Integrated Analog Front-End for Heart Rate Monitors and Low-Cost Pulse Oximeters

FEATURES

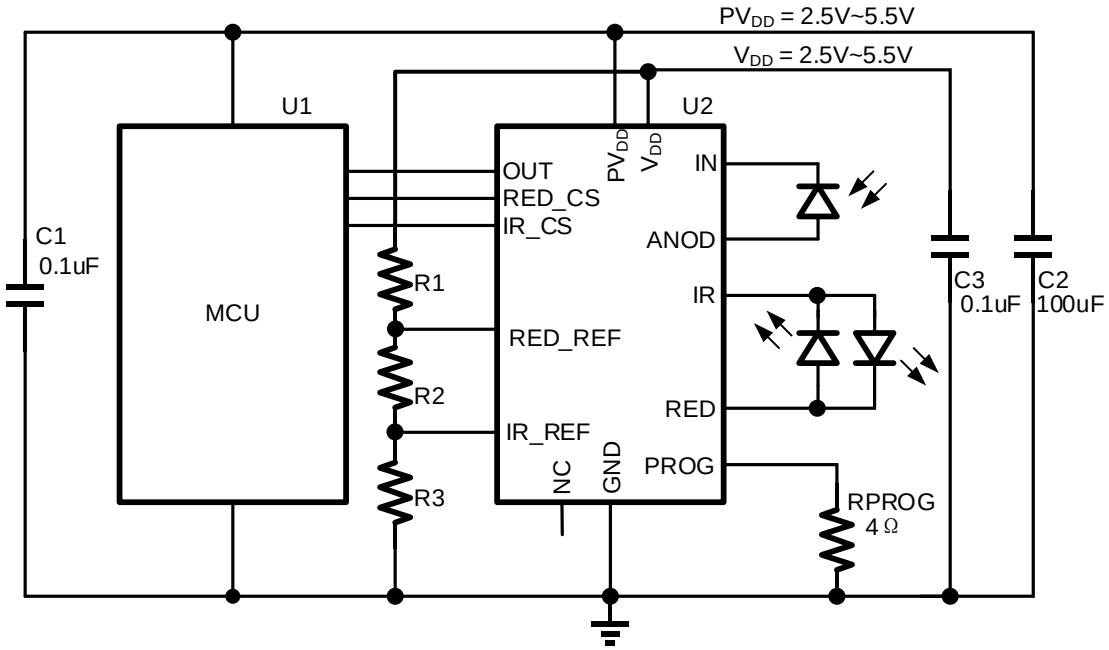
- **Fully-Integrated Analog Front-End for Pulse Oximeter Applications**
- **Receiver:**
  High Accuracy Current to Frequency Converter up to 500kHz
- **Transmitter:**
  Flexible Pulse Sequencing and Timing Control with Integrated LED Driver (H-Bridge)
  95dB Dynamic Range
  LED Currents Programmable with an External Resistor and Analog Input Voltages
- **Power Supplies: 2.5V to 5.5V**
  Low Power: 1.25mA at 3.3V Supply
- **Specified Temperature Range: -40℃ to +85℃**
- **Package: QFNWB3×3-16L**

APPLICATIONS

- **Low-Cost Medical Pulse Oximeter Applications**
- **Optical HRM**

PRODUCT DESCRIPTION

The TS9514 is a fully-integrated analog front-end (AFE) that is ideally suited for pulse oximeter applications. The device consists of a low-noise I/F converter and a LED transmitter section. The I/F converter converts photodiode current to frequency signal. The LED transmitter currents can be easily controlled through analog input voltages. The TS9514's flexibility allows users to have complete control of the device's timing characteristics. The TS9514 is an AFE solution in QFNWB3×3-16L package and is specified over the operating temperature from -40℃ to +85℃.



ORDERING INFORMATION

Product	Package	Package Option	Package Qty	Operating Temperature Range
TS9514EQR	QFNWB3×3-16L	Tape and Reel	5000	-40˚C to +85˚C

ABSOLUTE MAXIMUM RATINGS

Over operating free-air temperature range (unless otherwise noted) (1)

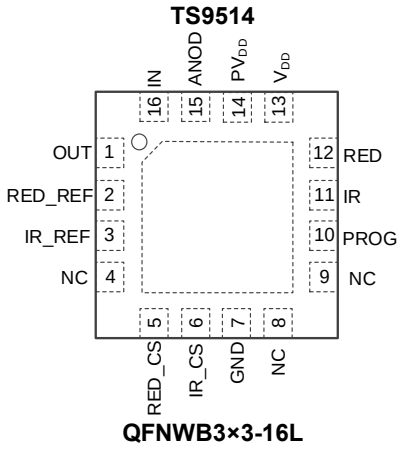
Parameter		Value	Unit
V_{DD} to GND		2.5 to 5.5	V
Input Current to Any Pin except Supply Pins		±10	mA
Input Current	Momentary	±50	mA
	Continuous	±10	mA
Operating Temperature Range		–40 to +85	˚C
Storage Temperature Range		–65 to +150	˚C
Maximum Junction Temperature, TJ		+125	˚C
Electrostatic Discharge (ESD) Ratings	Human Body Model (HBM)	±2000	V
	Machine Model (MM)	±200	V
	Charge Device Model (CDM)	±500	V

(1) Stresses beyond those listed under “Absolute 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 beyond those indicated in the operational sections of this specification is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

ESD CAUTION

ESD (electrostatic discharge) sensitive device. Charged devices and circuit boards can discharge without detection. Although this product features patented or proprietary protection circuitry, damage may occur on devices subjects to high energy ESD. Therefore, proper ESD precautions should be taken to avoid performance degradation or loss of functionality.

PIN CONFIGURATION



QFNWB3×3-16L

Table 1. PIN DESCRIPTIONS

NO.	Name	Function	Description
1	OUT	Output	Frequency Output
2	RED_REF	Input	RED LED Driver Reference Voltage Input
3	IR_REF	Input	IR LED Driver Reference Voltage Input
4,8,9	NC	Input	No Connection Pin
5	RED_CS	Input	RED LED Control Input. High Active
6	IR_CS	Input	IR LED Control Input. High Active
7	GND	Supply	Supply Ground Pin
10	PROG	I/O	LED driver current program pin, connect a resistor to this pin.
12	RED	Output	RED LED Drive Output
11	IR	Output	IR LED Drive Output
14	PV_{DD}	Supply	LED Driver Power Supply Pin
13	V_{DD}	Supply	Power Supply Pin
15	ANOD	Input	Current Input, Connect to PIN Diode Anode
16	IN	Input	Current Input, Connect to PIN Diode Cathode

ELECTRICAL CHARACTERISTICS

Minimum and maximum specification are at **T_A = -40℃ to +85℃**. Typical specifications are at +25℃.
All specifications are at V_{DD} = 3.3V (unless otherwise noticed)

Parameter		Test Conditions	Min	Typ	Max	Unit
Performance (Full-Signal Chain)						
V_{DD}	Receiver Supply Voltage	T_A = 0℃ to +85℃ **T_A = -40℃ to +85℃**	2.5 **2.7**		5.5 **5.5**	V **V**
PV_{DD}	LED Driver Supply Voltage (2)		2.5		5.5	V
I_{DD}	Supply Current	T_A = 25℃, V_{DD} = 5.5V		1.25	1.7	mA
PRF	Pulse Repetition Frequency				1000	SPS
I-F Transimpedance Amplifier						
f_O	Output Frequency	I_{IN} = 1uA		100		kHz
	Full-Scale Frequency		500		1000	kHz
	Nonlinearity	f_O = 0 to 100kHz		±1%		%FS
R_e	Current Responsivity			100		kHz/μA
PSRR	Power-Supply Rejection Ratio	f_O = 100kHz		0.3		%/V
Transmitter						
	Full-Scale Output Current (2)	T_A = 25℃, V_{DD} = 5V, R_{PROG} = 4Ω; $V_{CONTROL}$ = 0.8V		200		mA
$V_{CONTROL}$	Analog Input Voltage		0		V_{DD} - 2	V
	Output Current Offset	V_{DD} = 5V, R_{PROG} = 4Ω		0.25	1.25	mA
	Transmitter Noise Dynamic Range, Over 0.1Hz to 5Hz Bandwidth	At 5mA Output Current		TBD		dB
		At 25mA Output Current		TBD		dB
		At 50mA Output Current		TBD		dB
	Minimum on Time of LEDs			50		μs
	LED Current Linearity vs Analog Input Voltage	Percent of Full-Scale Current		1%		
	Output Current Settling Time	From 0 to 50mA		TBD		μs
		From 50mA to 0		TBD		μs
Temperature						
	Specified Temperature Range		-40		+85	℃
	Storage Temperature Range		-65		+150	℃

(2) The Maximum LED output current depends on PV_{DD}, R_{PROG} resistance and LED forward voltage strongly; it can be smaller than the full-scale current.

OVERVIEW

The TS9514 is a complete analog front-end (AFE) circuit targeting pulse oximeter applications. The device consists of a low-noise I/F converter and a LED transmitter section. The I/F converter converts the photodiode current to frequency signal precisely. The output of the device connects directly to a high resolution timer of the external microcontroller (MCU) for which an A/D converter is not necessary. The LED transmitter current can be adjusted through analog input voltages.

RECEIVER

The receiver consists of a high precision current-to-frequency (I/F) converter section. The I/F converter converts the photodiode current to frequency signal with high dynamic range and linearity. The converter continuously converts input current to frequency without being interrupted by the LED control signals.

TRANSMITTER SECTION

The transmitter section integrates a voltage controlled constant current source, an H-bridge LED driver and its control logic. Two LED driver schemes are supported: an H-bridge drive for a two-terminal back-to-back LED package and a push-pull drive for a three-terminal LED package. The on-off of the LED current is controlled by logic signals at the input pins of RED_CS and IR_CS, and each LED current can be adjusted by the corresponding analog input voltage independently. An external resistor R_{PROG} at the PROG pin sets the ratio of the input voltage to the LED current and the maximum output current is primarily dependent on R_{PROG}, the power supply voltage PV_{DD}, and the forward voltage of the LEDs.

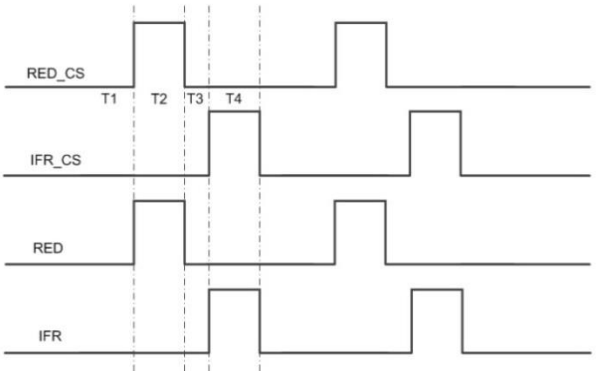


Figure 1. Timing of LED Control.

LED CURRENT CONTROL

The output currents of the transmitter are controlled by the analog input voltages and are given by the following equation:

$$I_{LED} = \frac{V_{REF}}{R_{PROG}}$$

where V_{REF} is the voltage at RED_REF or IR_REF pin. The voltages at RED_REF pin and IR_REF pin control the RED LED current and IR LED current respectively and independently.

TIMING DIAGRAM OF THE TRANSMITTER

Figure 1 shows the timing diagram for the LED transmitter control. Through the internal logic, signals at the RED_CS and IR_CS pins control the switches of the H-Bridge. In T1 and T3 cycles, both LEDs are turned off. In T2 and T4 cycles, RED LED and IR LED are turned on respectively. Both of the RED_CS and IR_CS pins are active ‘high’, however, when both are high at the same time, there will be no current flow through the two-terminal back-to-back packaged LEDs (see Table 2 and Table 3).

Table 2. Transmitter True Table (Two-Terminal Back-to-Back Packaged LEDs)

Inputs		Outputs			
RED_CS	IR_CS	RED	IR	RED Transmit	IR Transmit
0	0	Z	Z	OFF	OFF
1	0	H	L	ON	OFF
0	1	L	H	OFF	ON
1	1	H	H	OFF	OFF

Table 3. Timing Requirements

Parameter		Min	Typ	Max	Unit
t_{RED_CS}	Red LED on Time, Active High	50			μs
t_{IR_CS}	Infrared LED on Time, Active High	50			μs
t_{INT}	The Time Interval between Red LED on and IR LED on	50			μs

APPLICATION EXAMPLES

Figure 2 show the typical application circuit of TS9514 as an analog front-end for Pulse Oximeters. Please note that the pins of RED and IR and pins of V_{DD} and PV_{DD} are interchanged between the two packages.

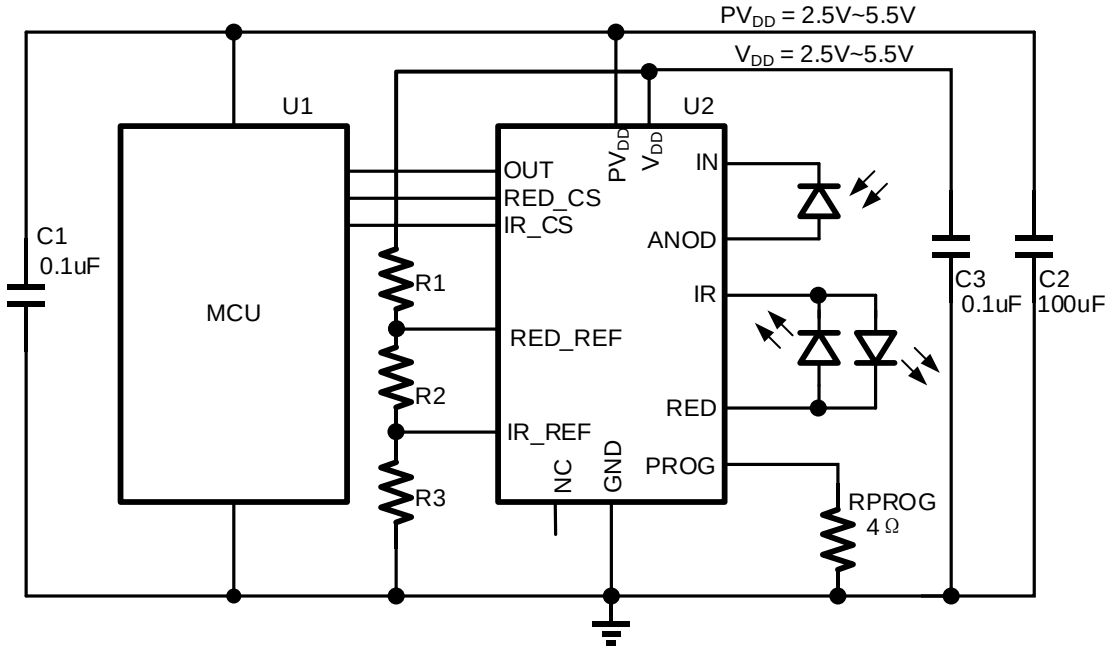
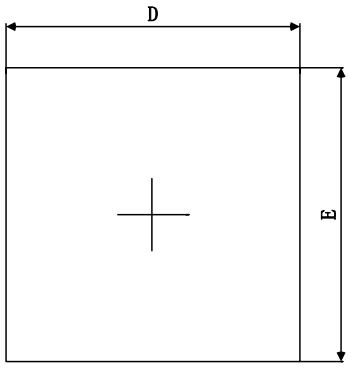


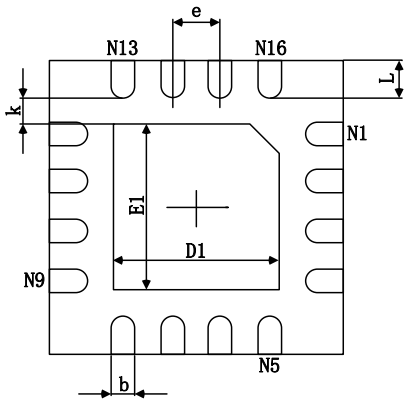
Figure 2. Typical Application of TS9514

MECHANICAL DIMENSIONS

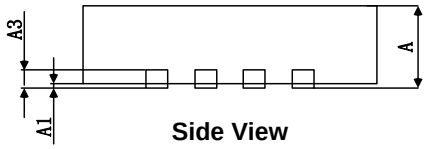
QFNWB3×3-16L PACKAGE MECHANICAL DRAWING



TOP View



Bottom View



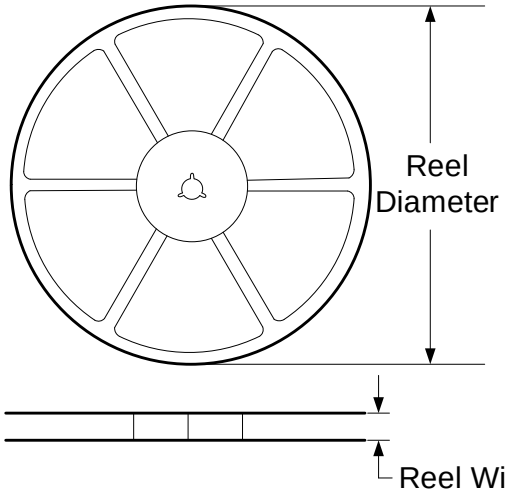
Side View

QFNWB3×3-16L PACKAGE MECHANICAL DATA

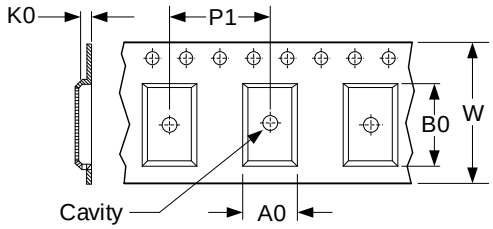
symbol	dimensions			
	millimeters		inches	
	min	max	min	max
A	0.700	0.800	0.028	0.031
A1	0	0.050	0	0.002
A3	0.203REF		0.008REF	
D	2.900	3.100	0.114	0.122
E	2.900	3.100	0.114	0.122
D1	1.600	1.800	0.063	0.071
E1	1.600	1.800	0.063	0.071
k	0.200MIN		0.008MIN	
b	0.180	0.300	0.007	0.012
e	0.500TYP		0.02TYP	
L	0.300	0.500	0.012	0.020

TAPE AND REEL INFORMATION

REEL DIMENSIONS

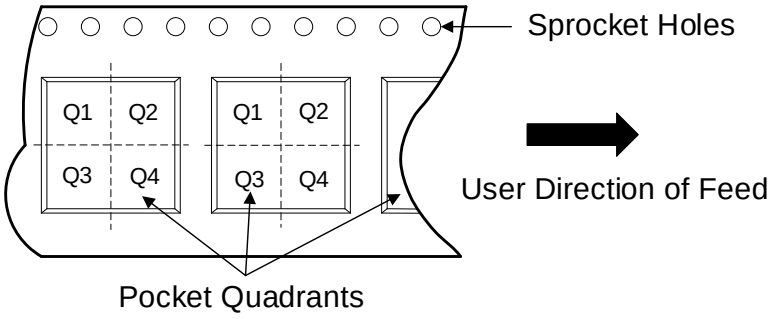


TAPE DIMENSIONS



A0	Dimensioon designed to accommodate the component width
B0	Dimensioon designed to accommodate the component length
K0	Dimensioon designed to accommodate the component width thickness
W	Overall width of the carrier tape
P1	Pitch between successive cavity centers

QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE



Device	Package Type	Pins	SPQ	Reel Diameter (mm)	Reel Width W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P1 (mm)	W (mm)	Pin1 Quadrant
TS9514EQRQFNWB3316LR	QFNWB3×3-16L	16	5000	330.0	12.4	6.4	5.4	2.1	8.0	12.0	Q1

REVISION HISTORY

NOTE: Page numbers for previous revisions may be different from that of the current version.

2020/6/18 — REV KY1.0.4 to REV KY1.0.5

Changes Figure 2……7
Changes Figure 3……7

2020/8/21 — REV KY1.0.5 to REV KY1.1.5

Changed to Figure 2……1
Deleted Figure 3……7

2020/11/23 — REV KY1.1.5 to REV KY1.1.6

Deleted package TSSOP16……12

2022/5/9 — REV KY1.1.6 to REV KY1.2.6

Changed to QFNWB3×3-16L PACKAGE MECHANICAL DATA……8

CONTACT INFORMATION

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