (Note 3), (Note 4)

Parameter	Symbol	Test Pin	Min.	Typical	Max.	Units	Conditions
CO Detection (COAEn = 1 COREn = 1, COTest = 0, COTRi = 0) (CO amplifier and reference enabled, CO test functions disabled)							
I_{DD}	$I_{DDCOREF}$	V_{BAT}	—	1.5	3	µA	No loads
	I_{DDCO}		—	1.1	2.2	µA	No loads, COREn = 0
	$I_{DDCOTst}$		—	7	12	µA	COTest = 1, COTRi = 1
Startup Time	t_{SUCO}	CO_{OUT}	—	900	—	µs	CO_{OUT} = 0.27V, CO_{INP} = 0.3V, Unity gain, C_{LOAD} = 50 pF, R_{LOAD} = 50 kΩ
Reference Voltage	CO V_{Ref}	CO V_{REF}	0.27	0.3	0.33	V	$I_{CO\ VREF}$ = ±10 µA, COREn = 1
Input Offset Voltage	V_{OSCO1}	CO_{INP}, CO_{INN}	-3	—	3	mV	V_{CM} = 0.3V
	V_{OSCO2}	CO_{INP}, CO_{INN}	-1	—	1	mV	V_{CM} = 0.3V, T_A = +25°C
Input Bias Current	I_{BOP1}	CO_{INN}	-200	—	200	pA	T_A = +25°C
	I_{BOP2}	CO_{INP}	-100	—	100	nA	
Test Source Current	I_{COTst1}	CO_{INP}, CO_{INN}	-2.5	-2	-1.6	µA	V_{CM} = 0.3V, COTri = 1, COTest = 1, COCurSel = 0 or 1, COCurPol = 0 or 1
Test Sink Current	I_{COTst2}	CO_{INP}, CO_{INN}	1.6	2	2.5	µA	V_{CM} = 0.3V, COTri = 1, COTest = 1, COCurSel = 0 or 1, COCurPol = 1 or 0
Common-Mode Input Range	V_{CMR}	CO_{INP}, CO_{INN}	0	—	V_{BAT}	V	
Common-Mode rejection Ratio	CMRR	CO_{INP}, CO_{INN}	—	85	—	dB	V_{CM} = 0V to V_{BAT}
DC Open Loop Gain (large signal)	AOL	CO_{INP}, CO_{INN}	—	100	—	dB	R_{LOAD} = 50 kΩ to 0.5 * V_{BAT}
Maximum Output Voltage Swing	V_{OLCO}, V_{OHCO}	CO_{OUT}	Vss + 0.010	—	V_{BAT} - 0.020	V	R_{LOAD} = 50 kΩ to 0.5 * V_{BAT}, 0.5V input overdrive
Short Circuit Current	I_{OS}	CO_{OUT}	—	16	—	mA	
CO AC Response (COAEn = 1, COREn = 1)							
CO GBW	GBWCO	CO_{OUT}	—	10	—	kHz	Gain = 1, C_{LOAD} = 50 pF
Phase margin	PM	CO_{OUT}	—	65	—	º	Gain = 1, C_{LOAD} = 50 pF
Slew Rate	SRCO	CO_{OUT}	—	3	—	V/ms	Gain = 1, C_{LOAD} = 50 pF

Note 1: Wherever a specific V_{BST} value is listed under test conditions, V_{BST} is externally forced with the inductor disconnected and the Boost converter NOT running. LBEn = 0, HBEn = 0.

2: Typical values are for design information only and apply at T_A = +25°C.

3: Limits shown are 100% tested at T_A = +25°C only. Test limits are guard-banded based on temperature characterization to warrant compliance at temperature extremes.

4: All analog functions are off, unless otherwise noted: ABUF[3:0] = 0000, LBEn = 0, HBEn = 0, IRCEn = 0, PAEn = 0, LED2En = 0, LED1En = 0, HrnEn = 0, IOEn = 0, RLEn = 0, RegEn = 0, COAEn = 0, COREn = 0, COTest = 0, WDEn = 0.

5: Not production-tested.

6: ΔmV = ABUF – 200 mV

TABLE 1-1: ELECTRICAL CHARACTERISTICS (CONTINUED)

Electrical Characteristics: Unless otherwise indicated, all parameters apply at T_A = -10°C to +60°C, V_{BAT} = 3V, V_{SS} = 0V, V_{BST} = 9V, V_{IRCAP} = 5.5V, C_3 = 22 µF, C_4 = 10 µF, C_5 = 100 µF, BatSel = `1`, RegEn = `0`, RegSel = `0`, LBEn = `0`, HBEn = `0` (Note 1), (Note 2), (Note 3), (Note 4)

Parameter	Symbol	Test Pin	Min.	Typical	Max.	Units	Conditions
CO Operational Amplifier Noise							
Input Voltage Noise	eni	CO_{OUT}	—	5	—	$µV_{PP}$	
Input Voltage Noise Density	eni	CO_{OUT}	—	170	—	nV/√Hz	
Input Current Noise Density	ini	CO_{OUT}	—	0.6	—	fA/√Hz	
ABUF Operational Amplifier (ABUF[3:0] = `1010`) ABUF enabled, Input at pin CO_{INP}							
I_{DD}	I_{DDABUF}	V_{BAT}	—	50	120	µA	No load, ABUF[3:0] = `1010`, CO_{INP} = 2.965V
Input Offset Voltage	V_{osABUF}	ABUF	-3	—	3	mV	
Startup Time	t_{SUABUF}	ABUF	—	10	—	µs	From ABUF[3:0] = `0000` to 95% ABUF[3:0] = `0101`, V_{BST} = 10V
Maximum Output Voltage Swing	V_{OLABUF}	ABUF	V_{SS} + 0.035	—	—	V	R_{LOAD} = 50 kΩ, 0.5V input overdrive
	V_{OHABUF}	ABUF	—	—	V_{BAT} - 0.035	V	R_{LOAD} = 50 kΩ, 0.5V input overdrive
Short Circuit Current	I_{SC}	ABUF	—	12	—	mA	1.5V input, R_{LOAD} = 75 kΩ
Pull-Down Current Low	I_{OL_off}	ABUF	0.5	3	6	mA	ABUF[3:0] = `0000`, V_{ABUF} = 3.0V

Note 1: Wherever a specific V_{BST} value is listed under test conditions, V_{BST} is externally forced with the inductor disconnected and the Boost converter NOT running. LBEn = `0`, HBEn = `0`.

2: Typical values are for design information only and apply at T_A = +25°C.

3: Limits shown are 100% tested at T_A = +25°C only. Test limits are guard-banded based on temperature characterization to warrant compliance at temperature extremes.

4: All analog functions are off, unless otherwise noted: ABUF[3:0] = `0000`, LBEn = `0`, HBEn = `0`, IRCEn = `0`, PAEn = `0`, LED2En = `0`, LED1En = `0`, HrnEn = `0`, IOEn = `0`, RLEn = `0`, RegEn = `0`, COAEn = `0`, COREn = `0`, COTest = `0`, WDEn = `0`.

5: Not production-tested.

6: ΔmV = ABUF – 200 mV

TABLE 1-1: ELECTRICAL CHARACTERISTICS (CONTINUED)

Electrical Characteristics: Unless otherwise indicated, all parameters apply at T_A = -10°C to +60°C, V_{BAT} = 3V, V_{SS} = 0V, V_{BST} = 9V, V_{IRCAP} = 5.5V, C_3 = 22 µF, C_4 = 10 µF, C_5 = 100 µF, BatSel = 1, RegEn = 0, RegSel = 0, LBEn = 0, HBEn = 0 (Note 1), (Note 2), (Note 3), (Note 4)

Parameter	Symbol	Test Pin	Min.	Typical	Max.	Units	Conditions
ABUF Operational Amplifier (continued) (ABUF[3:0] = 1010) ABUF enabled, Input at pin CO_{INP}							
ABUF R Divider Ratio	ABUFVBAT	ABUF	0.475	0.5	0.525	—	ABUF[3:0] = 0111, BatSel = 1
	ABUFVREG	ABUF	0.475	0.5	0.525	—	V_{REG} = 3.3V, ABUF[3:0] = 1000, RegEn = 0
	ABUFIRCAP	ABUF	0.238	0.25	0.262	—	IRCAP = 5V, ABUF[3:0] = 0110, IRCEn = 0
	ABUFVBST	ABUF	0.095	0.1	0.105	—	V_{BST} = 10V, ABUF[3:0] = 0101, LBEn = 0, HBEn = 0
	ABUFPHOTO	ABUF	—	1	—	—	ABUF[3:0] = 0010, PAEn = 1, INSEL = 0, EnBuf = 1, Status = 1
	ABUF200REF	ABUF	—	1	—	—	ABUF[3:0] = 0001, PAEn = 1
	ABUFCO	ABUF	0.95	1	1.05	—	CO_{OUT} = 1.5V, ABUF[3:0] = 0011, COAEn = 0
	ABUFCOREF	ABUF	0.95	1	1.05	—	CO V_{REF} = 0.3V, ABUF[3:0] = 0100, COREn = 0
	ABUFIOtr	ABUF	0.095	0.1	0.105	—	V_{IO} = 10V, ABUF[3:0] = 1001, IOEn = 0
	ABUFCOinp	ABUF	0.95	1	1.05	—	CO_{INP} = 0.3V, ABUF[3:0] = 1010, COAEn = 0
	ABUFCOinn	ABUF	0.95	1	1.05	—	CO_{INN} = 0.3V, ABUF[3:0] = 1011, COAEn = 0
	ABUFIRED1	ABUF	0.238	0.25	0.262	—	IRED1 = 2V, V_{IRCAP} = 5, ABUF[3:0] = 1100
	ABUFIRED2	ABUF	0.238	0.25	0.262	—	IRED2 = 2V, V_{IRCAP} = 5, ABUF[3:0] = 1101
ABUF AC Response							
ABUF GBW	GBWABUF	ABUF	—	1.24	—	MHz	C_{LOAD} = 50 pF
Phase Margin	PM	ABUF	—	65	—	°	C_{LOAD} = 50 pF
ABUF Slew Rate	SRABUF	ABUF	—	400	—	V/ms	C_{LOAD} = 50 pF
ABUF Settle Time	STABUF	ABUF	—	3	—	µs	CO_{INP} = 0.3V to 1.3V, ABUF = 95% Final Value

Note 1: Wherever a specific V_{BST} value is listed under test conditions, V_{BST} is externally forced with the inductor disconnected and the Boost converter NOT running. LBEn = 0, HBEn = 0.

2: Typical values are for design information only and apply at T_A = +25°C.

3: Limits shown are 100% tested at T_A = +25°C only. Test limits are guard-banded based on temperature characterization to warrant compliance at temperature extremes.

4: All analog functions are off, unless otherwise noted: ABUF[3:0] = 0000, LBEn = 0, HBEn = 0, IRCEn = 0, PAEn = 0, LED2En = 0, LED1En = 0, HrnEn = 0, IOEn = 0, RLEn = 0, RegEn = 0, COAEn = 0, COREn = 0, COTest = 0, WDEn = 0.

5: Not production-tested.

6: ΔmV = ABUF – 200 mV

TABLE 1-1: ELECTRICAL CHARACTERISTICS (CONTINUED)

Electrical Characteristics: Unless otherwise indicated, all parameters apply at T_A = -10°C to +60°C, V_{BAT} = 3V, V_{SS} = 0V, V_{BST} = 9V, V_{IRCAP} = 5.5V, C_3 = 22 µF, C_4 = 10 µF, C_5 = 100 µF, BatSel = 1, RegEn = 0, RegSel = 0, LBEn = 0, HBEn = 0 (Note 1), (Note 2), (Note 3), (Note 4)

Parameter	Symbol	Test Pin	Min.	Typical	Max.	Units	Conditions
IO Function (IOEn = 0, IOThrsh = 0, IRCEn = 0, IOout = 0, HiIO = 0, HiDmp = 0) (IO Receive mode, low threshold voltages, IRCAP off, IO output set to 0, high-source current disabled, high-sink current disabled)							
I_{DD}	I_{DDIO}	V_{BAT}	5	9	13	µA	I_{LOAD} = 200 µA, IOEn = 1, IOout = 1, HiIO = 0
	I_{DDIOHI}	V_{BAT}	—	400	—	nA	No load, IO_{TR} = 4V
I_{POS}	I_{POSIO}	V_{BST}	—	700	850	µA	I_{LOAD} = 200 µA, IOEn = 1, IOout = 1
IRCAP Supply Current	$I_{IRCAPIO}$	IRCAP	—	200	600	µA	I_{LOAD} = 200 µA, IRCEn = 1, IOEn = 1, IOout = 1, HiIO = 1
	$I_{IRCAPIODMP}$		—	1	—	µA	No load, IRCEn = 1, IOEn = 1, IOout = 0, HiDmp = 1
Startup Time	t_{IO}	IO_{TR}	—	5	—	µs	Transmit, IOEn = 1, IOout = 1, HiIO = 0, COAEn = 1, (Band-gap and current reference already enabled)
Input Voltage Low	V_{IL3}	IO_{TR}	—	—	1.16	V	V_{BAT} = 3V
	V_{IL3B}	IO_{TR}	—	—	1.25	V	V_{BAT} = 3.3V
	V_{IL4}	IO_{TR}	—	—	2.3	V	V_{BAT} = 3V, IO_{THRSH} = 1
	V_{IL4B}	IO_{TR}	—	—	2.5	V	V_{BAT} = 3.3V, IO_{THRSH} = 1
Input Voltage High	V_{IH3}	IO_{TR}	1.95	—	—	V	V_{BAT} = 3V
	V_{IH3B}	IO_{TR}	2.05	—	—	V	V_{BAT} = 3.3V
	V_{IH4}	IO_{TR}	3.8	—	—	V	V_{BAT} = 3V, IO_{THRSH} = 1
	V_{IH4B}	IO_{TR}	4	—	—	V	V_{BAT} = 3.3V, IO_{THRSH} = 1
Input Voltage Hysteresis	V_{HYS3}	IO_{TR}	—	0.3	—	V	V_{BAT} = 3V
	V_{HYS3B}	IO_{TR}	—	0.3	—	V	V_{BAT} = 3.3V
	V_{HYS4}	IO_{TR}	—	0.55	—	V	V_{BAT} = 3V, IO_{THRSH} = 1
	V_{HYS4B}	IO_{TR}	—	0.56	—	V	V_{BAT} = 3.3V, IO_{THRSH} = 1
IO Filter Delay	t_{d_IO}	IO_{TR}, IOF_{OUT}	20	30	41	ms	IO_{TR} = 0V to 4V
Output Voltage Low	V_{OLIO}	IO_{TR}	—	0.3	0.5	V	I_{LOAD} = 4 mA, IOEn = 1, IOout = 0, HiDmp = 0
Output Voltage High	V_{OHIO}	IO_{TR}	6.6	7.3	—	V	I_{OUT} = -4 mA, IOEn = 1, IOout = 1, HiIO = 0

Note 1: Wherever a specific V_{BST} value is listed under test conditions, V_{BST} is externally forced with the inductor disconnected and the Boost converter NOT running. LBEn = 0, HBEn = 0.

2: Typical values are for design information only and apply at T_A = +25°C.

3: Limits shown are 100% tested at T_A = +25°C only. Test limits are guard-banded based on temperature characterization to warrant compliance at temperature extremes.

4: All analog functions are off, unless otherwise noted: ABUF[3:0] = 0000, LBEn = 0, HBEn = 0, IRCEn = 0, PAEn = 0, LED2En = 0, LED1En = 0, HrnEn = 0, IOEn = 0, RLEn = 0, RegEn = 0, COAEn = 0, COREn = 0, COTest = 0, WDEn = 0.

5: Not production-tested.

6: ΔmV = ABUF – 200 mV

TABLE 1-1: ELECTRICAL CHARACTERISTICS (CONTINUED)

Electrical Characteristics: Unless otherwise indicated, all parameters apply at T_A = -10°C to +60°C, V_{BAT} = 3V, V_{SS} = 0V, V_{BST} = 9V, V_{IRCAP} = 5.5V, C_3 = 22 µF, C_4 = 10 µF, C_5 = 100 µF, BatSel = 1, RegEn = 0, RegSel = 0, LBEn = 0, HBEn = 0 (Note 1), (Note 2), (Note 3), (Note 4)

Parameter	Symbol	Test Pin	Min.	Typical	Max.	Units	Conditions
IO Function (continued) (IOEn = 0, IOThrsh = 0, IRCEn = 0, IOout = 0, HiIO = 0, HiDmp = 0) (IO Receive mode, low threshold voltages, IRCAP off, IO output set to 0, high-source current disabled, high-sink current disabled)							
IO Output Current	I_{OIH1}	IO_{TR}	25	35	60	µA	IO_{TR} = 1V
	I_{OIH2}	IO_{TR}	—	—	150	µA	IO_{TR} = 15V
	I_{OIOH1}	IO_{TR}	-4	-5	-6	mA	IO_{TR} = 4V; IOEn = 1, IOout = 1, HiIO = 0
	I_{OIOH2}	IO_{TR}	-4	-5	-6.5	mA	IO_{TR} = 0V; IOEn = 1, IOout = 1, HiIO = 0
	I_{OIOH3}	IO_{TR}	-30	-40	-55	mA	IO_{TR} = 4V, IRCAP = 5.2V; IOEn = 1, IOout = 1, HiIO = 1
	I_{OIOH4}	IO_{TR}	-60	-74	-90	mA	IO_{TR} = 0V, IRCAP = 5.2V; IOEn = 1, IOout = 1, HiIO = 1
	I_{O1IOL1}	IO_{TR}	8	14	22	mA	IO_{TR} = 1V; IOEn = 1, IOout = 0, HiDMP = 0
	I_{O1IOL2}	IO_{TR}	25	35	60	mA	IO_{TR}=1V, IRCAP = 5.2V; IOEn = 1, IOout = 0, HiDMP = 1
Red LED							
Output Voltage Low	V_{RLED}	RLED	—	0.15	0.5	V	I_{LOAD} = 10 mA, RLEn = 1
RLED Turn On time	t_{RLED}	RLED	—	0.6	1	µs	I_{RLED} = 10 mA, RLEn = 0 to 1
Watchdog Timer (WDEn = 1)							
I_{DD}	I_{DDWD}	—	—	360	—	nA	
Watchdog Timer	t_{WD}	—	13	19	27	s	WDHrn = 1
Watchdog Reset Pulse Width	t_{pw_WD}	—	14	20	27	ms	
Watchdog Osc Period (800Hz)	t_{p_OSC}	—	0.85	1.25	1.71	ms	Internal Use Only

Note 1: Wherever a specific V_{BST} value is listed under test conditions, V_{BST} is externally forced with the inductor disconnected and the Boost converter NOT running. LBEn = 0, HBEn = 0.

2: Typical values are for design information only and apply at T_A = +25°C.

3: Limits shown are 100% tested at T_A = +25°C only. Test limits are guard-banded based on temperature characterization to warrant compliance at temperature extremes.

4: All analog functions are off, unless otherwise noted: ABUF[3:0] = 0000, LBEn = 0, HBEn = 0, IRCEn = 0, PAEn = 0, LED2En = 0, LED1En = 0, HrnEn = 0, IOEn = 0, RLEn = 0, RegEn = 0, COAEn = 0, COREn = 0, COTest = 0, WDEn = 0.

5: Not production-tested.

6: ΔmV = ABUF – 200 mV

TABLE 1-1: ELECTRICAL CHARACTERISTICS (CONTINUED)

Electrical Characteristics: Unless otherwise indicated, all parameters apply at T_A = -10°C to +60°C, V_{BAT} = 3V, V_{SS} = 0V, V_{BST} = 9V, V_{IRCAP} = 5.5V, C_3 = 22 µF, C_4 = 10 µF, C_5 = 100 µF, BatSel = 1, RegEn = 0, RegSel = 0, LBEn = 0, HBEn = 0 (Note 1), (Note 2), (Note 3), (Note 4)

Parameter	Symbol	Test Pin	Min.	Typical	Max.	Units	Conditions
Horn (T_A = -10°C to +60°C) (HrnEn = 1, HEnCn = 0, HrnBrdg = 0, FEED = 0) (Horn enabled, horn controlled by Enable pin or HrnEn bit, HrnBridge disabled)							
Output Voltage Low	V_{OL}	HS, HB	—	0.3	0.5	V	I_{OUT} = 16 mA, V_{BST} = 10V
Output Voltage High	V_{OH}	HS, HB	9.5	9.6	—	V	I_{OUT} = -16 mA, V_{BST} = 10V
Startup Delay	t_{HRN}	HS, HB	—	—	1	µs	HS, HB = 10 mA, HrnEn = 1
Input Leakage Low	I_{ILF}	FEED	-50	-15	—	µA	FEED (pin) = -10V
Input Leakage High	I_{IHF}	FEED	—	20	50	µA	FEED (pin) = 22V
Input Voltage Low	V_{IL1}	FEED	—	—	0.9	V	V_{BAT} = 3V, HrnBrdg = 1
	V_{IL2}	FEED	—	—	3	V	V_{BST} = 10V
Input Voltage High	V_{IH1}	FEED	2.1	—	—	V	V_{BAT} = 3V, HrnBrdg = 1
	V_{IH2}	FEED	7	—	—	V	V_{BST} = 10V
SPI and Digital I/O							
Input Leakage Low	I_{IL}	$\overline{CS}$, SCK, SDI, Enable	-100	—	—	nA	
Input Leakage High	I_{IH1}	$\overline{CS}$, SCK, SDI, Enable	—	—	100	nA	
Input Voltage Low	V_{IL1A}	$\overline{CS}$, SCK, SDI	—	—	0.9	V	
	V_{IL1B}	Enable	—	—	0.9	V	HrnEn = 1, HrnBrdg = 0, Monitor HB
Input Voltage High	V_{IH1}	$\overline{CS}$, SCK, SDI	2.1	—	—	V	
	V_{IH1}	Enable	2.1	—	—	V	HrnEn = 1, HrnBrdg = 0, Monitor HB
Input Voltage Hysteresis	V_{HYS}	$\overline{CS}$, SCK, SDI, Enable	—	0.15	—	V	
Output Voltage Low	V_{OLL}	SDO, IOF_{OUT}	—	0.3	0.5	V	I_{LOAD} = 1 mA
Output Voltage High	V_{OHH}	SDO, IOF_{OUT}	2.4	2.6	—	V	I_{LOAD} = -1 mA
Minimum Enable Pulse Width	EnPW	Enable	—	1	—	µs	ITCn = 0, EnCntl = 0

Note 1: Wherever a specific V_{BST} value is listed under test conditions, V_{BST} is externally forced with the inductor disconnected and the Boost converter NOT running. LBEn = 0, HBEn = 0.

2: Typical values are for design information only and apply at T_A = +25°C.

3: Limits shown are 100% tested at T_A = +25°C only. Test limits are guard-banded based on temperature characterization to warrant compliance at temperature extremes.

4: All analog functions are off, unless otherwise noted: ABUF[3:0] = 0000, LBEn = 0, HBEn = 0, IRCEn = 0, PAEn = 0, LED2En = 0, LED1En = 0, HrnEn = 0, IOEn = 0, RLEn = 0, RegEn = 0, COAEn = 0, COREn = 0, COTest = 0, WDEn = 0.

5: Not production-tested.

6: ΔmV = ABUF – 200 mV

TABLE 1-1: ELECTRICAL CHARACTERISTICS (CONTINUED)

Electrical Characteristics: Unless otherwise indicated, all parameters apply at T_A = -10°C to +60°C, V_{BAT} = 3V, V_{SS} = 0V, V_{BST} = 9V, V_{IRCAP} = 5.5V, C_3 = 22 µF, C_4 = 10 µF, C_5 = 100 µF, BatSel = 1, RegEn = 0, RegSel = 0, LBEn = 0, HBEn = 0 (Note 1), (Note 2), (Note 3), (Note 4)

Parameter	Symbol	Test Pin	Min.	Typical	Max.	Units	Conditions
SPI Timing (Figure 1-1)							
Digal Pin Capacitance	C_{IN}, C_{OUT}	—	—	10	—	pF	(All logic inputs/outputs)
Clock Frequency	FCLK	—	—	—	10	MHz	C_{LOAD} = 50 pF
Clock High Time	t_{HI}	—	—	50	—	ns	C_{LOAD} = 50 pF
Clock Low Time	t_{LO}	—	—	50	—	ns	C_{LOAD} = 50 pF
$\overline{CS}$ to First Rising Clock Edge	t_{CSSR}	—	50	—	—	ns	C_{LOAD} = 50 pF
Data Input Setup Time	t_{SU}	—	20	—	—	ns	C_{LOAD} = 50 pF
Data Input Hold Time	t_{HD}	—	40	—	—	ns	C_{LOAD} = 50 pF
SCK to $\overline{CS}$ Rise Hold Time	t_{CHS}	—	50	—	—	ns	C_{LOAD} = 50 pF
$\overline{CS}$ High Time	t_{CSH}	—	100	—	—	ns	C_{LOAD} = 50 pF

Note 1: Wherever a specific V_{BST} value is listed under test conditions, V_{BST} is externally forced with the inductor disconnected and the Boost converter NOT running. LBEn = 0, HBEn = 0.

2: Typical values are for design information only and apply at T_A = +25°C.

3: Limits shown are 100% tested at T_A = +25°C only. Test limits are guard-banded based on temperature characterization to warrant compliance at temperature extremes.

4: All analog functions are off, unless otherwise noted: ABUF[3:0] = 0000, LBEn = 0, HBEn = 0, IRCEn = 0, PAEn = 0, LED2En = 0, LED1En = 0, HrnEn = 0, IOEn = 0, RLEn = 0, RegEn = 0, COAEn = 0, COREn = 0, COTest = 0, WDEn = 0.

5: Not production-tested.

6: ΔmV = ABUF – 200 mV

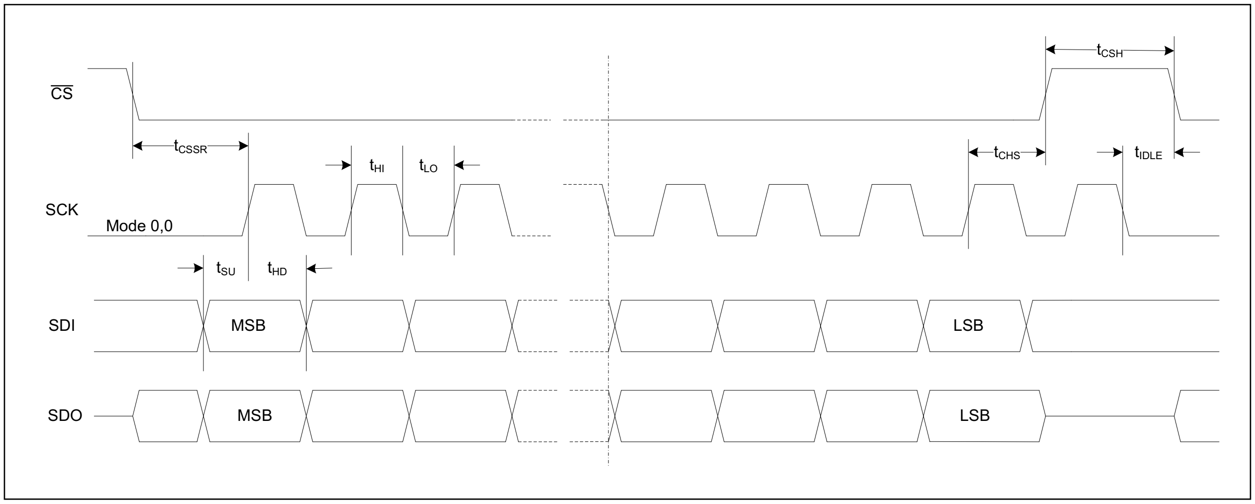


FIGURE 1-1: *SPI Timing Mode 0,0.*

TEMPERATURE SPECIFICATIONS

Parameters	Symbol	Min.	Typical	Max.	Units	Conditions
Temperature Ranges						
Operating Temperature Range	T_A	-10	—	60	°C	
Storage Temperature Range	T_{STG}	-55	—	125	°C	
Thermal Package Resistances						
Thermal Resistance, 28-Lead VQFN	θ_{JA}	—	39.1	—	°C/W	
Thermal Resistance, 32-Lead VQFN	θ_{JA}	—	36.1	—	°C/W	

2.0 PIN DESCRIPTION

TABLE 2-1: 28-LEAD VQFN (RE46C420) PIN FUNCTION TABLE

Pin Number	Symbol	Description
1	ABUF	Analog Buffer operational amplifier output. Used as the analog interface to the MCU.
2	$\overline{CS}$	Digital input for SPI chip select.
3	SCK	Digital input for SPI clock.
4	SDO	Digital output for SPI data.
5	SDI	Digital input for SPI data.
6	Enable	Multiplexed digital input to provide enable signal for various functions.
7	IOF_{OUT}	Filtered and level shifted IO signal.
8	$\overline{MCLR}$	Watchdog Master Clear output.
9	FEED	Usually connected to the feedback electrode of the piezoelectric horn through a resistor. If not used, this pin must be connected to V_{SS}.
10	HB	This pin is connected to the metal electrode (G) of a piezoelectric transducer.
11	HS	HS is a complementary output to HB and connects to the ceramic electrode (M) of the piezoelectric transducer.
12	LED1	Provides regulated sink current for infrared LED or blue LED.
13	LED2	Provides regulated sink current for infrared LED or blue LED.
14	V_{SSP}	Connect to the negative supply voltage.
15	LX	Open drain NMOS to drive the boost converter inductor.
16	IRCAP	Used to charge and monitor the LED capacitor.
17	IO_{TR}	Pin for bidirectional communication with remote units. This pin has an internal pull-down device. High level is V_{BST}.
18	V_{BST}	Regulated boost converter output voltage.
19	V_{REG}	3.3V Regulator output.
20	RLED	Open drain NMOS output used to drive a red LED.
21	V_{BAT}	Connect to the positive supply voltage.
22	V_{SSA}	Connect to the negative supply voltage for analog circuits.
23	IRP1	Input for anode of the photodiode 1.
24	IRN1	Input for cathode of the photodiode 1.
25	CO_{OUT}	Analog output of CO operational amplifier.
26	CO_{INP}	Noninverting input of the CO operational amplifier.
27	CO_{INN}	Inverting input of the CO operational amplifier.
28	CO V_{REF}	CO Voltage Reference.

TABLE 2-2: 28-LEAD VQFN (RE46C421) PIN FUNCTION TABLE

Pin Number	Symbol	Description
1	ABUF	Analog Buffer operational amplifier output. Used as the analog interface to the MCU.
2	$\overline{CS}$	Digital input for SPI chip select.
3	SCK	Digital input for SPI clock.
4	SDO	Digital output for SPI data.
5	SDI	Digital input for SPI data.
6	Enable	Multiplexed digital input to provide enable signal for various functions.
7	IOF_{OUT}	Filtered and level shifted IO signal.
8	$\overline{MCLR}$	Watchdog Master Clear output.
9	FEED	Usually connected to the feedback electrode of the piezoelectric horn through a resistor. If not used, this pin must be connected to V_{SS}.
10	HB	This pin is connected to the metal electrode (G) of a piezoelectric transducer.
11	HS	HS is a complementary output to HB and connects to the ceramic electrode (M) of the piezoelectric transducer.
12	LED1	Provides regulated sink current for infrared LED or blue LED.
13	LED2	Provides regulated sink current for infrared LED or blue LED.
14	V_{SSP}	Connect to the negative supply voltage.
15	LX	Open drain NMOS to drive the boost converter inductor.
16	IRCAP	Used to charge and monitor the LED capacitor.
17	IO_{TR}	Pin for bidirectional communication with remote units. This pin has an internal pull-down device. High level is V_{BST}.
18	V_{BST}	Regulated boost converter output voltage.
19	V_{REG}	3.3V Regulator output.
20	RLED	Open drain NMOS output used to drive a red LED.
21	V_{BAT}	Connect to the positive supply voltage.
22	V_{SSA}	Connect to the negative supply voltage for analog circuits.
23	IRP1	Input for anode of the photodiode 1.
24	IRN1	Input for cathode of the photodiode 1.
25	NC	Not Connected.
26	IRP2	Input for anode of the photodiode 2.
27	IRN2	Input for cathode of the photodiode 2.
28	NC	Not Connected.

TABLE 2-3: 32-LEAD VQFN (RE46C422) PIN FUNCTION TABLE

Pin Number	Symbol	Description
1	CO V_{REF}	CO Voltage Reference.
2	ABUF	Analog Buffer operational amplifier output. Used as the analog interface to the MCU.
3	$\overline{CS}$	Digital input for SPI chip select.
4	SCK	Digital input for SPI clock.
5	SDO	Digital output for SPI data.
6	SDI	Digital input for SPI data.
7	ENABLE	Multiplexed digital input to provide enable signal for various functions.
8	IOF_{OUT}	Filtered and level shifted IO signal.
9	$\overline{MCLR}$	Watchdog Master Clear output.
10	FEED	Usually connected to the feedback electrode of the piezoelectric horn through a resistor. If not used, this pin must be connected to V_{SS}.
11	HB	This pin is connected to the metal electrode (G) of a piezoelectric transducer.
12	HS	HS is a complementary output to HB and connects to the ceramic electrode (M) of the piezoelectric transducer.
13	LED1	Provides regulated sink current for infrared LED or blue LED.
14	LED2	Provides regulated sink current for infrared LED or blue LED.
15	NC	Not Connected.
16	NC	Not Connected.
17	V_{SSP}	Connect to the negative supply voltage.
18	LX	Open drain NMOS output used to drive the boost converter inductor.
19	IRCAP	Used to charge and monitor the LED capacitor.
20	IO_{TR}	Pin for bidirectional communication with remote units. This pin has an internal pull-down device. High level is V_{BST}.
21	V_{BST}	Regulated boost converter output voltage.
22	V_{REG}	3.3V Regulator output.
23	RLED	Open drain NMOS output used to drive a red LED.
24	V_{BAT}	Connect to the positive supply voltage.
25	V_{SSA}	Connect to the negative supply voltage for analog circuits.
26	IRP1	Input for anode of the photodiode 1.
27	IRN1	Input for cathode of the photodiode 1.
28	IRP2	Input for anode of the photodiode 2.
29	IRN2	Input for cathode of the photodiode 2.
30	CO_{OUT}	Analog output of CO operational amplifier.
31	CO_{INP}	Noninverting input of the CO operational amplifier.
32	CO_{INN}	Inverting input of the CO operational amplifier.

3.0 DEVICE OVERVIEW

3.1 Introduction

The RE46C420/1/2 provides the analog functions necessary to build a microcontroller-based multicriteria smoke detector. This includes a dual-input integrating amplifier for photoelectric current sensing, two independently controlled regulated current sink drivers for infrared and blue LED emitters, an operational amplifier and a reference for interfacing with a two-terminal CO sensor, a horn driver, a detector interconnect function, a boost regulator for low voltage operation and a 3.3V regulator to power the microcontroller. The SPI allows the microcontroller unit to have full control over the RE46C420/1/2 operation.

3.2 Photoelectric Sensor Circuit

The RE46C420 device provides a single photodiode input, while the RE46C421/RE46C422 provide a dual photodiode input. The dual photodiode inputs are multiplexed via the SPI control. The photo amplifier block diagram is shown in Figure 3-1 along with the LED1 and LED2 driver circuits. The photo amplifier is configured as an integrating amplifier with gain. The photodiode is connected to IRPX and IRNX. The photodiode current is integrated by the photo amplifier to generate an output voltage. Equation 3-1 determines the operation of this amplifier.

EQUATION 3-1:

$$V_{OUT} = 0.2V + I_{PD} \times (t_i / C_I) \times Gain$$

Where:

I_{PD}	=	Photodiode Current (A)
t_i	=	Integration Time (S)
C_I	=	Integrating Capacitor (5 pF)
$Gain$	=	Selectable Programmable Gain

The integrator timing is controlled by the Integrate/Hold Logic. The Integrate/Hold logic provides two methods of controlling the integration time.

First, an internal timer can be programmed to select one of four possible fixed integration times: 100 µs, 200 µs, 300 µs and 400 µs. Integration begins when the Integrate/Hold input is pulsed high. The Integrate/Hold input is connected to the Enable pin. This mode of operation is designated Timer mode.

Second, the integration time can be controlled directly by the microprocessor using the Integrate/Hold input. When a logic high is applied to the Integrate/Hold input, an integration begins and when a logic low is applied to the Integrate/Hold input, the integration stops and the photo amplifier circuit is placed in Hold mode. This mode of operation is designated Direct Control mode.

In Timer mode, the integrating capacitor and the timing capacitor are matched and the timing resistor is trimmed. Because the capacitor matching minimizes the effect of the capacitor tolerance, this mode of operation provides a more repeatable photo amplifier output voltage for a given photodiode current.

In the Direct Control mode, a fixed integration time produces a wider variation in the photo amplifier voltage. By adjusting the integration time to achieve a specific photo amplifier voltage, the effect can compensate for component tolerances, such as for the LED brightness. In the Hold mode, switches SW0 and SW5 are closed and switches SW1 and SW2 are open. Switches SW3 and SW4 can be open or closed. Switches SW3 and SW4 zero the integrating capacitors, which must be done before each measurement is made.

While in Integration mode, switches SW0 and SW5 are open and switches SW1 and SW2 are closed. Switches SW3 and SW4 are opened by the Integrate/Hold logic high. Switches SW3 and SW4 remain open when Hold mode is started. Switches SW3 and SW4 must be closed by an SPI command, before the start of the next integration. This ensures the integration capacitors are zeroed at the start of integration. Switch SW5 connects the photo amplifier output to the Analog Buffer (ABUF) input. The EnBuf bit in the SPI register forces the SW5 switch to remain closed during the integration operation. The photo amplifier output can be monitored at the ABUF output. Switch SW6 connects the 0.2V reference to ABUF when switch SW5 is open.

IRCAP provides the positive supply for the photo amplifier, while V_{REG} provides the positive supply for the ABUF. Clipping of the photo amplifier signal can occur, if the integration time or photo amplifier gain is not selected properly.

The photo amplifier gain is set by the SPI register. The available gain settings are 1, 2, 4, 8, 16 and 32.

The photo amplifier can be powered on and off by the SPI register to save power. The photo amplifier powers up in the Hold mode, with switches SW3 and SW4 closed.

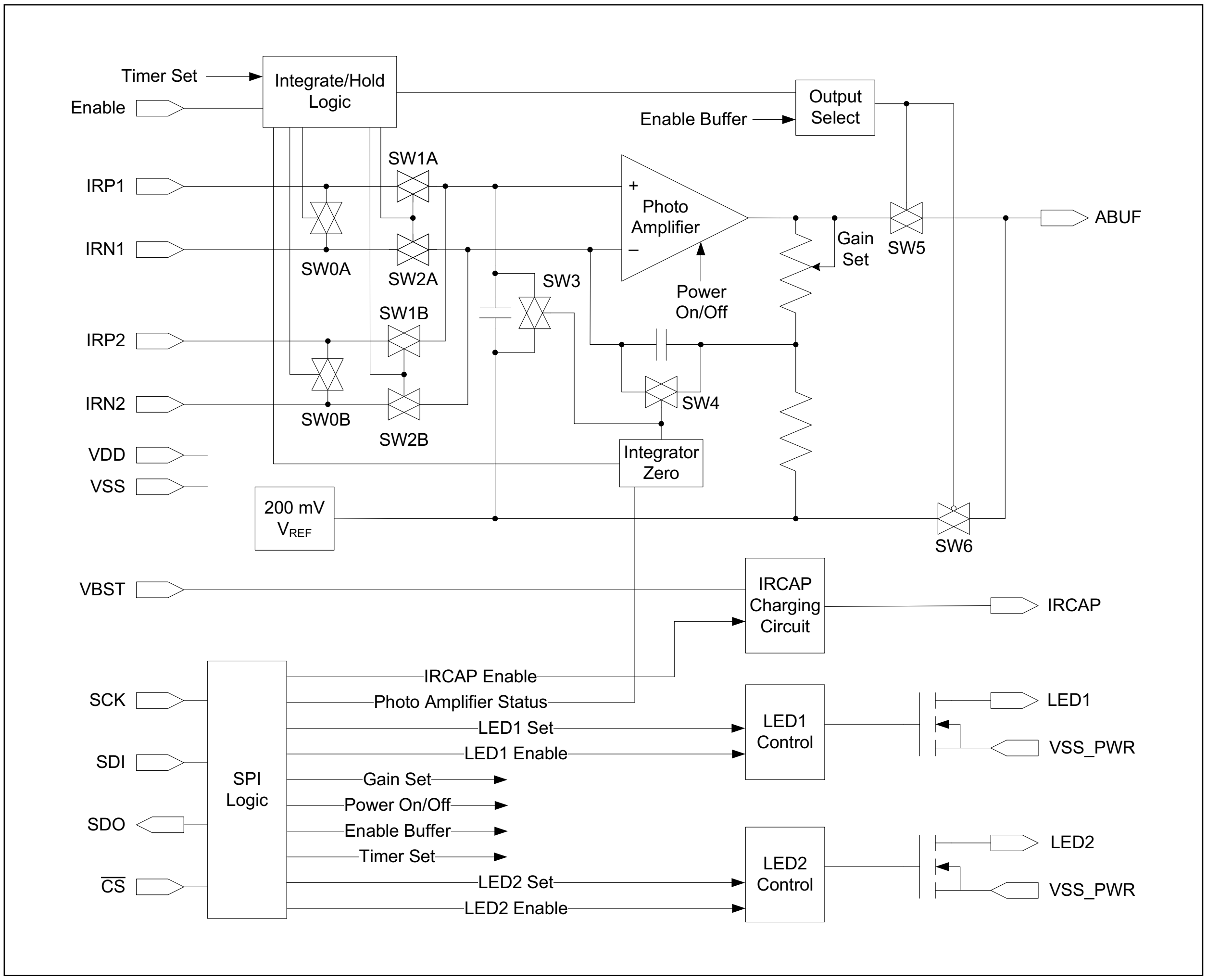


FIGURE 3-1: *Photoelectric Smoke Detection System.*

3.3 LED1 and LED2 Drivers and IRCAP

The LED1 and LED2 driver circuits provide a regulated and programmable current to the LED1 and LED2. Possible current values are 20 mA, 40 mA, 50 mA, 60 mA, 80 mA, 100 mA, 150 mA and 200 mA. The SPI also provides an enable function for the drive circuits. This enable function allows the programmed current to be turned on or off by the Integrate/Hold command. The Integrate/Hold command turns on the LED1/LED2 current. The integration does not start until the current reaches 70% of the set value. If the LED1/LED2 is not fully on when integration starts, variability in the integrator output voltage can occur.

The LED1 and LED2 diodes are biased from the IRCAP pin. The IRCAP charging circuit charges the IRCAP capacitor to 4.4V nominally with V_{BST} nominally set to 5.2V. This ensures there is adequate headroom for diode operation and preserves the regulated current operation. The IRCAP charging circuit can be enabled by the SPI. This helps reduce power consumption. The IRCAP charging circuit is powered from the V_{BST} pin in Low-Boost mode, unless a high-boost voltage has been commanded. The IRCAP voltage can be clamped by the V_{BST} voltage.

3.4 CO Sensor Circuit

The RE46C420/1/2 provides a low-offset operational amplifier and a voltage reference, CO V_{REF}, for a two-terminal CO or toxic gas sensor. The unity gain stable operational amplifier provides rail-to-rail inputs and output. The operational amplifier output is monitored by the microcontroller to determine the CO concentration. The operational amplifier output can be monitored directly or via the ABUF output. The CO amplifier and reference can be turned on and off independently by the SPI. The uncommitted CO operational amplifier can be used for other purposes.

In order to test the CO sensor, the CO_{INP} pin and the CO_{INN} pin are each connected to a 2 µA current source/sink. The current source/sink operation is controlled by individual bits in the SPI register, COCurSel (register 3, bit 6), and COCurPol (register 4, bit 6). In the case of testing the CO_{INN} pin, the CO operational amplifier output is disabled by tristating the CO amplifier output with the SPI bit COTri (register 3, bit 7).

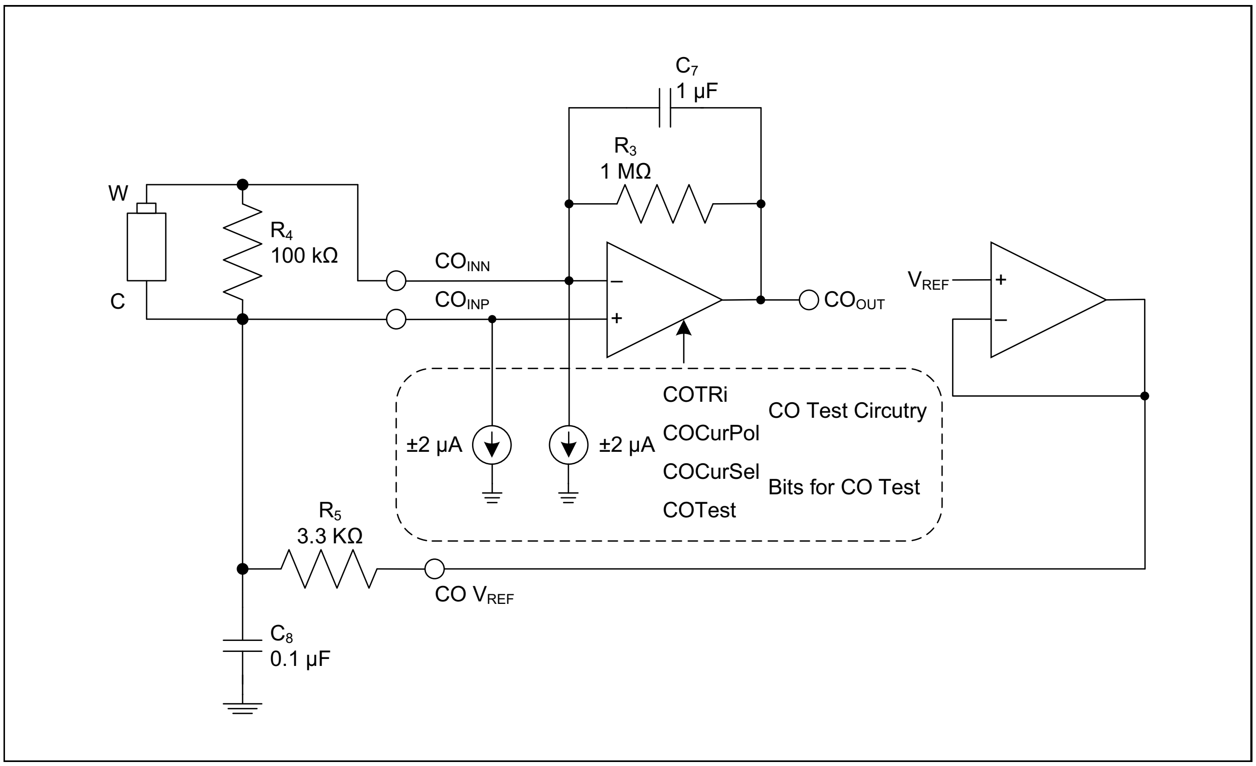


FIGURE 3-2: *CO Test Circuit.*

3.5 Analog Buffer

The analog buffer amplifier provides the means to monitor a number of signals under SPI control. The signals are listed in Table 3-1. The analog buffer can be turned off until needed, which reduces the I_{DD} requirements of the system.

TABLE 3-1: ABUF AVAILABLE SIGNALS

Address	Output Signal
0	ABUF Off output low
1	Photo Amplifier 0.2V Reference
2	Photo Amplifier Output
3	CO_{OUT}
4	CO 0.3V Reference
5	Scaled V_{BST} Monitor
6	Scaled IRCAP Monitor
7	Scaled V_{BAT} Monitor
8	Scaled V_{REG} Monitor
9	Scaled IO_{TR} Input
10	CO_{INP} pin voltage
11	CO_{INN} pin voltage
12	Scaled IRED1 pin voltage
13	Scaled IRED2 pin voltage
14	ABUF Off output low
15	ABUF Off output low

3.6 Power Control System

The power control system allows the RE46C420/1/2 to be powered by a 3V or 9V battery or by AC power with battery backup. AC power is supplied as a DC voltage derived from an AC power supply. The AC power supply must include an AC on/off logic input for battery test.

In a 9V-battery-only system, the 9V battery connects directly to the V_{BST} pin. In this configuration, the MCU is powered from the V_{REG} pin, as is most of the internal circuitry of the RE46C420/1/2. The boost regulator is not used in this configuration and is disabled by the MCU.

In an AC system with 9V battery backup, the AC-derived voltage and the 9V battery must be diode-connected to the V_{BST} pin, as shown in Figure 4-11. In this configuration, the MCU is powered from the V_{REG} pin, as is most of the internal circuitry of the RE46C420/1/2. The boost regulator is not used in this configuration and is disabled by the MCU. The diodes can be replaced with switches controlled by the MCU.

In a 3V-battery-only system, the 3V battery connects to the V_{BAT} pin through the RC filter shown in Figure 4-10. The filter is intended to minimize any boost regulator switching noise that can be coupled on to the V_{BAT} pin. In this configuration, the MCU is powered directly from the battery, as is most of the internal circuitry of the RE46C420/1/2. The 3.3V regulator is not used in this configuration and is disabled by the MCU.

In an AC powered system with 3V battery backup, the AC derived power must be diode-connected to the V_{BST} pin, as shown in Figure 4-9. The boost regulator must be enabled. The voltage of the AC-derived power must be greater than the maximum high-boost voltage to hold off the boost regulator. The 3V battery is connected to the V_{BAT} pin through the RC filter shown in Figure 4-9. In this configuration, the microcontroller is powered from V_{REG}, as is most of the internal circuitry of the RE46C420/1/2. When AC power is lost, the boost regulator turns on to power the 3.3V regulator. The boost regulator must be configured to operate in Low-Boost mode. The analog buffer amplifier can be used to monitor V_{BST} and V_{BAT}.

3.7 Boost Regulator

The boost regulator is an adjustable off-time boost converter with peak current limiting. In low-boost operation, the peak current is nominally 0.6A and for high-boost operation it is 1.5A. The boost regulator provides power to the voltage regulator, IRCAP charging circuit, horn driver and interconnect circuit. The boost regulator is enabled by the SPI.

The boost regulator is intended only for 3V battery applications (3.6V absolute maximum). The boost regulator has two operating modes: Low-Boost voltage and High-Boost voltage. The boost regulator normally operates in the Low-Boost mode when enabled by the SPI bit LBEn or by the IRCAP Enable bit, IRCEn.

In Low-Boost mode, the boost voltage can be programmed to 4.0V or 5.2V. The boost regulator switches to high-boost operation via the SPI HBEn bit. The high-boost operating mode always overrides the low-boost operating mode. The high-boost voltage can be programmed to 8.5V, 10V, 11.5V or 16.9V. High-boost operation is used when the horn driver or IO is enabled.

The boost regulator includes a soft-start circuit for power up and for switching from low-boost to high-boost operation. In the case of short duration high-boost operation, such as a horn chirp, the soft-start time must be accounted for in the firmware controlling this operation.

Equation 3-2 defines the battery current draw, based on the boost converter load current, I_{BST}.

EQUATION 3-2:

$$I_{DD} = \frac{V_{BST}}{V_{DD} \times Eff} \times I_{BST}$$

Where:

I_{DD} = Battery Current (mA)

V_{BST} = Boost Regulator Output Voltage (V)

V_{DD} = Positive Supply Voltage (V)

Eff = Boost Regulator Efficiency (*)

I_{BST} = Boost Converter Load Current (mA)

* Select lower V_{BST} for specific operating modes, when practical, to minimize battery drain.

3.8 Voltage Regulator

The voltage regulator provides a nominal 3.3V output at the V_{REG} pin and is intended to power a microcontroller. The regulator voltage is turned on through the SPI. In normal operation, the regulator sources current up to 20 mA, but the current sinking capability is typically under 1 µA. The voltage regulator is powered from the V_{BST} pin. In low-voltage applications, the regulator is powered by the boost regulator and the regulator load current is part of the boost regulator load current. An over-voltage clamp is intended to limit the voltage at V_{REG} if it is pulled up by an external source to greater than 4 V. When the regulator is used in a 3V system, the low-boost regulator voltage is forced to be 5.2V to ensure adequate headroom for proper regulator operation and overrides the low-boost voltage setting in SPI register.

3.9 Interconnect Operation

The interconnect circuit provides the means for the smoke detector to communicate with other smoke detectors. The IO_{TR} pin is a bidirectional pin that provides both receive and transmit capabilities. The received IO signal is digitally filtered, level shifted and made available to the MCU on the IOF_{OUT} pin. The received signal has two selectable input thresholds controlled by the IO_{THRSH} bit (register 8, bit 7). The higher input thresholds are intended to improve noise immunity while the lower thresholds provide compatibility with older smoke detectors.

The IO_{TR} pin normally operates as an input and monitors the IO line for a logic high when the bit IO_{EN} (register 3, bit 1) is set low. A 30 ms digital filter prevents pulse widths less than 30 ms from asserting a logic high at the IOF_{OUT} pin. As a result of the filter action, the actual pulse width is shortened by 30 ms at IOF_{OUT}, e.g. a 40 ms pulse width appears as a 10 ms pulse width at IOF_{OUT}.

The microcontroller can set the IO_{EN} (register 3, bit 1) enable bit via the SPI, which causes the IO transmit circuit to turn on. The IO output acts as a current source that is biased from V_{BST}. In low-voltage applications, when IO_{EN} (register 3, bit 1), is asserted high, the boost regulator needs to enable high-boost operation. This ensures there is adequate IO drive capability. The IO state bit, IO_{OUT} (register 3, bit 2) controls the logic level at the IO_{TR} pin. When the IO_{OUT} bit is set high, the IO_{TR} pin sources 5 mA. A higher current can be sourced if the HiIO bit (register 8, bit 4) is set high. When the IO_{OUT} (register 3, bit 2) is set to a logic low, the IO_{TR} pin sinks 13 mA. This helps discharge the interconnect line. A higher sink current can be set by setting the HiDmp bit (register 8, bit 5) high. The IO_{TR} output voltage can be monitored via ABUF.

The high current operation of the interconnect circuit is powered by the IRCAP circuit, as well as boost regulator operating in High-Boost mode. This requires the capacitor used with the IRCAP function to be much larger than the capacitor shown in the applications drawings.

3.10 Horn Driver

The horn driver operates a standard three terminal piezoelectric horn connected to the pins HB, HS and FEED. The alarm is sounded by having the microcontroller set and reset the HRNEN bit (register 3, bit 0) with required horn modulation pattern. Alternatively, the horn modulation pattern can be controlled by the Enable pin, when the Enable pin is programmed to control the horn. In low-voltage applications, before HRNEN is asserted high, the SPI enables the high-boost operation. This ensures there is adequate horn drive capability to achieve the necessary sound pressure levels. The horn can begin to sound before the boost regulator reaches the high-boost level.

For two-terminal horns the Enable pin can be used to toggle the HB and HS pins at the desired operating frequency of the horn.

3.11 RLED Driver

The RLED driver provides the means to drive a red LED from a nominal 10V supplied by V_{BST}. This provides a means to perform a low-battery test or provide a visual signal. The RLED driver current must be set to match the horn driver load current, by using the external resistor. The RLED driver can be enabled or disabled via the SPI with the RLEn bit (register 3, bit 3).

3.12 Watchdog Timer

The RE46C420/1/2 includes a Watchdog Timer, which monitors the SCK input pin. An SPI clock must occur every 20 seconds to prevent a Watchdog Timer alert. The alert pulses the $\overline{MCLR}$ pin low for 20 ms. In addition, the SPI can be programmed to sound the horn continuously when a Watchdog Timer alert occurs. The Watchdog Timer can be disabled via the SPI to reduce current consumption.

3.13 SPI Control

The RE46C420/1/2 devices are designed to interface directly with the SPI port, available on many microcontrollers, and Support mode `0,0`. All the digital input pins are Schmitt-Triggered to avoid system noise perturbations during the communications.

Each SPI communication starts with a $\overline{CS}$ falling edge and stops with the $\overline{CS}$ rising edge. Each SPI communication is independent. When $\overline{CS}$ is logic high, SDO is in a high-impedance state, transitions on SCK and SDI have no effect. Any $\overline{CS}$ rising edge clears the communication and resets the SPI digital interface. If $\overline{CS}$ is at a logic low at power up, then $\overline{CS}$ must be driven high and then low before communications can start.

Refer to Figure 1-1 and the **SPI and Digital I/O** section of the Electrical Characteristics table for detailed input and output timing. The SPI provides complete control of the RE46C420/1/2 operation. SPI Registers can be programmed with setup information for each of the functions. The SPI Registers also control the operation of certain functions, as well as power each function on or off with an enable bit.

3.14 SPI Registers

The RE46C420/1/2 interface has a simple command structure. Every command is either a Write command to a register or a Read command from a register. The Read command is intended to verify the Write command results. Each register command consists of 2 bytes. The upper byte is the register address, which includes the read/write bit and the lower byte is the register data. The SPI RdNow bit allows the SPI to immediately read out data after the byte address has been read in. Alternatively, the data for a byte address can be readout when a second 16-bit clock cycle is completed. The RE46C420/1/2 device includes 9 registers defined in Register 3-1. Unused data bits read back as `0`. Data bits for nonexistent registers read back as `1`.

REGISTER 3-1: CONFIGURATION SETTINGS AND CALIBRATION SETTINGS

Register 9:0 Address Byte							
R/W	R/W	R/W	R/W	R/W	R/W	R/W	U
RW	AD5	AD4	AD3	AD2	AD1	AD0	—
bit 15							bit 8

Register 0 Data Byte		ABUF Control					
U	U	U	U	R/W-0	R/W-0	R/W-0	R/W-0
—	—	—	—	AB3	AB2	AB1	AB0
bit 7							bit 0

Register 1 Data Byte		Boost Control					
U	U	U	U	U	R/W-0	R/W-0	R/W-1
—	—	—	—	—	IRCEn	HBEn	LBEn
bit 7							bit 0

Register 2 Data Byte		Photo Amplifier Control					
U	U	R/W-0	R/W-0	R/W-0	U	R/W-1	R/W-0
—	—	InSel	LED2En	LED1En	—	Status	PAEn
bit 7							bit 0

Register 3 Data Byte		IO/HORN/CO Control					
R/W-0	R/W-0	R/W-0	U	R/W-0	R/W-0	R/W-0	R/W-0
COTri	COCurSel	COTest	—	RLEn	IOout	IOEn	HrnEn
bit 7							bit 0

Register 4 Data Byte		Regulator, CO Control					
U	R/W-0	R/W-0	R/W-0	U	R/W-0	R/W-0	R/W-1
—	COCurPol	COREn	COAEn	—	BatSel	RegSel	RegEn
bit 7							bit 0

REGISTER 3-1: CONFIGURATION SETTINGS AND CALIBRATION SETTINGS (CONTINUED)

Register 5 Data Byte		Boost/IRCAP/SPI/WD Setup					
R/W-1	R/W-1	U	R/W-1	U	R/W-0	R/W-0	R/W-1
WDHrn	WDEn	—	RdNow	—	HBV1	HBV0	LBV
bit 7							bit 0

Register 6 Data Byte		Photo Amplifier Setup					
R/W-0	U	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0
EnBuf	—	IT1	IT0	ITCn	Gain2	Gain1	Gain0
bit 7							bit 0

Register 7 Data Byte		LED Setup					
U	R/W-0	R/W-0	R/W-0	U	R/W-0	R/W-0	R/W-0
—	LED2 2	LED2 1	LED2 0	—	LED1 2	LED1 1	LED1 0
bit 7							bit 0

Register 8 Data Byte		IO Setup					
U	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0
—	IOThrsh	HiDmp	HiIO	EnCntl	HrnBrdg	HEnCn	FEED
bit 7							bit 0

Register 9 Data Byte		Photo LED TC Selection					
U	R/W-0	R/W-1	R/W-1	U	R/W-0	R/W-1	R/W-1
—	LED2 TC 2	LED2 TC 1	LED2 TC 0	—	LED1 TC 2	LED1 TC 1	LED1 TC 0
bit 7							bit 0

Legend:			
R = Readable bit	W = Writable bit	U = Unimplemented bit, read as ‘0’	
-n = Value at POR	‘1’ = Bit is set	‘0’ = Bit is cleared	x = Bit is unknown

Register#	Bit#	POR Value	Description
9:0	8	—	Not Used
	14:9	—	**AD[5:0]:** Address Select `00000` = Register 0; ABUF Select `00001` = Register 1; Boost Control `00010` = Register 2; Photo Amplifier Control `00011` = Register 3; IO/Horn Control `00100` = Register 4; Regulator, CO, SPI Control `00101` = Register 5; Boost Setup `00110` = Register 6; Photo Amplifier Setup `00111` = Register 7; LED1/LED2 Setup `01000` = Register 8; IO/Horn Setup `01001` = Register 9; LED1/LED2 TC Setup `X1XXX` = Don’t Care (Except `01000` and `01001`)
	15	—	**RW:** Read/Write Select `1` = Read contents of the specified register `0` = Write data to the specified register

REGISTER 3-1: CONFIGURATION SETTINGS AND CALIBRATION SETTINGS (CONTINUED)

0	3:0	0	**ABUF[3:0]:** ABUF Channel Select 0000 = ABUF off; output low 0001 = 0.2V Photo Amplifier Reference Output 0010 = Photo Amplifier Output 0011 = CO Amplifier Output 0100 = CO 0.3V Reference Output 0101 = Scaled V_{BST} Voltage Output 0110 = Scaled IRCAP Voltage Output 0111 = Scaled V_{BAT} Voltage Output 1000 = Scaled V_{REG} Voltage Output 1001 = Scaled IO_{TR} 1010 = CO_{INP} pin voltage 1011 = CO_{INN} pin voltage 1100 = Scaled IRED1 pin voltage 1101 = Scaled IRED2 pin voltage 1110 = ABUF off; output low 1111 = ABUF off; output low
	7:4	—	Not Used

1	0	0	**LBEn**: Low-Boost Operation Enabled 1 = Low-Boost Enable 0 = Low-Boost Disable Disabled at power up, after 10 ms, if V_{BAT} > V_{REG}, then low-boost is enabled.
1	1	0	**HBEn**: High-Boost Operation Enabled 1 = High-Boost Enable/Overrides Low-Boost Enable 0 = High-Boost Disable
1	2	0	**IRCEn**: IRCAP Power On/Off 1 = IRCAP Enable 0 = IRCAP Disable
1	7:3	—	Not Used

2	0	0	**PAEn**: Photo Amplifier Power On/Off 1 = Photo Amplifier On Enable 0 = Photo Amplifier On Disable
2	1	0	**Status**: Photo Integrator Status 1 = Ready 0 = Reset
2	2	0	Not Used
2	3	0	**LED1En**: LED1 Driver Power On 1 = LED1 Driver Power On Enable 0 = LED1 Driver Power On Disable
2	4	0	**LED2En**: LED2 Driver Power On 1 = LED2 Driver Power On Enable 0 = LED2 Driver Power On Disable
2	5	0	**InSel**: Photo Amplifier Input Select (Not Applicable RE46C420) 1 = IRN2, IRP2 0 = IRN1, IRP1
2	7:6	—	Not Used

REGISTER 3-1: CONFIGURATION SETTINGS AND CALIBRATION SETTINGS (CONTINUED)

3	0	0	**HrnEn**: Horn Enable 1 = Horn Enable 0 = Horn Disable
3	1	0	**IOEn**: IO Transmit On 1 = IO Transmit Output 0 = IO Read Input
3	2	0	**IOout**: Set IO Output State 1 = IO Out State Logic High 0 = IO Out State Logic Low
3	3	0	**RLEn**: RLED Enable/Disable 1 = RLED Power On Enable 0 = RLED Power On Disable
3	4	0	Not Used
3	5	0	**COTest**: CO Test On/Off (Not Applicable RE46C421) 1 = Current Test On 0 = Current Test Off
3	6	0	**COCurSel**: CO Current sink Source Select (Not Applicable RE46C421) 1 = CO Source at Noninverting Input 0 = CO Sink at Inverting Input
3	7	0	**COTri**: CO Operational amplifier Output Tristate Enable (Not Applicable RE46C421) 1 = Enable CO Operational Amplifier Output Tristate 0 = Disable CO Operational Amplifier Output Tristate

4	0	1	**RegEn**: Regulator Power On 1 = Regulator Power On Enable 0 = Regulator Power On Disable
4	1	0	**RegSel** 1 = Regulator powers internal circuitry Regulator powers boost comparators 0 = Regulator not used to power internal circuitry V_{BAT} powers boost comparators
4	2	0	**BatSel** 1 = V_{BAT} (3V Battery) powers internal circuitry 0 = V_{BAT} not used to power internal circuitry
4	3	0	Not Used
4	4	0	**COAEn**: CO Amplifier Power On (Not Applicable RE46C421) 1 = Enable CO Operational Amplifier 0 = Disable CO Operational Amplifier
4	5	0	**COREn**: CO Reference Power On (Not Applicable RE46C421) 1 = Enable CO Reference 0 = Disable CO Reference
4	6	0	**COCurPol**: CO Current sink source polarity (Not Applicable RE46C421) 1 = INN source/INP sink 0 = INN sink/INP source
4	7	0	Not Used

REGISTER 3-1: CONFIGURATION SETTINGS AND CALIBRATION SETTINGS (CONTINUED)

5	0	1	**LBV**: Low-Boost Voltage Setting 1 = Low-Boost Voltage = 5.2V 0 = Low-Boost Voltage = 4.0V
5	2:1	0	**HBV[2:1]**: High-Boost Voltage Setting 11 = High-Boost Voltage = 17.0V 10 = High-Boost Voltage = 11.5V 01 = High-Boost Voltage = 10.0V 00 = High-Boost Voltage = 8.5V
5	3	0	Not Used
5	4	1	**RdNow**: SPI read output delay 1 = SPI read output immediately ready 0 = SPI read output normal mode, data ready 1 (16-bit) word after requested
5	5	0	Not Used
5	6	1	**WDEn**: Watchdog Timer Power On 1 = Enable Watchdog Timer 0 = Disable Watchdog Timer
5	7	1	**WDHrn**: Watchdog Enable Horn on Continuously 1 = Enable Horn on continuously 0 = Disable Watchdog Horn

6	2:0	0	**Gain[2:0]**: Photo Amplifier Gain Setting 000 = Photo Gain = 1 001 = Photo Gain = 2 010 = Photo Gain = 4 011 = Photo Gain = 8 100 = Photo Gain = 16 101 = Photo Gain = 32 110 = Photo Gain = 16 111 = Photo Gain = 32
6	3	0	**ITCn**: Integration Time Control Method 1 = Integration Time Control is Enable Pin 0 = Integration Time Control is Internal Timer
6	5:4	0	**IT[5:4]**: Integration Internal Timer Setting 00 = Integration Time = 100 µs 01 = Integration Time = 200 µs 10 = Integration Time = 300 µs 11 = Integration Time = 400 µs
6	6	0	Not Used
6	7	0	**EnBuf**: Photo Amplifier Output to ABUF Control 1 = ABUF Output is the Photo Amplifier Output for the full integration cycle 0 = ABUF Output is the Photo Amplifier Hold Voltage or 0.2V Reference Voltage

REGISTER 3-1: CONFIGURATION SETTINGS AND CALIBRATION SETTINGS (CONTINUED)

7	2:0	0	**LED1[2:0]**: LED1 Driver Current Setting 000 = LED1 Current = 20 mA 001 = LED1 Current = 40 mA 010 = LED1 Current = 50 mA 011 = LED1 Current = 60 mA 100 = LED1 Current = 80 mA 101 = LED1 Current = 100 mA 110 = LED1 Current = 150 mA 111 = LED1 Current = 200 mA
7	3	0	Not Used
7	6:4	0	**LED2[2:0]**: LED1 Driver Current Setting 000 = LED2 Current = 20 mA 001 = LED2 Current = 40 mA 010 = LED2 Current = 50 mA 011 = LED2 Current = 60 mA 100 = LED2 Current = 80 mA 101 = LED2 Current = 100 mA 110 = LED2 Current = 150 mA 111 = LED2 Current = 200 mA
7	7	0	Not Used

8	0	0	**FEED**: Horn Control for 2 pin and 3 pin horns 1 = Enable pin is used to toggle HB and HS with Horn FEED pin not connected 0 = IC FEED pin uses Horn FEED pin connection
8	1	0	**HEnCntl**: Horn Enable Control Selection 0 = Horn controlled by bit 0 in register 3 only 1 = Horn controlled by Enable pin AND bit 0, register 3
8	2	0	**HrnBrdg**: Horn Bridge Enable Control Selection 0 = Horn in normal configuration 1 = Horn in bridge configuration (FEED pin drives HS, Enable pin drives HB)
8	3	0	**EnCntl**: Defines Function that Enable controls 1 = Enable controls Horn on time 0 = Enable controls Photo Integration on time or start
8	4	0	**HiIO**: Select high or low-current operation for IO out at logic high 1 = High-current operation 0 = Low-current operation
8	5	0	**HiDmp**: Select high or low-current operation for IO out at a logic low 1 = High-current operation 0 = Low-current operation
8	6	0	**IOThrsh**: IO Input Switching Thresholds 1 = High-voltage switching threshold 0 = Nominal voltage switching threshold
8	7	0	Not Used

REGISTER 3-1: CONFIGURATION SETTINGS AND CALIBRATION SETTINGS (CONTINUED)

9	2:0	3	**LED1 TC [2:0]** 000 = 0.0%/°C 001 = 0.2%/°C 010 = 0.3%/°C 011 = 0.4%/°C 1XX = 0.5%/°C
9	3	0	Not Used
9	6:4	3	**LED2 TC [2:0]** 000 = 0.0%/°C 001 = 0.2%/°C 010 = 0.3%/°C 011 = 0.4%/°C 1XX = 0.5%/°C
9	7	0	Not Used

4.0 APPLICATIONS INFORMATION

4.1 Power Management

4.1.1 POWER UP

The RE46C420/1/2 devices can be powered from the V_{BAT} pin or the V_{BST} pin. At power up, the internal logic is powered through resistive switches connected to V_{BAT} and V_{REG}. V_{REG} is powered via V_{BST}. The first MCU SPI instruction, after power up, must select the power source for detector operation. Register 4, bit[2:0] controls the power source selection and regulator enable. Table 4-1 shows the bit settings for register 4 for the different power source configurations.

TABLE 4-1: REGISTER 4 POWER MANAGEMENT BIT SETTINGS

Operating Modes	RegEn (r4b0)	RegSel (r4b1)	BatSel (r4b2)	Application Figures
9V Battery Only	1	1	0	Figure 4-4, Figure 4-8, Figure 4-12
AC/9V Battery Backup	1	1	0	Figure 4-3, Figure 4-7, Figure 4-11
3V Battery Only	0	0	1	Figure 4-2, Figure 4-6, Figure 4-10
AC/3V Battery Backup	1	1	0	Figure 4-1, Figure 4-5, Figure 4-9

4.1.2 OPERATING MODES

9V Battery Only

For 9V-battery-only operation, the battery is connected to the V_{BST} pin and the 3.3V regulator is used to power the MCU and the internal circuitry of the RE46C420/1/2. The boost regulator is disabled.

AC with 9V Battery Backup

AC with 9V battery backup relies on the diode-connected power sources to power the RE46C420/1/2 at the V_{BST} pin. The voltage of the AC-derived power must be set to a voltage higher than the voltage of a new battery. The AC-derived power needs to include an on/off function for the MCU to perform a battery test by loading the V_{BST} pin with the RLED current. Table 4-2 shows the power-up flow chart for 9V or AC-powered systems.

TABLE 4-2: POWER-UP FLOW CHART FOR 9V BATTERY OR AC POWERED SYSTEM

SPI Hex Code		SPI Register/Comment
1	**Apply power to V_{BST} pin. After the MCU is powered on, send the following SPI commands:**	
2	0x0803	**Register 4**: RegSel = 1, RegEn = 1, BatSel = 0, COAEn = 0. COREn = 0, COCurPol = 0 Set the regulator as the internal power source and turn on the regulator.
3	**Precharge the IRCAP (capacitor C5), then begin the setup of the smoke and CO detector operation.**	
4	0x0A53	**Register 5**: WDHrn = 0, WDEn = 1, RdNow = 1, LBV = 1 (5.2V), HBV[2:1] = [01] (10V) Enable Watchdog Timer with no watchdog horn alert; set SPI read-now to immediate; set high and low-boost voltages. Low-boost voltage also sets IRCAP voltage.
5	0x0204	**Register 1**: LBEn = 0, HBEn = 0, IRCEn = 1 Turn on the IRCAP charging.
6	0x0200	**Register 1**: LBEn = 0, HBEn = 0, IRCEn = 0 Turn off the IRCAP charging after approximately 25 ms (delay determined by the size of C5).
7	0x0833	**Register 4**: RegSel = 1, RegEn = 1, BatSel = 0, COAEn = 1, COREn = 1, COCurPol = 0 Turn on CO operational amplifier and CO reference voltage.
8	**Continue with additional setup commands:**	
9	0x0C93	**Register 6**: Gain[2:0] = [011] (8), ITCn = 0, IT[5:4] = [01] (200 µs), EnBuf = 1 Set photo amplifier gain, integration time, integration control, ABUF control for photo amplifier output.
10	0x0E64	**Register 7**: LED1[2:0] = [100] (80 mA), LED2[6:4] = [110] (150 mA) Set LED currents.
11	0x1030	**Register 8**: FEED = 0, HEnCntl = 0, HrnBrdg = 0, EnCntl = 0, HiIO = 1, HiDmp = 1, IO_{THRSH} = 0 Setup horn control, high or low-current IO operation and high or low-input threshold voltage.
12	0x1233	**Register 9**: LED1 TC[2:0] = [011] (0.5%), LED2 TC[6:4] = [011] (0.5%) Set LED current TC.
13	**Continue with normal operation.**	

3V Battery Only

For 3V-battery-only operation, the battery is connected to the V_{BAT} pin and is used to power the MCU along with the internal circuitry of the RE46C420/1/2. The boost regulator is enabled when needed and the 3.3V regulator is disabled. The boost regulator must be turned on only when specific functions need it.

TABLE 4-3: POWER-UP FLOW CHART FOR 3V BATTERY SYSTEM

	SPI Hex Code	SPI Register/Comment
1	**Apply power to V_{BAT} pin. After the MCU is powered on, send the following SPI commands:**	
2	0x0804	**Register 4**: RegSel = 0, RegEn = 0, BatSel = 1, COAEn = 0. COREn = 0, COCurPol = 0 Set the battery as the internal power source and leave regulator off.
3	**Precharge IRCAP (capacitor C5) and begin the setup of the smoke and CO detector operation:**	
4	0x0A53	**Register 5**: WDHrn = 0, WDEn = 1, RdNow = 1, LBV = 1(5.2V), HBV[2:1] = [01] (10V) Enable Watchdog Timer with no watchdog horn alert; set SPI read-now to immediate; set high and low-boost voltages.
5	0x0201	**Register 1**: LBEn = 1, HBEn = 0, IRCEn = 0 Turn on low-boost and wait for soft startup time to finish.
6	0x0205	**Register 1**: LBEn = 1, HBEn = 0, IRCEn = 1 Turn on the IRCAP charging.
7	0x0200	**Register 1**: LBEn = 0, HBEn = 0, IRCEn = 0 Turn off low-boost and IRCAP charging after ~ 25 ms (delay determined by the size of C5).
8	0x0834	**Register 4**: RegSel = 0, RegEn = 0, BatSel = 1, COAEn = 1. COREn = 1, COCurPol = 0 Turn on CO operational amplifier and CO reference voltage.
9	**Continue with additional setup commands, as shown in Table 4-2, then begin normal operation.**	

AC with 3V Battery Backup

AC with 3V battery backup uses the 3.3V regulator to power the system. AC power is diode-connected to the V_{BST} pin and is greater than the selected high-boost voltage plus a diode drop. The boost regulator must be enabled. This allows the boost regulator to turn on when the AC derived voltage drops below the high-boost voltage or low-boost voltage, whichever is selected. Table 4-4 assumes AC power is turned on first at power up.

TABLE 4-4: POWER-UP FLOW CHART FOR AC POWER WITH 3V BATTERY BACKUP SYSTEM

	SPI Hex Code	SPI Register/Comment
1	**Apply AC power to V_{BST} pin. After the MCU is powered on, send the following SPI commands:**	
2	0x0803	**Register 4**: RegSel = 1, RegEn = 1, BatSel = 0, COAEn = 0. COREn = 0, COCurPol = 0 Set the regulator as the internal power source and turn on the regulator.
3	0x0A55	**Register 5**: WDHrn = 0, WDEn = 1, RdNow = 1, LBV = 1 (5.2V), HBV[2:1] = [10] (11.5V) Enable Watchdog Timer with no watchdog horn alert; set SPI read-now to immediate; set high and low-boost voltages.
4	0x0201	**Register 1**: LBEn = 1, HBEn = 0, IRCEn = 0 Turn on low-boost; AC power has precharged C4.
5	0x0205	**Register 1**: LBEn = 1, HBEn = 0, IRCEn = 1; Turn on the IRCAP charging.
6	0x0201	**Register 1**: LBEn = 1, HBEn = 0, IRCEn = 0; Turn off the IRCAP charging after approximately 25 ms; leave low-boost on.
7	**Begin setup of smoke and CO detector operation:**	
8	0x0833	**Register 4**: RegSel = 1, RegEn = 1, BatSel = 0, COAEn = 1. COREn = 1, COCurPol = 0; Turn on CO operational amplifier and CO reference voltage.
9	**Continue with additional setup commands, as shown in Table 4-2, then begin normal operation.**	

AC Power Failure

Table 4-5 exemplifies the response to an AC power failure.

Scenario:

The AC power is normally supplied at startup. If the AC power is removed after startup for a long-enough period of time, the AC power supply shuts down. The AC power is restored afterwards.

Response:

In a 3V-battery system, the boost regulator is left on continuously, but held off by the AC power with a voltage greater than the boost voltage. When the AC power fails and its voltage output decays, the boost regulator turns on to maintain the voltage until the AC power is restored.

TABLE 4-5: POWER FAIL FLOW CHART FOR AC POWER WITH 3V BATTERY BACKUP SYSTEM

	SPI Hex Code	SPI Register/Comment
1	**Apply AC power to V_{BST} pin. After the MCU is powered on, send the following SPI commands:**	
2	0x0803	**Register 4**: RegSel = 1, RegEn = 1, BatSel = 0, COAEn = 0. COREn = 0, COCurPol = 0 Set regulator as internal power source and turn on regulator.
3	0x0A55	**Register 5**: WDHrn = 0, WDEn = 1, RdNow = 1, LBV = 1 (5.2V), HBV[2:1] = [10] (11.5V) Enable Watchdog Timer with no watchdog horn alert; set SPI read-now to immediate; set high and low-boost voltages.
4	0x0201	**Register 1**: LBEn = 1, HBEn = 0, IRCEn = 0 Turn on low-boost; AC power has precharged C4.
5	0x0205	**Register 1**: LBEn = 1, HBEn = 0, IRCEn = 1 Turn on the IRCAP charging.
6	0x0201	**Register 1**: LBEn = 1, HBEn = 0, IRCEn = 0 Turn off the IRCAP charging after approximately 25 ms; leave low-boost on.
7	0x0833	**Register 4**: RegSel = 1, RegEn = 1, BatSel = 0, COAEn = 1. COREn = 1, COCurPol = 0 Turn on CO operational amplifier and CO reference voltage.
8	**Continue with additional setup commands, as shown in Table 4-2, then begin normal operation.**	
9	**AC power fails. Boost regulator begins operation as necessary.**	
10	**Continue normal operation.**	
11	**AC power restored. AC power holds off the boost regulator.**	
12	**Continue normal operation.**	

4.1.3 BOOST REGULATOR

Boost converter in Active mode can draw current pulses greater than 0.6A in low-boost operation and 1.5A in high-boost operation and is, therefore, very sensitive to series resistance. Critical components of this resistance are the inductor DC resistance, the internal resistance of the battery and the resistance in the connections from the inductor to the battery, from the inductor to the LX pin, from the inductor through the boost capacitor and from the V_{SS} pin to the battery. In order to function properly under full load at V_{BAT} = 2V, the total of the inductor and interconnect resistances must not exceed 0.3Ω. The internal battery resistance must not exceed 0.5Ω and a low-ESR capacitor of 10 µF or more must be connected in parallel with the battery to average the current draw over the boost converter switching cycle. The Schottky diode and inductor must have a maximum operating current of 1.5A or higher. The Schottky diode must be low-leakage to prevent unwanted battery charging current under reverse bias. The boost capacitor must have a low ESR.

The boost regulator is used to power the 3.3V regulator, the horn driver, the interconnect circuit and the IRCAP circuit. The 3.3V regulator and the IRCAP circuit are powered by boost regulator when it is operating in either Low-Boost or High-Boost mode. The horn driver requires a high-boost voltage, so the piezo horn can achieve the necessary sound pressure levels. The interconnect function needs a high-boost voltage to provide proper interconnect operation with interconnected alarms. The boost regulator can supply a nominal maximum current shown in Table 4-6. These data apply for a temperature of +60°C.

TABLE 4-6: V_{BST} NOMINAL MAXIMUM I_{LOAD}

V_{BAT} (V)	V_{BST} (V)	I_{LOAD} (mA)
2	4	38
2	5.2	32
2	8.5	40
2.1	10	40
2.1	11.5	40
2.1	16	30

To conserve battery current, the boost voltage must be set to the lowest value that produces the desired operating result.

EQUATION 4-1: BATTERY CURRENT CALCULATION

$$I_{BAT} = I_{LOAD} \times \frac{V_{BST}}{V_{BAT}}$$

Where:

I_{BAT}	=	Battery Current (mA)
I_{LOAD}	=	Battery Load Current (mA)
V_{BST}	=	Boost Regulator Output Voltage (V)
V_{BAT}	=	Battery Voltage (V)

4.1.4 LOW BATTERY TEST

During smoke alarm operation, the horn driver current is typically the largest sustained current that the battery must supply. The red LED and resistor R2 shown in Table 4-7 provide a visual signal and a battery load current when RLED is enabled, RLEn (register 3, bit 3). The resistor R2 must be selected to draw the equivalent RMS current the horn draws. Current draw from the IO_{TR} pin must also be accounted for if it is used.

For systems using AC-derived power, the AC power supply must include a disable input. The voltage of AC-derived power must be reduced below the battery voltage in 9V systems or reduced below the minimum high-boost voltage in 3V systems. This ensures that only the battery is powering the system. Alternatively, the AC supply input can turn off the AC supply, but power-up timing must be accounted for.

For 3V systems, the high-boost operating mode must be used to perform the battery test, just as it is used when sounding a smoke alarm. The boost regulator soft start timing needs to be accounted for when making the measurement of V_{BAT}. The ABUF is used to monitor the voltage at V_{BAT} or V_{BST}, depending on the detector operating mode.

TABLE 4-7: LOW-BATTERY TEST 3V

	SPI Hex Code	SPI Register/Comment
1	**Normal operation – start low-battery test.**	
2	0x0202	**Register 1**: LBEn = 0, HBEn = 1, IRCEn = 0 Turn on high-boost.
3	**Wait for boost soft start to complete and enable red LED.**	
4	0x0608	**Register 3**: HrnEn = 0, IOEn = 0, IOout = 0, RLEn = 1, COTest = 0, COCurSel = 0, COTri = 0 Turn on the red LED.
5	**Wait ~ 10 ms to allow the system to stabilize.**	
6	0x0007	**Register 0**: ABUF[3:0] = [0111] Measure V_{BAT} via ABUF
7	**Make ADC conversion and compare to limit.**	
8	0x0000	**Register 0**: ABUF[3:0] = [0000] Turn off the ABUF.
9	0x0600	**Register 3**: HrnEn = 0, IOEn = 0, IOout = 0, RLEn = 0, COTest = 0, COCurSel = 0, COTri = 0 Turn off the red LED.
10	0x0200	**Register 1**: LBEn = 1, HBEn = 0, IRCEn = 0 Turn off high-boost and turn on low-boost.
11	**Continue normal operation. Sound the low-battery chirp warning as necessary.**	

TABLE 4-8: LOW BATTERY TEST AC WITH 9V BATTERY BACKUP

	SPI Hex Code	SPI Register/Comment
1	**Normal operation – start low-battery test.**	
2	**The MCU disables the AC supply, then enables the red LED.**	
3	0x0608	**Register 3**: HrnEn = 0, IOEn = 0, IOout = 0, RLEn = 1, COTest = 0, COCurSel = 0, COTri = 0 Turn on the red LED.
4	**Wait ~ 10 ms to allow the system to stabilize.**	
5	0x0005	**Register 0**: ABUF[3:0] = [0101] Connect V_{BST} to ADC via ABUF.
6	**Make the ADC conversion and compare to limit.**	
7	0x0000	**Register 0**: ABUF[3:0] = [0000] Turn off the ABUF.
8	0x0600	**Register 3**: HrnEn = 0, IOEn = 0, IOout = 0, RLEn = 0, COTest = 0, COCurSel = 0, COTri = 0 Turn off the red LED.
9	**MCU enables the AC supply.**	
10	**Continue normal operation. Sound the low-battery chirp warning as necessary.**	

4.1.5 IRCAP

The IRCAP is the bias supply for the smoke chamber LEDs and the photo amplifier. The IRCAP voltage needs to be large enough to maintain a 1V drop across the LED drivers for LED driver currents ≥ 80 mA and a 0.8V drop across the LED drivers, when the LED driver current is < 80 mA. For a blue LED, the maximum forward voltage drop is about 4V. The minimum high-voltage for IRCAP is 5V, which provides a 1V drop across the LED driver when using a blue LED. For an infrared diode-only system, the worst-case forward voltage drop is about 2V. In this case, the lower low-boost voltage can be used, which also selects the lower IRCAP voltage of 4V. The IRCAP is powered on with SPI bit IRCEn (register 1, bit 2), which charges the IRCAP capacitor, C_5, using a 21 mA current source. The IRCAP must be one of the first functions powered on at system power up.

Each smoke check discharges capacitor C_5 by an amount equal to the LED driver current multiplied by the integration time and divided by the value of C_5, as shown in Equation 4-2.

EQUATION 4-2: IRCAP DISCHARGING CALCULATION

$$\Delta V_{IRCAP} = \frac{I_{LED} \times t_i}{C_5}$$

Where:

ΔV_{IRCAP} = IRCAP Voltage Change (V)

I_{LED} = LED Driver Current (A)

t_i = Integration Time (S)

C_5 = Capacitance C_5 (100 µF)

The IRCAP is turned on at the beginning of the smoke check cycle. The IRCAP is turned off before the smoke check photo amplifier integrations start to prevent possible switching noise, which could cause measurement errors.

4.2 Operation Overview

After the initial power up is complete, the remaining setup registers must be set. The setup registers are Register 5 through Register 9. The setup registers set operating parameters for the various analog and interface functions. The setup registers can be changed at any time during smoke detector operation. Register 0 through Register 4 are control registers and are used to turn on and off the various analog and interface functions. Practice care with the register addresses, since the LSB of the address byte is a don't care. Effectively, the decimal value for the register is multiplied by 2 when the full hex value is used for the address byte. For example, to turn on the RLED by using Register 3, the hex SPI code is 0x0608.

To reduce battery current draw and conserve battery energy, all analog and interface functions can be turned off until needed. For AC and 9V operations, the boost regulator can be powered off as well. In a 3V system, the boost regulator must be pulsed on only when it is needed. The boost capacitor, C_4, must be a low-leakage ceramic capacitor, since any energy loss due to a leakage current must be recovered when the boost converter is turned on. For CO detection, the CO operational amplifier and reference can be turned on continuously. High-boost operation is intended to power the horn driver and interconnect circuits. The IRCAP circuit operates properly independent of boost regulator operating mode.

4.3 Smoke Check

The recommended smoke check makes two measurements. The first measurement is made with the LED off, a dark measurement, and the second measurement is made with the LED on, a lit measurement. The result of the dark measurement is subtracted from the result of the lit measurement to determine the smoke check result. The dark measurement includes the 200 mV offset from ground, offset voltage effects, leakage current effects and any smoke chamber light leakage effects. These are all sources of error that are included in the lit measurement result and are removed by the dark measurement subtraction to produce an accurate smoke check measurement.

A smoke measurement is performed by first turning on the boost regulator in 3V systems, LBEn (register 1, bit 0), in low-boost operation and then ensuring the IRCAP capacitor is fully charged. High-boost operation (register 0, bit 1) can also be used. High-boost operation overrides low-boost operation. The correct low-boost voltage must be selected using LBV (register 5, bit 0) to insure the correct IRCAP voltage is used. The IRCAP capacitor is the source of current for the LEDs. Then, the LED driver must be enabled, LED1En (register 2, bit 3) or LED2En (register 2, bit 4), to turn on the necessary internal bias circuitry, unless a dark measurement is being made. The LED driver current is not turned on by this operation. Then, the integrating photo amplifier must be turned on, PAEn (register 2, bit 0), and ABUF must be turned on, ABUF[3:0]. The integrating capacitors must be zeroed before an integration is started by setting SPI register 2, bit 1 = `0` and then setting SPI register 2, bit 1 = `1`. The startup time specifications for the LED driver, the photo amplifier, and ABUF set the stabilization time for these circuits. The Enable pin being driven high starts the integration by turning on the LED.

In Figure 3-1 there is a switch, SW5, between the photo amplifier output and the ABUF input. If the switch is closed, the ABUF output follows the photo amplifier output. Monitoring the photo amplifier output during an integration can be a useful diagnostic tool, but stray capacitive coupling between ABUF out and the photo amplifier inputs can cause an output error. To eliminate possible errors, set EnBuf (register 6, bit 7) to `0` and set ABUF to monitor a scaled LED voltage, ABUF[3:0] is `0xC` or `0xD`, during the integration period. When the integration is complete, set ABUF to the photo amplifier output ABUF[3:0] = `0x2` (register 0, bit [3:0]) and make the ADC conversion after the ABUF output has settled.

4.3.1 INTEGRATOR TIMING

The smoke check integration timing setup has two operating modes: Timer mode and Direct Control mode. In either operating mode, a dark measurement must be subtracted from a lit measurement.

In Timer mode, there are four fixed integration times selectable by SPI register 6, bit [5:4]: 100 µs, 200 µs, 300 µs and 400 µs. Timer mode compensates for internal chip tolerances. After powering on IRCAP, the LED driver, photo amplifier and ABUF, a smoke measurement is made by pulsing the Enable pin high for a minimum of 1 µs. This turns on the LED Driver, if enabled, and starts the integration timer, which runs to completion for the selected timing. To ensure the integration completes properly, wait for the maximum specified time for the selected integration time. Then, select the photo amplifier output for ABUF out and complete the A/D conversion.

In Direct Control mode, the width of the Enable pin pulse is the integration time. After powering on IRCAP, the LED driver, photo amplifier and ABUF, a smoke measurement is made by pulsing the Enable pin high for the length of the desired integration time. The minimum length must be 50 µs or higher. The rising edge of the Enable pin pulse turns on the LED Driver, if it is enabled. The manufacturing tolerances for photodiode current, integrating capacitor value and photo amplifier gain affects the photo amplifier output voltage for each detector. Adjusting the integration time to produce a consistent result for given smoke check condition, such as clean air, simplifies detector calibration. Table 4-9 shows the smoke check flow chart for a 9V system.

TABLE 4-9: SMOKE CHECK 9V SYSTEM SAMPLE CODE

	SPI Hex Code	SPI Register/Comment
1	**Photo amplifier setup after power up.**	
2	0x0A55	**Register 5**: LBV = 1 (5.2V), HBV[2:1] = [10] (11.5V), RdNow = 1, WDEn = 1, WDHrn = 0 Set low and high-boost voltages; low-boost voltage sets the IRCAP voltage.
3	0x0C93	**Register 6**: Gain[2:0] = [011] (8), ITCn = 0, IT[5:4] = [01] (200 µs), EnBuf = 1 Set photo amplifier gain, integration time, integration control and ABUF control.
4	0x0E25	**Register 7**: ILED1[2:0] = [101] 100 mA, ILED2[6:4] = [010] 50 mA Set LED currents.
5	0x1000	**Register 8**: FEED = 0, HEnCtl = 0, HrnBrdg = 0, EnCtl = 0, HiIO = 0, HiDmp = 0, IOThrsh = 0 Enable pin controls integration on time or start.
6	0x1203	**Register 9**: TCLED1[2:0] = [011] 0.5%/°C, TCLED2[6:4] = [000] 0%/°C Set LED current TC.
7	**Normal operation (Sleep).**	
8	**Photo amplifier operation (Wake Up):**	
9	0x0204	**Register 1**: LBEn = 0, HBEn = 0, IRCEn = 1 Turn on IRCAP charging; boost regulator not needed; use Equation 4-2 to calculate charging time.
10	0x0006	**Register 0**: ABUF[3:0] = [0110] Check IRCAP voltage via ABUF pin to make sure it is sufficiently charged (≥ 5V for blue LED and ≥ 3V for infrared LED).
11	**ADC ABUF voltage measurement conversion after waiting for IRCAP to charge.**	
12	0x0200	**Register 1**: LBEn = 0, HBEn = 0, IRCEn = 0 Turn off the IRCAP charging.
13	**Dark measurement LED2; photo amplifier is on.**	
14	0x000D	**Register 0**: ABUF[3:0] = [1101] Set the ABUF to measure the LED2 voltage; keep the ABUF on, but disconnected from the photo amplifier output.
15	0x0C82	**Register 6**: EnBuf = 1, IT[5:4] = [00] (100us), ITCn = 0, and Gain[2:0] = [010] (4) Setup photo amplifier for LED2 measurement.
16	0x0401	**Register 2**: PAEn = 1, Status = 0, InSel = 0, LED1En = 0, LED2En = 0 Zero integrating capacitors.
17	**Photo amplifier biases up and stabilizes; wait 110 µs.**	
18	0x0403	**Register 2**: PAEn = 1, Status = 1, InSel = 0, LED1En = 0, LED2En = 0 Ready, LED2 disabled
19	**Enable pin pulsed high to start fixed time integration of 100 µs.**	
20	**Wait 125 µs.**	
21	0x0002	**Register 0**: ABUF[3:0] = [0010] Set the ABUF to measure LED2 photo amplifier voltage.
22	**ADC makes dark photo measurement conversion.**	
23	0x000D	**Register 0**: ABUF[3:0] = [1101]; Keep the ABUF on, but disconnected from the photo amplifier output.
24	**Lit measurement LED2:**	
25	0x0401	**Register 2**: PAEn = 1, Status = 0, InSel = 0, LED1En = 0, LED2En = 0 Zero integrating capacitors.
26	0x0413	**Register 2**: PAEn = 1, Status = 1, InSel = 0, LED1En = 0, LED2En = 1 Ready, LED2 enabled.
27	**Enable pin pulsed high to start fixed time integration of 100 µs.**	
28	**Wait 125 µs.**	

TABLE 4-9: SMOKE CHECK 9V SYSTEM SAMPLE CODE (CONTINUED)

	SPI Hex Code	SPI Register/Comment
29	0x0002	**Register 0**: ABUF[3:0] = [0010] Set the ABUF to measure the LED2 photo amplifier voltage.
30	**ADC makes lit photo measurement conversion. Subtract dark ADC value from lit ADC value to get LED2 smoke check value.**	
31	**Smoke check measurement LED1:**	
32	0x0204	**Register 1**: LBEn = 0, HBEn = 0, IRCEn = 1 Turn on the IRCAP charging, briefly (optional).
33	**Adjust photo amplifier gain and integration time for LED1.**	
34	0x0C92	**Register 6**: EnBuf = 1, IT[5:4] = [01] (200 us), ITCn = 0, Gain[2:0] = [011] (8) Photo amplifier setup for LED1 measurement.
35	0x0200	Register 1: LBEn = 0, HBEn = 0, IRCEn = 0 Turn off IRCAP charging.
36	**Dark measurement for LED1:**	
37	0x0401	**Register 2**: PAEn = 1, Status = 0, InSel = 0, LED1En = 0, LED2En = 0 Zero integrating capacitors
38	0x0403	**Register 2**: PAEn = 1, Status = 1, InSel = 0, LED1En = 0, LED2En = 0 Ready, LED1 disabled.
39	**Enable pin pulsed high to start fixed time integration of 200 µs.**	
40	**Wait 250 µs.**	
41	**ADC makes dark photo measurement conversion.**	
42	**Lit measurement LED1:**	
43	0x0401	**Register 2**: PAEn = 1, Status = 0, InSel = 0, LED1En = 0, LED2En = 0 Zero integrating capacitors.
44	0x040B	**Register 2**: PAEn = 1, Status = 1, InSel = 0, LED1En = 1, LED2En = 0 Ready, LED1 enabled.
45	**Enable pin pulsed high to start fixed time integration of 200 µs.**	
46	**Wait 250 µs.**	
47	**ADC makes lit photo measurement conversion. Subtract dark ADC value from lit ADC value to get LED1 smoke check value.**	
48	0x0400	**Register 2**: PAEn = 0, Status = 0, InSel = 0, LED1En = 0, LED2En = 0 Turn off the photo amplifier and the LEDs.

4.4 CO Detection and Sensor Test

The CO operational amplifier is a high performance low current operational amplifier that is configured as a transimpedance amplifier. The 300 mV CO reference ensures the operational amplifier output operates above ground. The CO operational amplifier is powered on by SPI register 4, bit 4 (COAEn) and the CO reference is powered on by SPI register 4, bit 5 (COREn). Each operational amplifier input is connected to a 2 µA current source/sink. Only one current source/sink on one pin can be turned on at a time. The current source/sink is powered on by COTest (register 3, bit 5). Register 3, bit 6, COCurSel, controls which input is used for the CO test. The current source/sink polarity is controlled by COCurPol (register 4, bit 6). SPI register 3, bit 7 (COTri) tristates the CO operational amplifier output, which prevents the CO operational amplifier output from correcting for the test charge injection.

To test the CO sensor, use the following procedure:

The CO operational amplifier and reference are assumed to be running with a stable CO operational amplifier output. The CO test pin must be selected with COCurSel (register 3, bit 6) and the current source polarity must be set with COCurPol (register 4, bit 6).

First, turn off the operational amplifier output with register 3, bit 7, COTri, so the operational amplifier output does not override the test current injection. Then, turn on the current source with register 3, bit 5, COTest, for 2s to 5s. About 50 µs after the current source is turned off, turn on the operational amplifier output using register 3, bit 7, COTri. About 5s after operational amplifier output turns on, check the operational amplifier output voltage. Refer to the CO manufacturers documentation for information regarding testing the CO sensor.

TABLE 4-10: 9V POWER-UP AND CO TEST

SPI Hex Code		SPI Register/Comment
1	**Apply power to V_{BST} pin. After the MCU is powered on, send the following SPI commands:**	
2	0x0833	**Register 4**: RegSel = 1, RegEn = 1, BatSel = 0, COAEn = 1. COREn = 1, COCurPol = 0
3	**Continue with additional setup commands, as shown in Table 4-2, then begin normal operation.**	
4	**Begin CO Test.**	
5	0x0203	**Register 1**: Abuf[3:0] = [0011] (3) Monitor the CO operational amplifier output.
6	0x0680	**Register 3**: HrnEn = 0, IOEn = 0, IOout = 0, RLEn = 0, COTest = 0, COCurSel = 0, COTri = 1 Tristate the CO amplifier output.
7	0x06A0	**Register 3**: HrnEn = 0, IOEn = 0, IOout = 0, RLEn = 0, COTest = 1, COCurSel = 0, COTri = 1 Turn on the test current source.
8	**Wait from 2s to 5s, then turn off the current source.**	
9	0x0680	**Register 3**: HrnEn = 0, IOEn = 0, IOout = 0, RLEn = 0, COTest = 0, COCurSel = 0, COTri = 1 Turn off the current source.
10	**Wait 50 µs then turn on the operational amplifier output.**	
11	0x0600	**Register 3**: HrnEn = 0, IOEn = 0, IOout = 0, RLEn = 0, COTest = 0, COCurSel = 0, COTri = 0 Turn the CO operational amplifier output.
12	**Make ADC measurement at ABUF pin per CO manufacturers recommendations.**	
13	0x0000	**Register 0:** Turn off the ABUF.

4.5 Interconnect Circuit

The interconnect circuit, IO, is a bidirectional communication interface between smoke detectors in a home. All the detectors in the home operate in Listen mode and assert a logic high during a smoke alarm event. During a CO event, the line is pulsed on and off. The communication line is subject to noise pickup, especially in AC-powered systems, where the communication line is the third wire in a three wire cable. A digital filter prevents noise pulses less than 30 ms wide from asserting a logic high at IOF_{OUT}. This simplifies any external filtering that may be required.

The interconnect circuit operation as a receiver or transmitter is controlled via SPI register 3, bit 1, IOEn. The receive operation is set by register 3, bit 1 = 0. The receive circuit logic thresholds and hysteresis are set via SPI register 8, bit 6, IO_{THRSH}. The transmit operation is set by register 3, bit 1 = 1. The transmit logic high or low is set by register 3, bit 2. A transmit logic high, register 3, bit 2 = 1, is implemented with a current source that supplies -4 mA and pulls up to 6.6V minimum. A logic low (register 3, bit 2 = 0) is implemented with a current sink of 13 mA.

In the case of CO signaling, the interconnect line can be pulsed. A high-current mode is available when the external detectors present a high capacitance to the system. The high-current source operation is implemented by register 8, bit 4, HiIO. The high-current sink operation is implemented by register 8, bit 5, HiDmp. The duration of these current sink and source events is controlled by the MCU firmware.

TABLE 4-11: 3V BATTERY HORN AND IO OPERATION FOR SMOKE ALARM

	SPI Hex Code	SPI Register/Comment
1	**Horn uses T3 temporal pattern; on 0.5s, off 0.5s, on 0.5s, off 0.5s, on 0.5s, off 1.5s.**	
2	**Horn and low-current IO setup; use register 3, bit 0 (HrnEn), to modulate horn pattern.**	
3	0x1000	**Register 8**: FEED = 0, HEnCtl = 0, HrnBrdg = 0, EnCtl = 0, HiIO = 0, HiDmp = 0, IOThrsh = 0; Horn modulation controlled by register 3, bit 0 (HrnEn).
4	**Normal operation detects smoke after smoke check completes; Leave photo amplifier and LEDs off. Turn on high voltage boost regulator operation.**	
5	0x0202	**Register 1**: LBEn = 0, HBEn = 1, IRCEn = 0. Turn on high-boost operation.
6	**Turn on IO.**	
7	0x0606	**Register 3**: HrnEn = 0, IOEn = 1, IOout = 1, RLEn = 0, COTest = 0, COCurSel = 0, COTri = 0 Enable IOout and set IOout to logic high.
8	**MCU sounds horn using SPI register 3, bit 0 (HrnEn),**	
9	0x0607	**Register 3**: HrnEn = 1, IOEn = 1, IOout = 1, RLEn = 0, COTest = 0, COCurSel = 0, COTri = 0 Turn horn on for 0.5s.
10	0x0606	**Register 3**: HrnEn = 0, IOEn = 1, IOout = 1, RLEn = 0, COTest = 0, COCurSel = 0, COTri = 0 Turn horn off for 0.5s.
11	**System continues with smoke check measurements when horn is off.**	
12	0x0607	**Register 3**: HrnEn = 1, IOEn = 1, IOout = 1, RLEn = 0, COTest = 0, COCurSel = 0, COTri = 0 Turn horn on for 0.5s.
13	0x0606	**Register 3**: HrnEn = 0, IOEn = 1, IOout = 1, RLEn = 0, COTest = 0, COCurSel = 0, COTri = 0 Turn horn off for 0.5s.
14	**System continues with smoke check measurements when horn is off.**	
15	0x0607	**Register 3**: HrnEn = 1, IOEn = 1, IOout = 1, RLEn = 0, COTest = 0, COCurSel = 0, COTri = 0 Turn horn on for 0.5s.
16	0x0606	**Register 3**: HrnEn = 0, IOEn = 1, IOout = 1, RLEn = 0, COTest = 0, COCurSel = 0, COTri = 0 Turn horn off for 1.5s.
17	**System continues with smoke check measurements when horn is off.**	

TABLE 4-11: 3V BATTERY HORN AND IO OPERATION FOR SMOKE ALARM (CONTINUED)

SPI Hex Code		SPI Register/Comment
18	**Smoke alarm condition ends; MCU stops sounding the horn. Turn on IO dump (sink) to discharge IO line for ~ 1s.**	
19	0x0602	**Register 3**: HrnEn = 0, IOEn = 1, IOout = 0, RLEn = 0, COTest = 0, COCurSel = 0, COTri = 0 Turn horn off, set IOout to logic low.
20	0x0600	**Register 3**: HrnEn = 0, IOEn = 0, IOout = 0, RLEn = 0, COTest = 0, COCurSel = 0, COTri = 0 Turn off IOout dump after ~ 1s.
21	**Continue with normal operation.**	

4.6 Enable Pin

The Enable pin can control both the photo amplifier integration time and the horn modulation. Register 8, bit 3 = 0 selects the photo amplifier integration control by the Enable pin and register 8, bit 3 = 1 allows horn on time to be controlled by the Enable pin or by the HrnEn (register 3, bit 0). Register 8, bit1 determines how the horn is controlled. For register 8, bit 1 = 0, the horn modulation is only controlled by bit HrnEn (register 3, bit 0) and for register 8, bit 1 = 1, the horn is controlled by the register 3, bit 0 = 1 and by the Enable pin. If register 3, bit 0 = 0, then the Enable pin does not modulate the horn output. To reduce the impact of horn related noise, perform smoke check measurements with the horn off. In general, it is recommended to let only the Enable pin control the photo amplifier integration time and to use the HrnEn bit to modulate the horn.

4.7 Applications Drawings

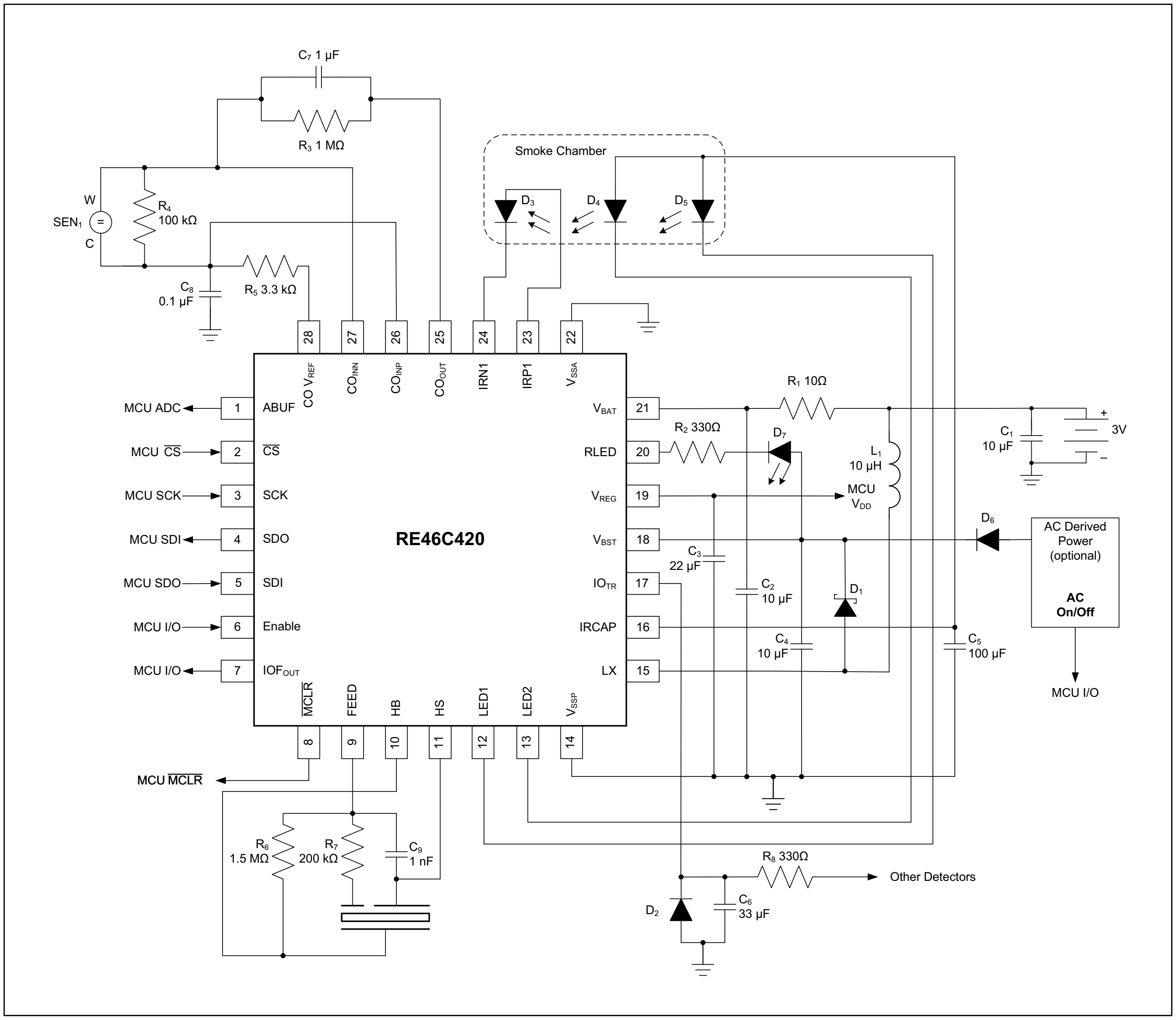


FIGURE 4-1: *RE46C420 Typical 3V AC Application.*

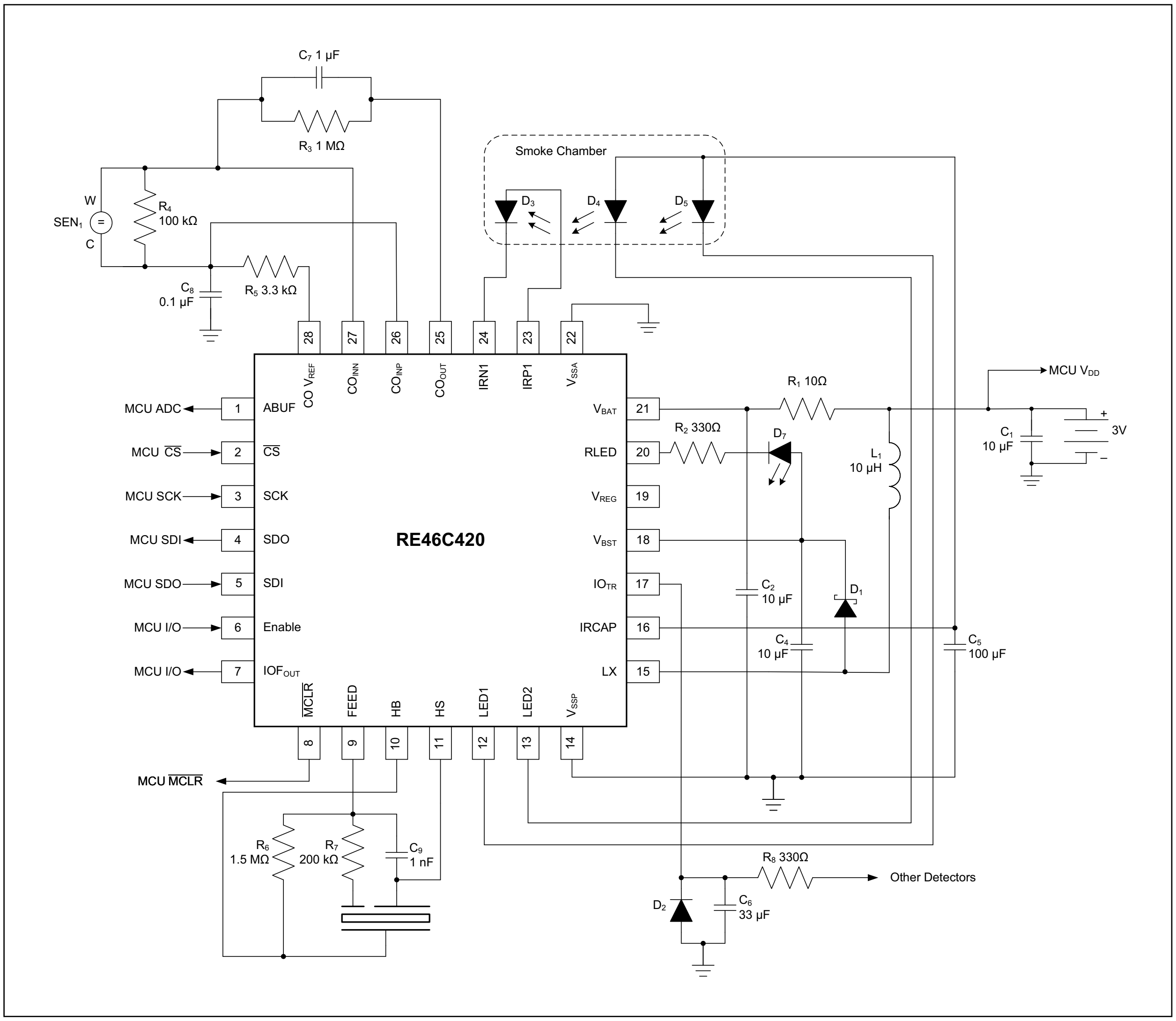


FIGURE 4-2: *RE46C420 Typical 3V Battery-Only Application.*

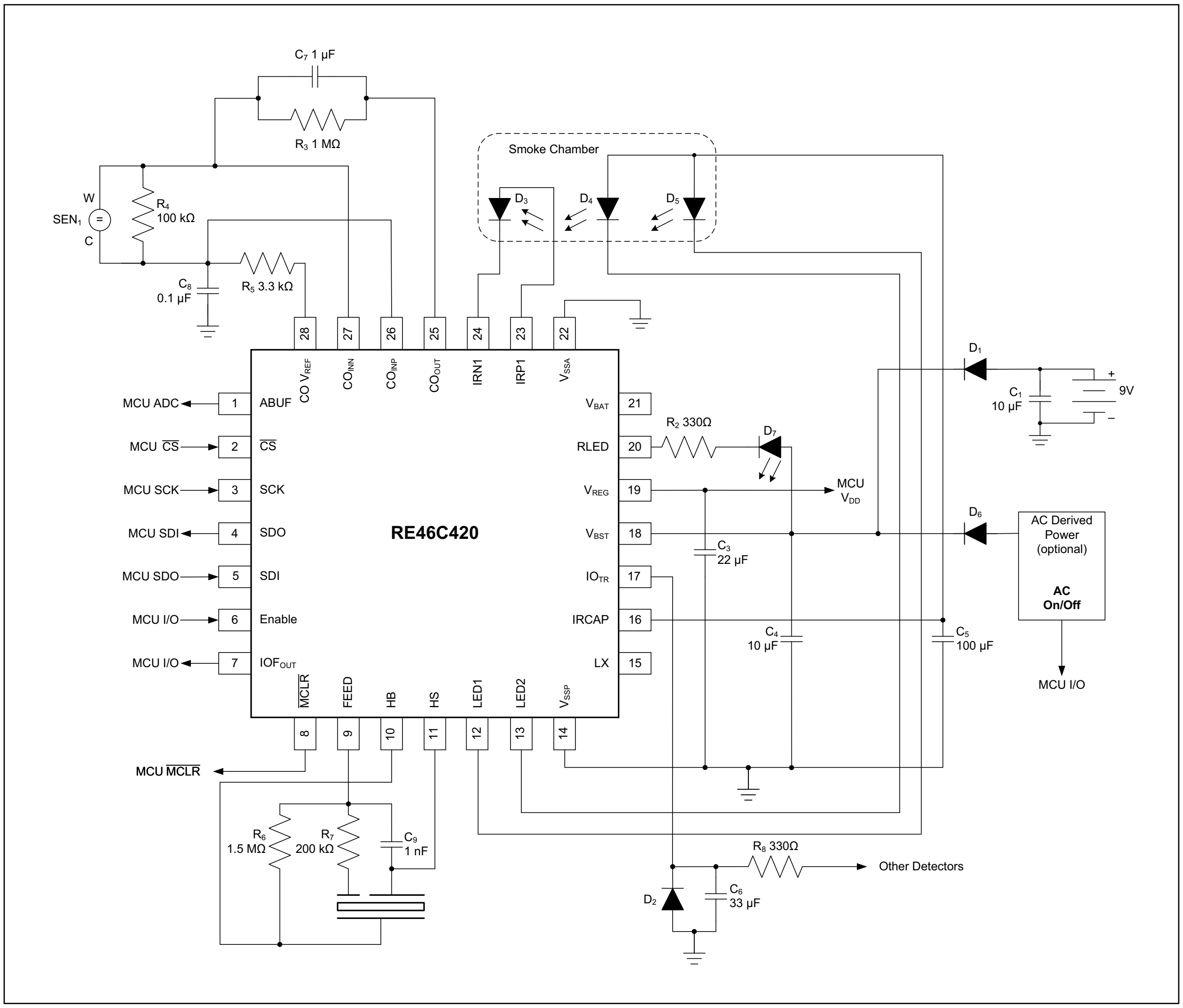


FIGURE 4-3: *RE46C420 Typical 9V AC Application.*

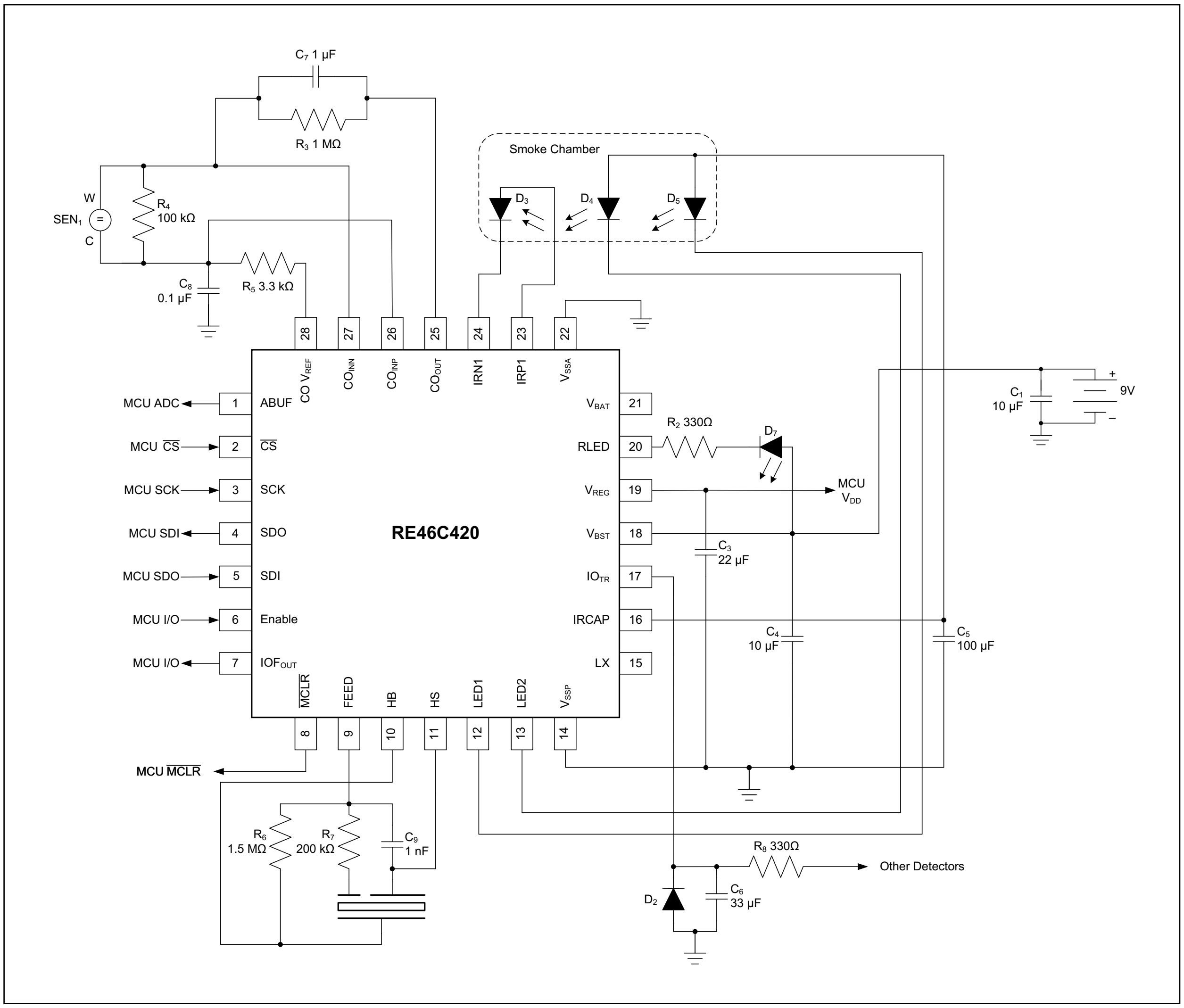


FIGURE 4-4: *RE46C420 Typical 9V Battery-Only Application.*

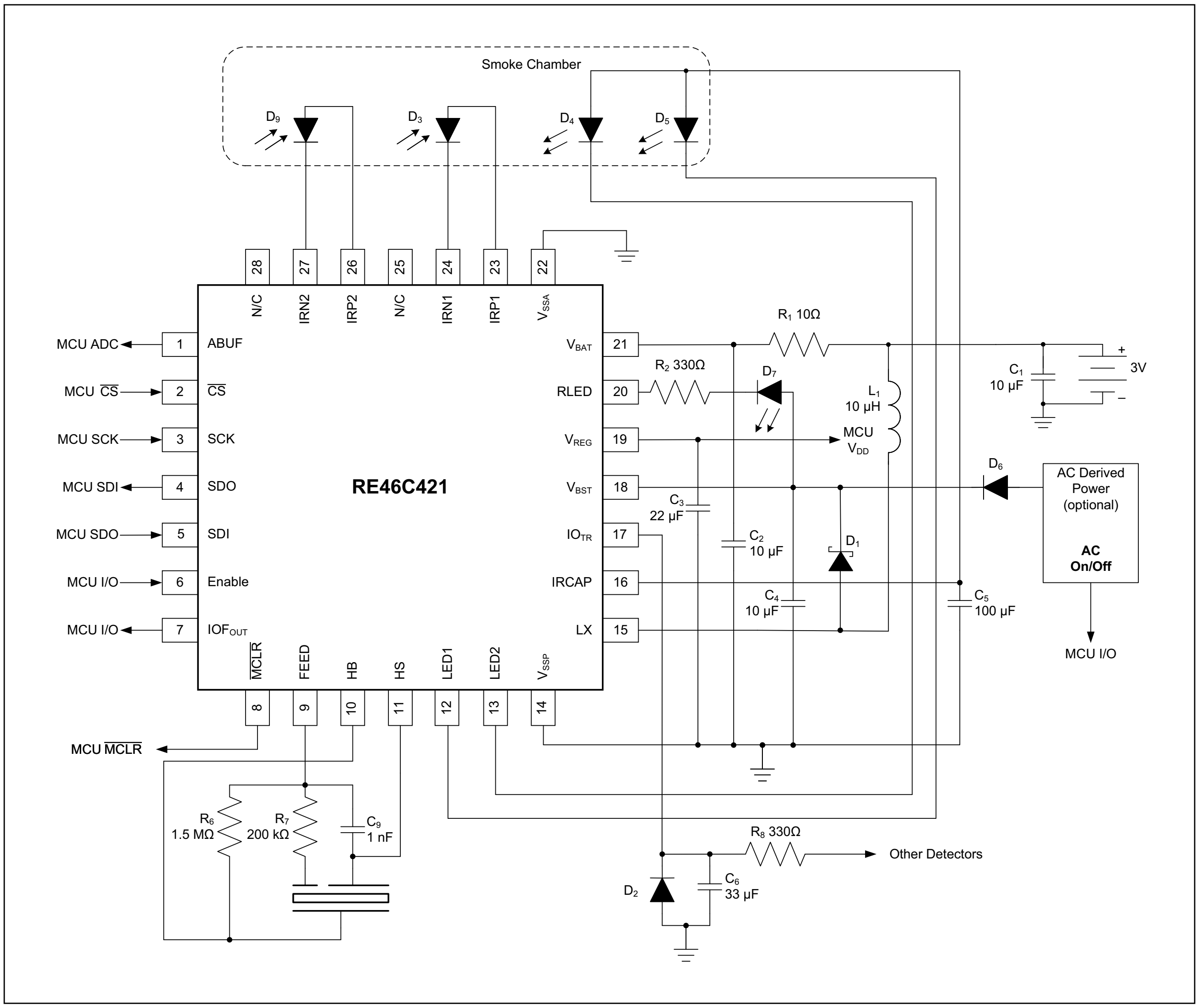


FIGURE 4-5: *RE46C421 Typical 3V AC Application.*

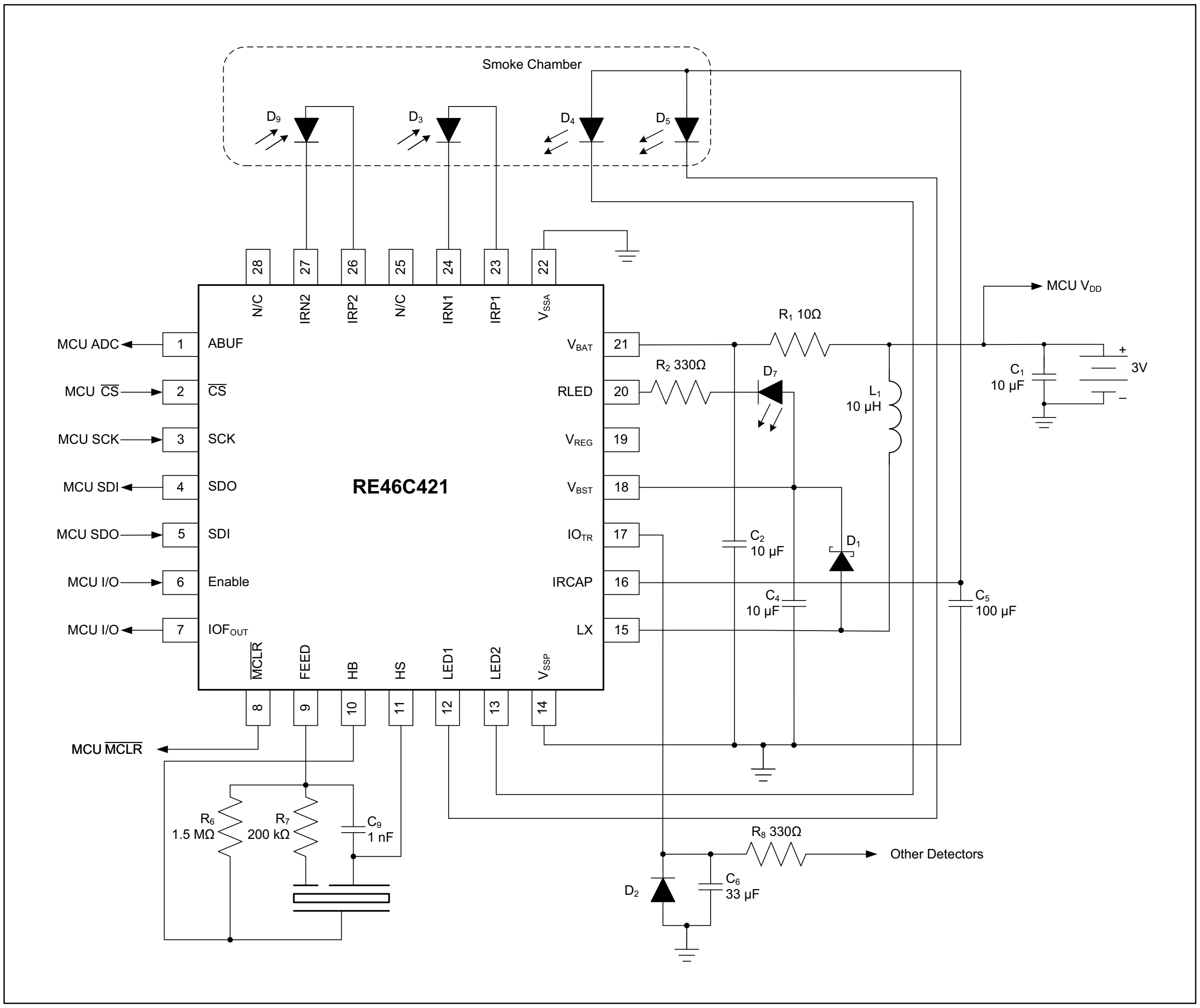


FIGURE 4-6: *RE46C421 Typical 3V Battery-Only Application.*

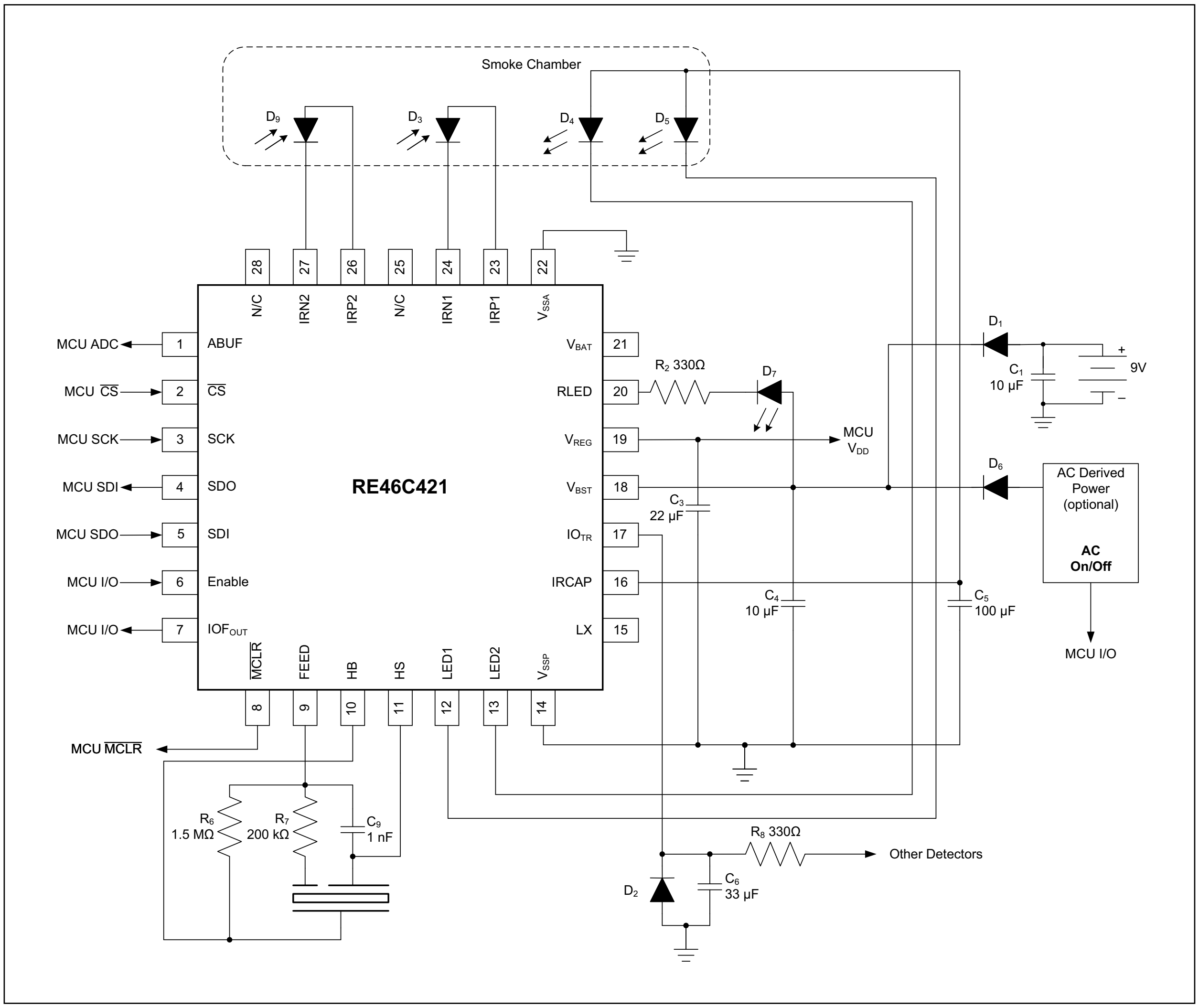


FIGURE 4-7: *RE46C421 Typical 9V AC Application.*

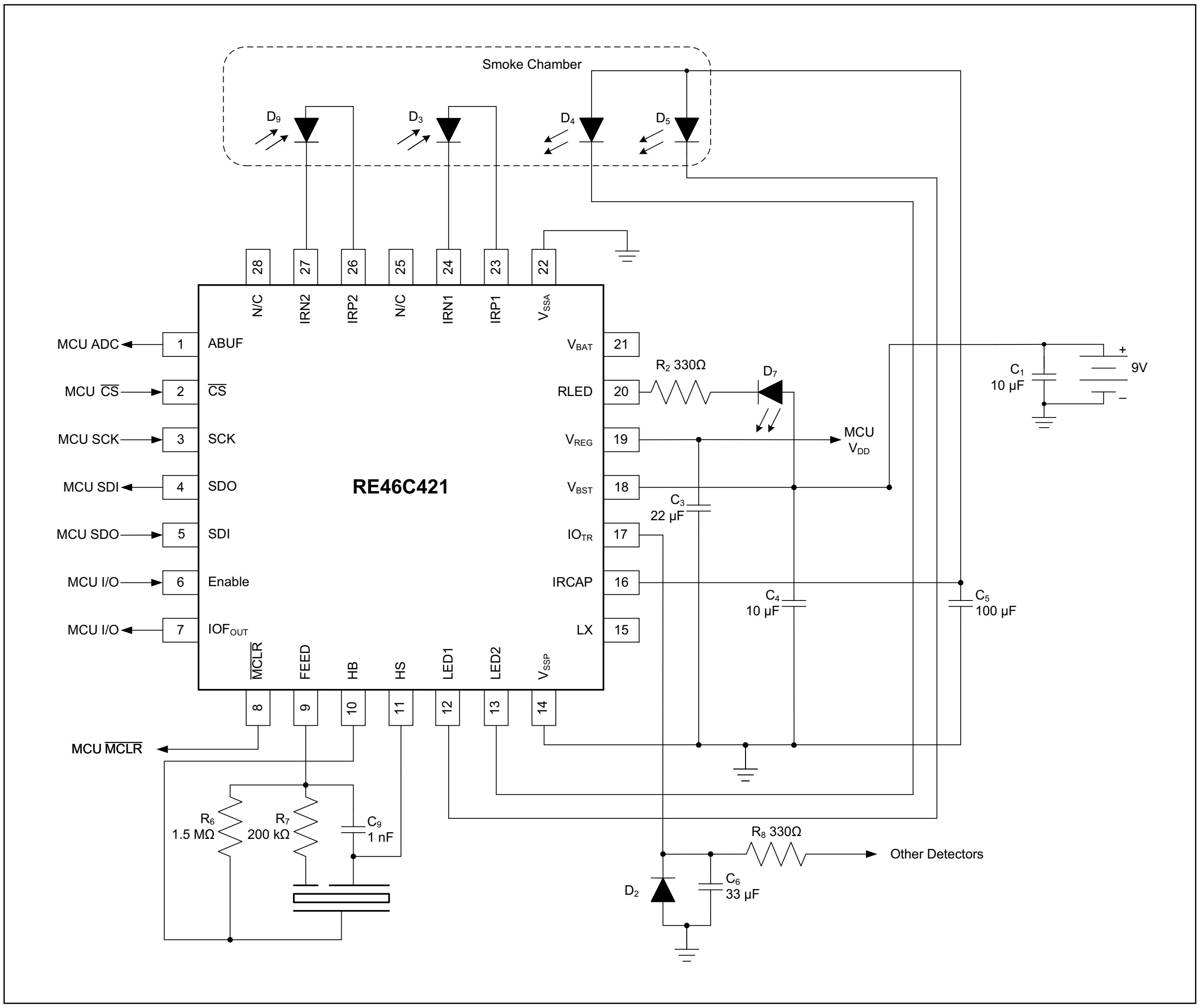


FIGURE 4-8: *RE46C421 Typical 9V Application.*

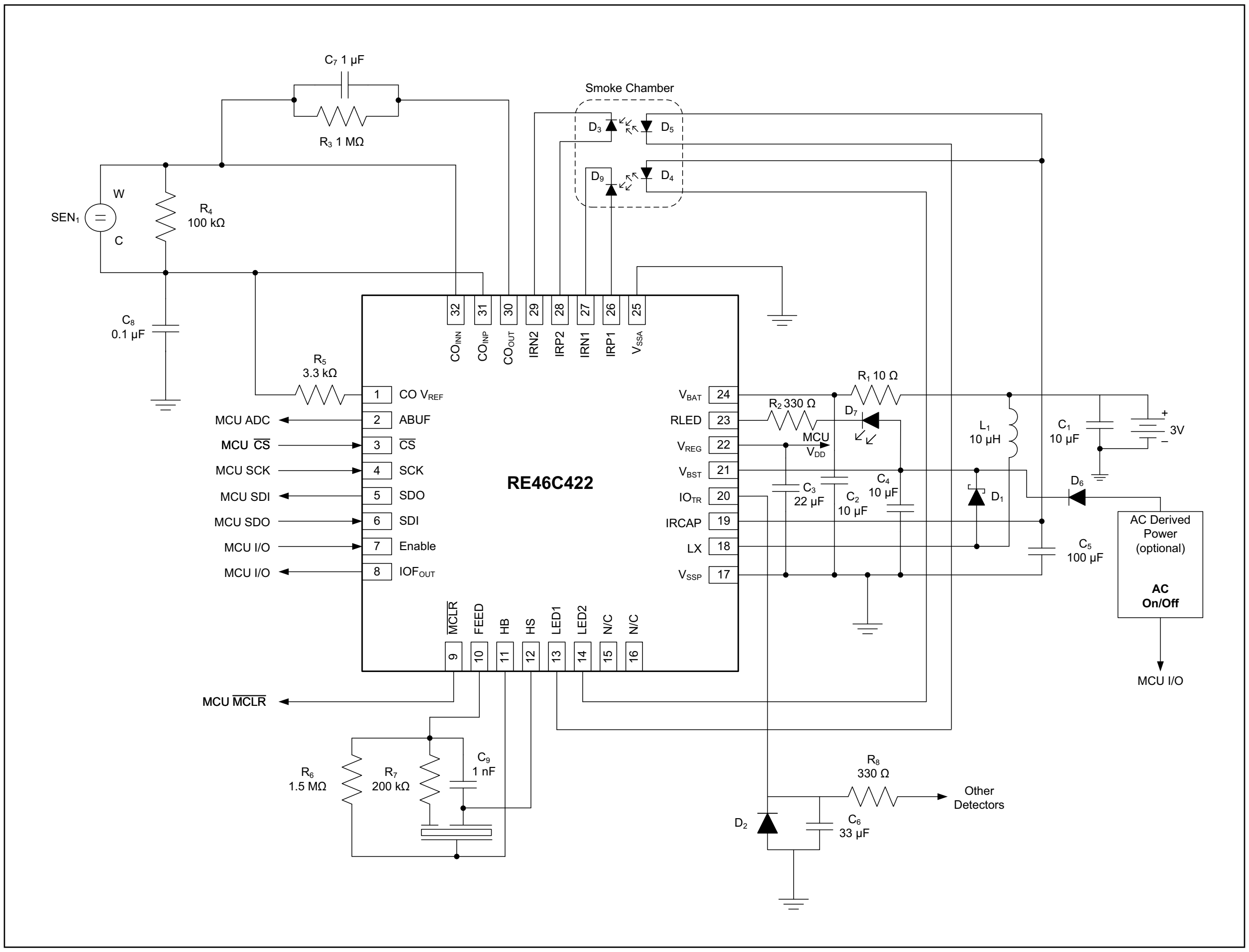


FIGURE 4-9: *RE46C422 Typical 3V AC Application.*

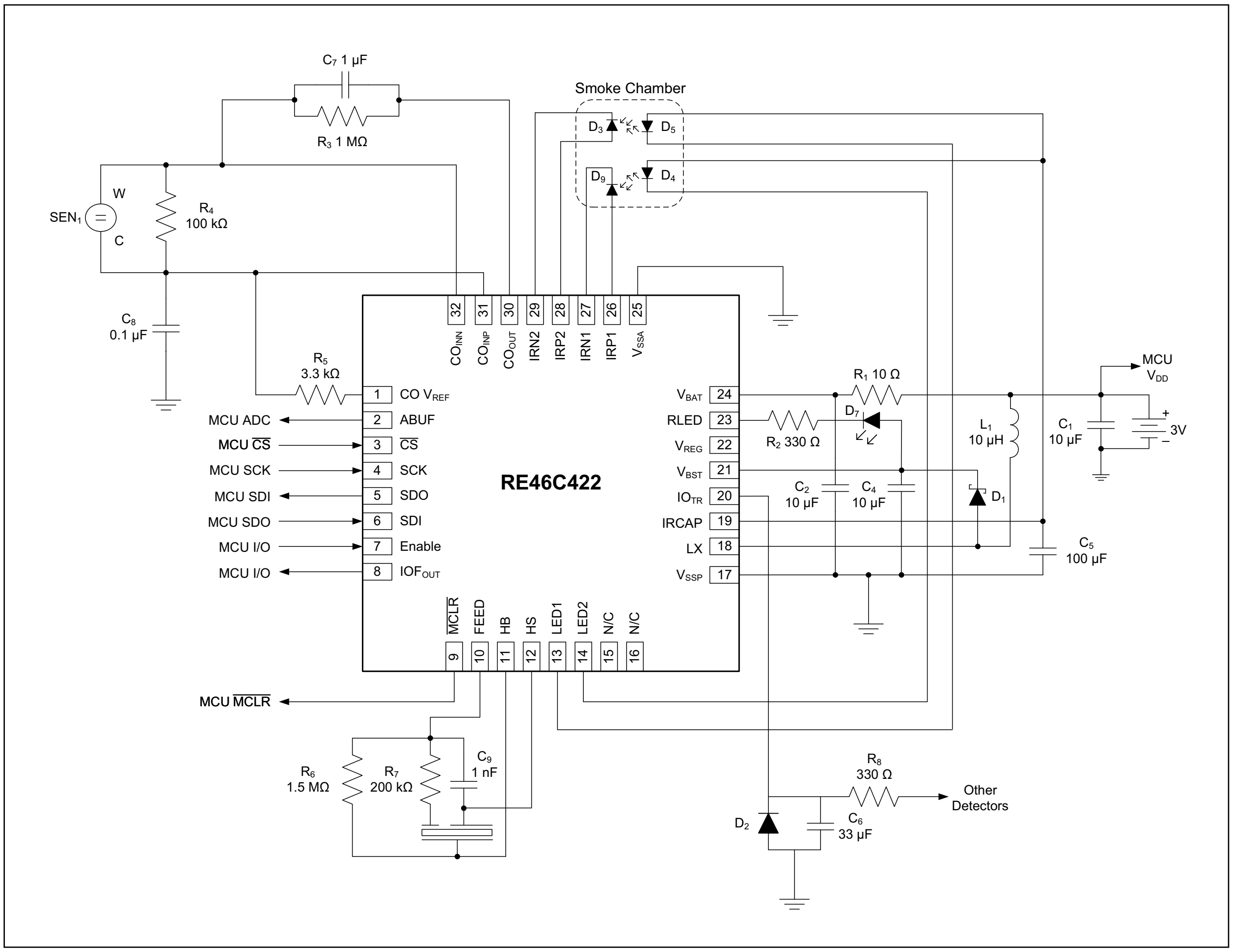


FIGURE 4-10: *RE46C422 Typical 3V Battery-Only Application.*

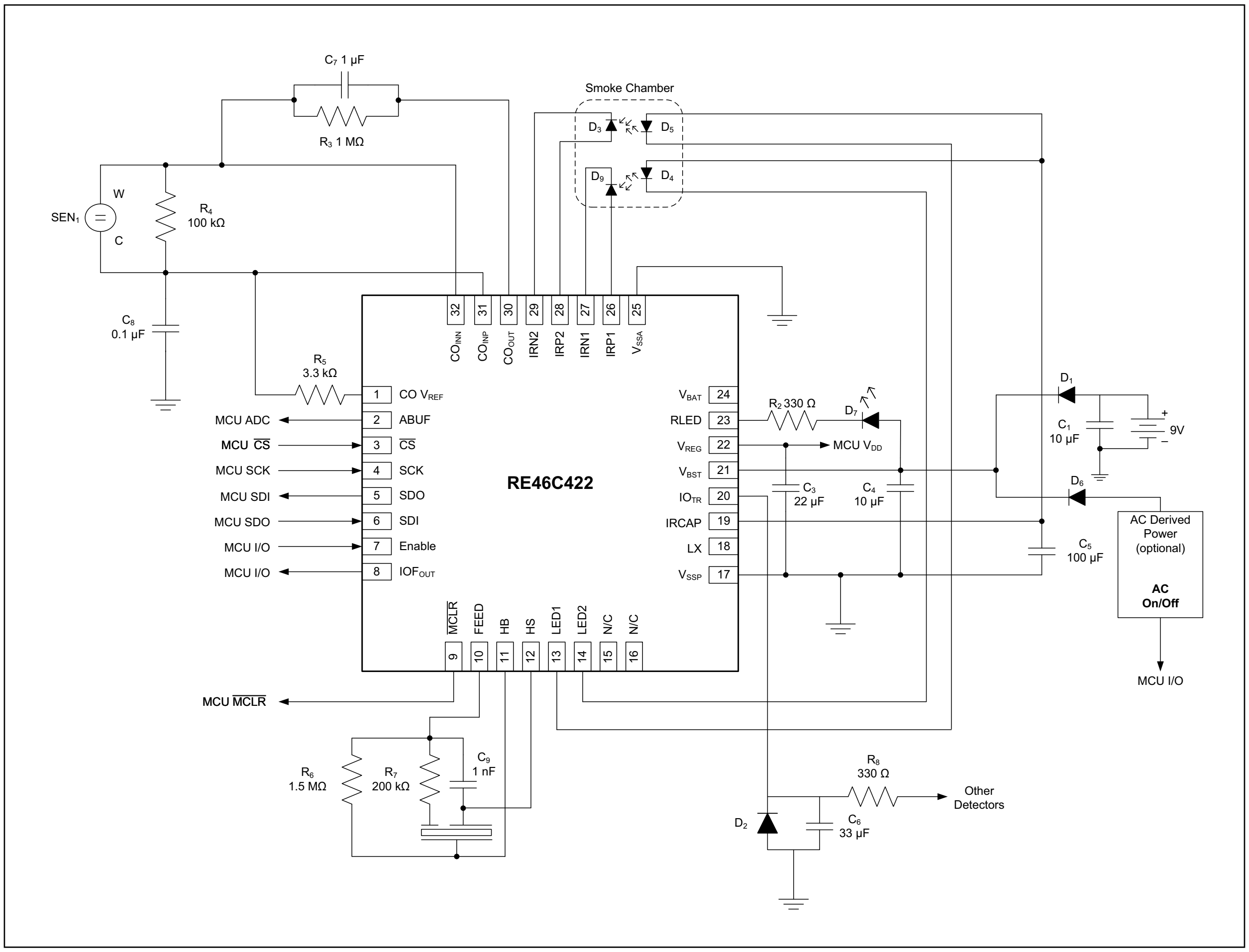


FIGURE 4-11: *RE46C422 Typical 9V AC Application.*

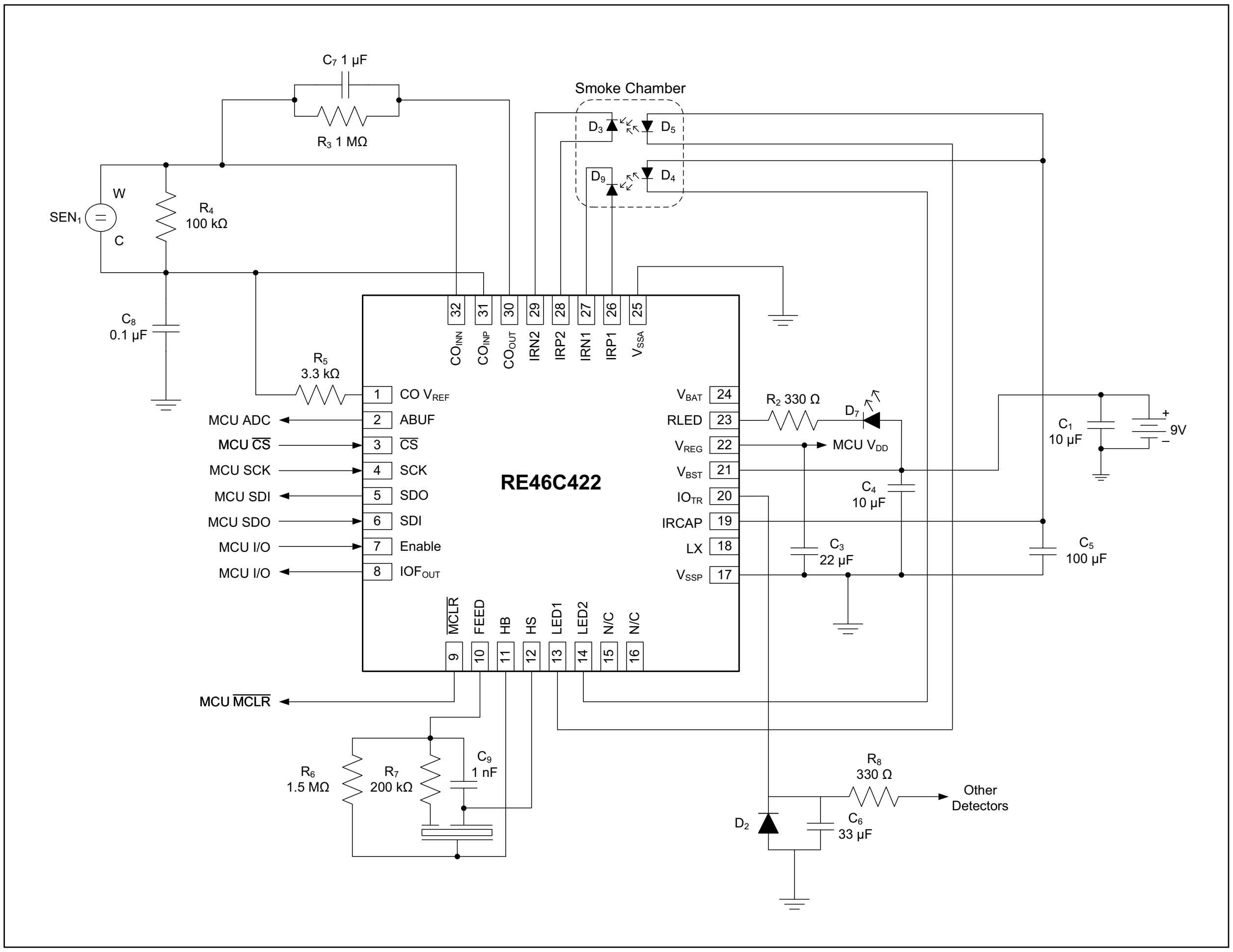
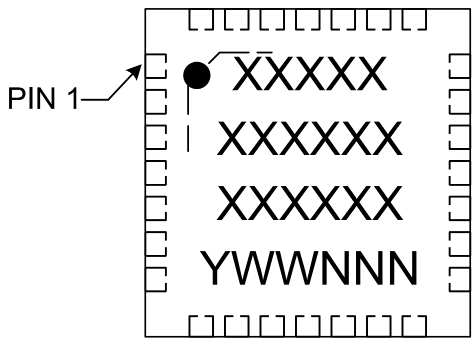


FIGURE 4-12: *RE46C422 Typical 9V Battery-Only Application.*

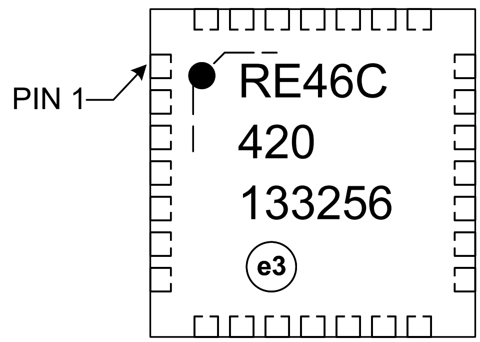
5.0 PACKAGING INFORMATION

5.1 Package Marking Information

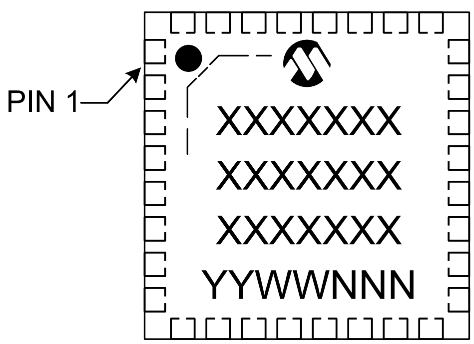
28-Lead VQFN, 4 x 4 x 1 mm
(RE46C420 and RE46C421)



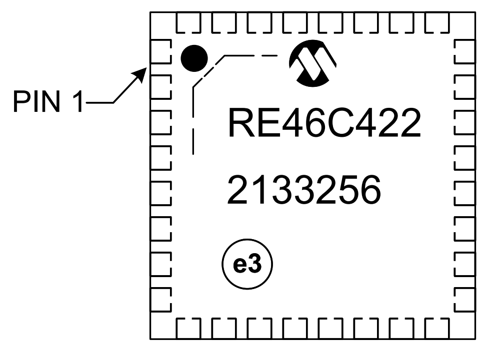
Example:



32-Lead VQFN, 5 x 5 x 1 mm
(RE46C422)



Example:

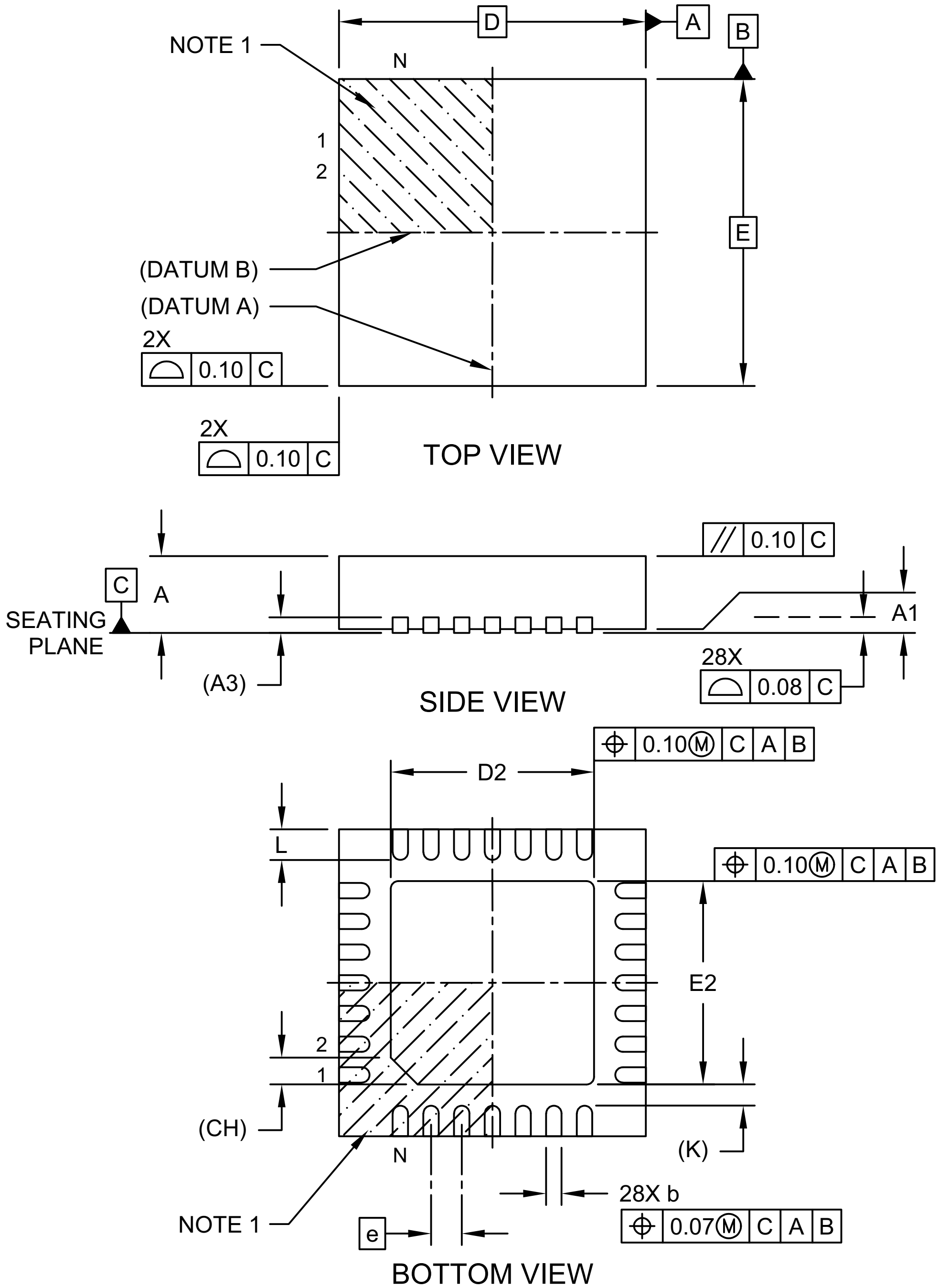


Legend:	XX...X	Customer-specific information
	Y	Year code (last digit of calendar year)
	YY	Year code (last 2 digits of calendar year)
	WW	Week code (week of January 1 is week ‘01’)
	NNN	Alphanumeric traceability code
	e3	Pb-free JEDEC designator for Matte Tin (Sn)
	*	This package is Pb-free. The Pb-free JEDEC designator (e3) can be found on the outer packaging for this package.

Note: In the event the full Microchip part number cannot be marked on one line, it will be carried over to the next line, thus limiting the number of available characters for customer-specific information.

28-Lead Very Thin Plastic Quad Flat, No Lead (STX) - 4x4x1.0 mm Body [VQFN] With 2.65x2.65 mm Exposed Pad

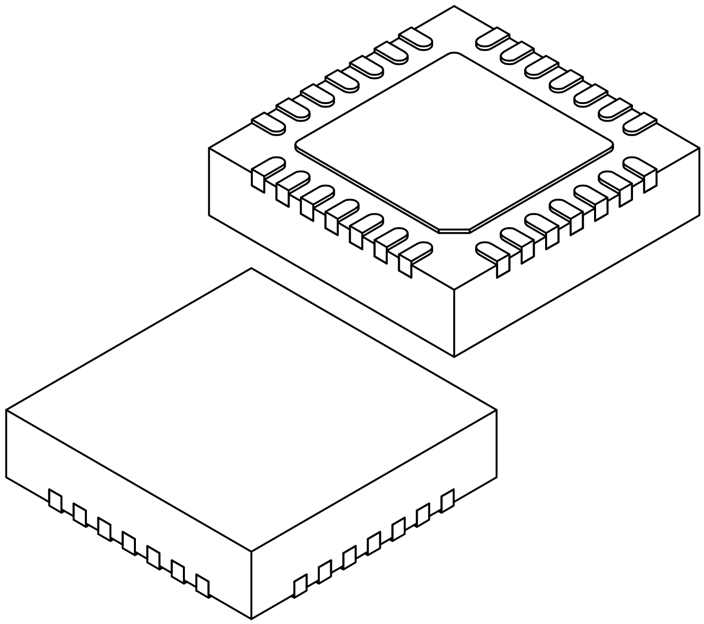
Note:	For the most current package drawings, please see the Microchip Packaging Specification located at http://www.microchip.com/packaging



Microchip Technology Drawing C04-456 Rev C Sheet 1 of 2

28-Lead Very Thin Plastic Quad Flat, No Lead (STX) - 4x4x1.0 mm Body [VQFN] With 2.65x2.65 mm Exposed Pad

Note: For the most current package drawings, please see the Microchip Packaging Specification located at http://www.microchip.com/packaging



Units		MILLIMETERS		
Dimension Limits		MIN	NOM	MAX
Number of Terminals	N		28	
Pitch	e		0.40 BSC	
Overall Height	A	0.80	0.90	1.00
Standoff	A1	0.00	0.02	0.05
Terminal Thickness	A3		0.203 REF	
Overall Length	D		4.00 BSC	
Exposed Pad Length	D2	2.55	2.65	2.75
Overall Width	E		4.00 BSC	
Exposed Pad Width	E2	2.55	2.65	2.75
Exposed Pad Corner Chamfer	CH		0.35 REF	
Terminal Width	b	0.15	0.20	0.25
Terminal Length	L	0.30	0.40	0.50
Terminal-to-Exposed-Pad	K		0.275 REF	

Notes:

1. Pin 1 visual index feature may vary, but must be located within the hatched area.
2. Package is saw singulated
3. Dimensioning and tolerancing per ASME Y14.5M

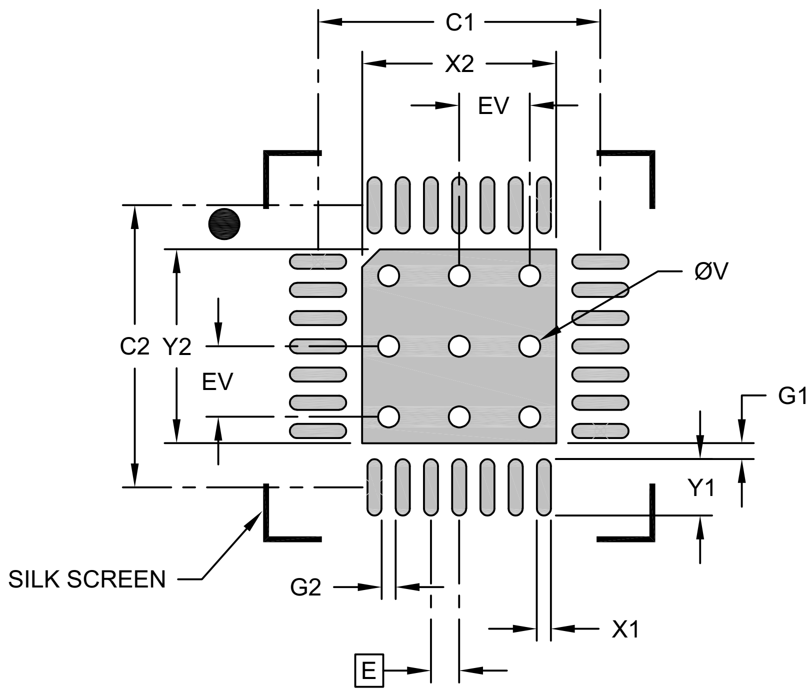
   BSC: Basic Dimension. Theoretically exact value shown without tolerances.

   REF: Reference Dimension, usually without tolerance, for information purposes only.

Microchip Technology Drawing C04-456 Rev C Sheet 2 of 2

28-Lead Very Thin Plastic Quad Flat, No Lead (STX) - 4x4x1.0 mm Body [VQFN] With 2.65x2.65 mm Exposed Pad

Note:	For the most current package drawings, please see the Microchip Packaging Specification located at http://www.microchip.com/packaging



RECOMMENDED LAND PATTERN

	Units	MILLIMETERS		
	Dimension Limits	MIN	NOM	MAX
Contact Pitch	E	0.40 BSC		
Optional Center Pad Width	X2			2.75
Optional Center Pad Length	Y2			2.75
Contact Pad Spacing	C1		4.00	
Contact Pad Spacing	C2		4.00	
Contact Pad Width (X28)	X1			0.20
Contact Pad Length (X28)	Y1			0.80
Contact Pad to Center Pad (X28)	G1	0.23		
Contact Pad to Contact Pad (X24)	G2	0.20		
Thermal Via Diameter	V		0.30	
Thermal Via Pitch	EV		1.00	

Notes:

1. Dimensioning and tolerancing per ASME Y14.5M

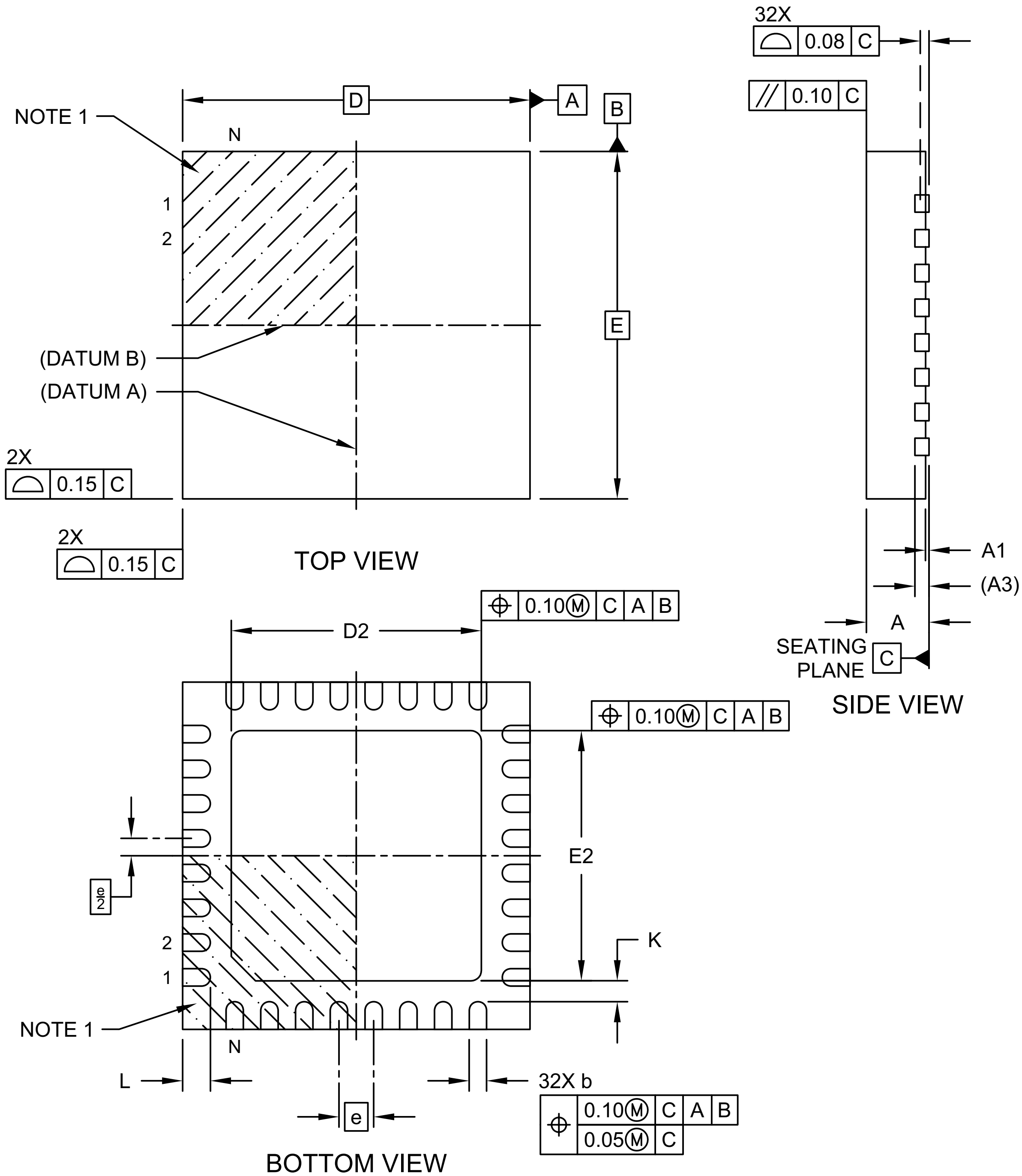
   BSC: Basic Dimension. Theoretically exact value shown without tolerances.

2. For best soldering results, thermal vias, if used, should be filled or tented to avoid solder loss during reflow process

Microchip Technology Drawing C04-2456 Rev C

32-Lead Very Thin Plastic Quad Flat, No Lead Package (S8B) - 5x5 mm Body [VQFN] With 3.60 mm Exposed Pad; Atmel Legacy Global Package Code ZKV

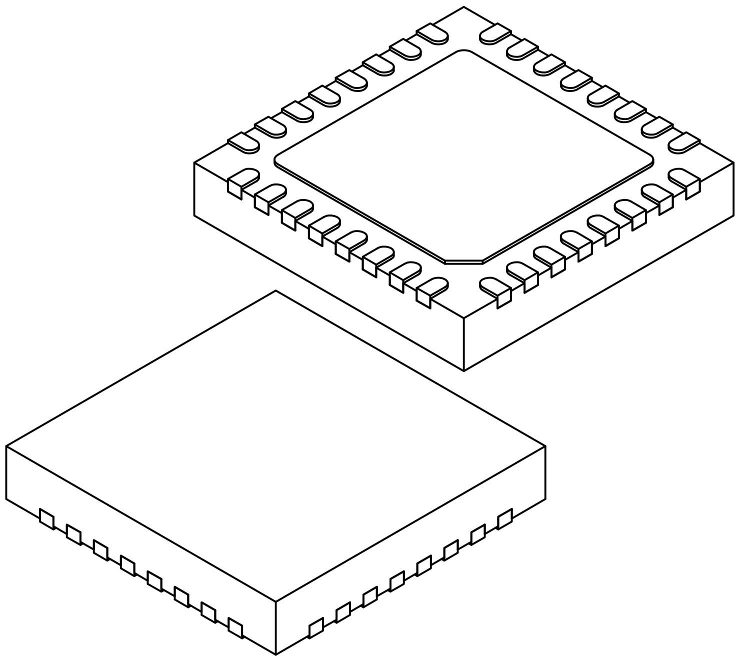
Note:	For the most current package drawings, please see the Microchip Packaging Specification located at http://www.microchip.com/packaging



Microchip Technology Drawing C04-21402 Rev A Sheet 1 of 2

32-Lead Very Thin Plastic Quad Flat, No Lead Package (S8B) - 5x5 mm Body [VQFN] With 3.60 mm Exposed Pad; Atmel Legacy Global Package Code ZKV

Note:	For the most current package drawings, please see the Microchip Packaging Specification located at http://www.microchip.com/packaging



	Units	MILLIMETERS		
	Dimension Limits	MIN	NOM	MAX
Number of Terminals	N		32	
Pitch	e		0.50 BSC	
Overall Height	A	0.80	0.90	1.00
Standoff	A1	0.00	0.02	0.05
Terminal Thickness	A3		0.20 REF	
Overall Length	D		5.00 BSC	
Exposed Pad Length	D2	3.50	3.60	3.70
Overall Width	E		5.00 BSC	
Exposed Pad Width	E2	3.50	3.60	3.70
Terminal Width	b	0.18	0.25	0.30
Terminal Length	L	0.30	0.40	0.50
Terminal-to-Exposed-Pad	K	0.20	-	-

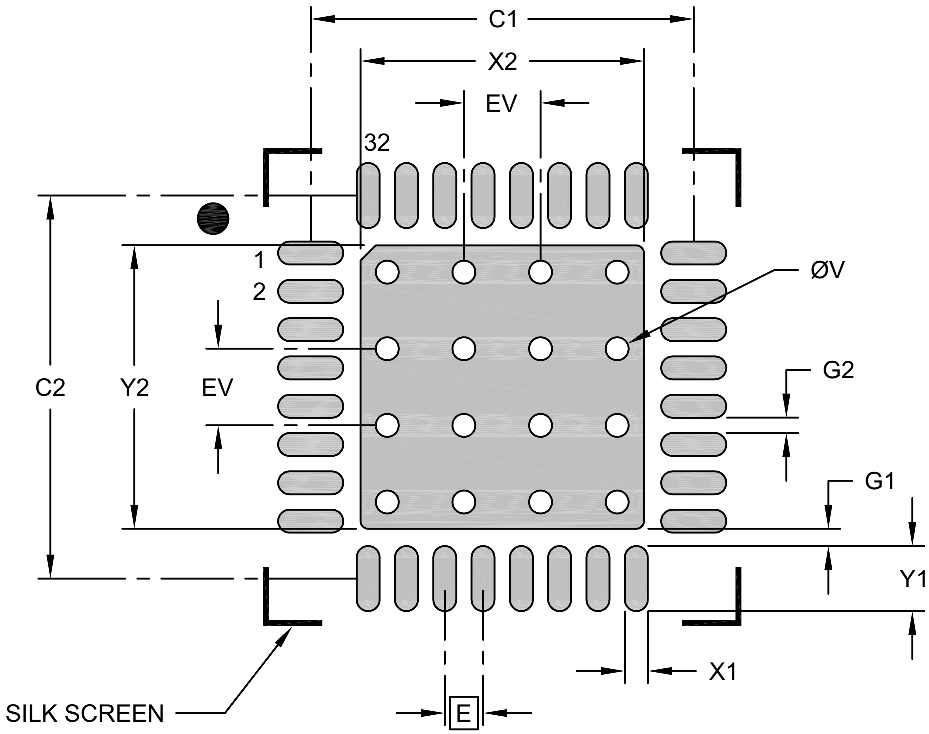
Notes:

1. Pin 1 visual index feature may vary, but must be located within the hatched area.
2. Package is saw singulated
3. Dimensioning and tolerancing per ASME Y14.5M
   BSC: Basic Dimension. Theoretically exact value shown without tolerances.
   REF: Reference Dimension, usually without tolerance, for information purposes only.

Microchip Technology Drawing C04-21402 Rev A Sheet 1 of 2

32-Lead Very Thin Plastic Quad Flat, No Lead Package (S8B) - 5x5 mm Body [VQFN] With 3.60 mm Exposed Pad; Atmel Legacy Global Package Code ZKV

Note:	For the most current package drawings, please see the Microchip Packaging Specification located at http://www.microchip.com/packaging



RECOMMENDED LAND PATTERN

Units		MILLIMETERS		
Dimension Limits		MIN	NOM	MAX
Contact Pitch	E		0.50 BSC	
Optional Center Pad Width	X2			3.70
Optional Center Pad Length	Y2			3.70
Contact Pad Spacing	C1		5.00	
Contact Pad Spacing	C2		5.00	
Contact Pad Width (X32)	X1			0.30
Contact Pad Length (X32)	Y1			0.85
Contact Pad to Center Pad (X32)	G1	0.23		
Contact Pad to Contact Pad (X28)	G2	0.20		
Thermal Via Diameter	V		0.30	
Thermal Via Pitch	EV		1.00	

Notes:

1. Dimensioning and tolerancing per ASME Y14.5M
   BSC: Basic Dimension. Theoretically exact value shown without tolerances.
2. For best soldering results, thermal vias, if used, should be filled or tented to avoid solder loss during reflow process

Microchip Technology Drawing C04-23402 Rev A

NOTES:

APPENDIX A: REVISION HISTORY

Revision D (June 2025)

Following are the changes made in this revision:

- Updated all application drawings throughout the document.
- Updated **Electrical Characteristics** table.
- Updated **Section 5.1 "Package Marking Information"**.
- Several minor improvements to text formatting, parameter symbols and figures.
- Updated ***Trademark***, ***Legal Notice*** and ***Microchip Devices Code Protection Feature*** information. For details, refer to the **Microchip Information** page.
- Removed **Worldwide Sales and Service** page.

Revision C (June 2023)

Following are the changes made in this revision:

- Updated **General Description**.
- Updated **Section 5.0 "Packaging Information"**.
- Updated **Product Identification System**.

Revision B (October 2021)

Following are the changes made in this revision:

- Updated the V_{BAT} value in the **Section 1.1 "Absolute Maximum Ratings(†)"** section.
- Added the IRCAP Voltage entry in **Section 1.2 "Electrical Specifications"**.
- Updated Figure 3-1.
- Updated the Operating Temperature Range in **Section 1.2 "Electrical Specifications"**.

Revision A (September 2021)

- Initial release of this document.

NOTES:

PRODUCT IDENTIFICATION SYSTEM

To order or obtain information, e.g., on pricing or delivery, refer to the factory or the listed sales office.

PART NO.	VXX	[X][(1)]
Device	Package	Tape and Reel Option

Device:	RE46C420:	Photoelectric Smoke Detector Companion IC
	RE46C421:	Photoelectric Smoke Detector Companion IC
	RE46C422:	Photoelectric Smoke Detector Companion IC
Package:	V28 =	Very Thin Plastic Quad Flat, No Lead (STX), 4 x 4 mm body, 28-Lead VQFN (RE46C420 and RE46C421 only)
	V32 =	Very Thin Plastic Quad Flat, No Lead (S8B), 5 x 5 mm body, 32-Lead VQFN (RE46C422 only)
Tape and Reel Option:	T =	Tape and Reel[(1)]

Note 1: Tape and Reel identifier only appears in the catalog part number description. This identifier is used for ordering purposes and is not printed on the device package. Check with your Microchip Sales Office for package availability with the Tape and Reel option.

Examples:

a) RE46C420V28T = Photoelectric Smoke Detector Companion IC, 28-Lead VQFN, Tape and Reel

a) RE46C421V28T = Photoelectric Smoke Detector Companion IC, 28-Lead QFN, Tape and Reel

a) RE46C422V32 = Photoelectric Smoke Detector Companion IC, 32-Lead VQFN

a) RE46C422V32T = Photoelectric Smoke Detector Companion IC, 32-Lead VQFN, Tape and Reel

NOTES:

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