

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

### Features

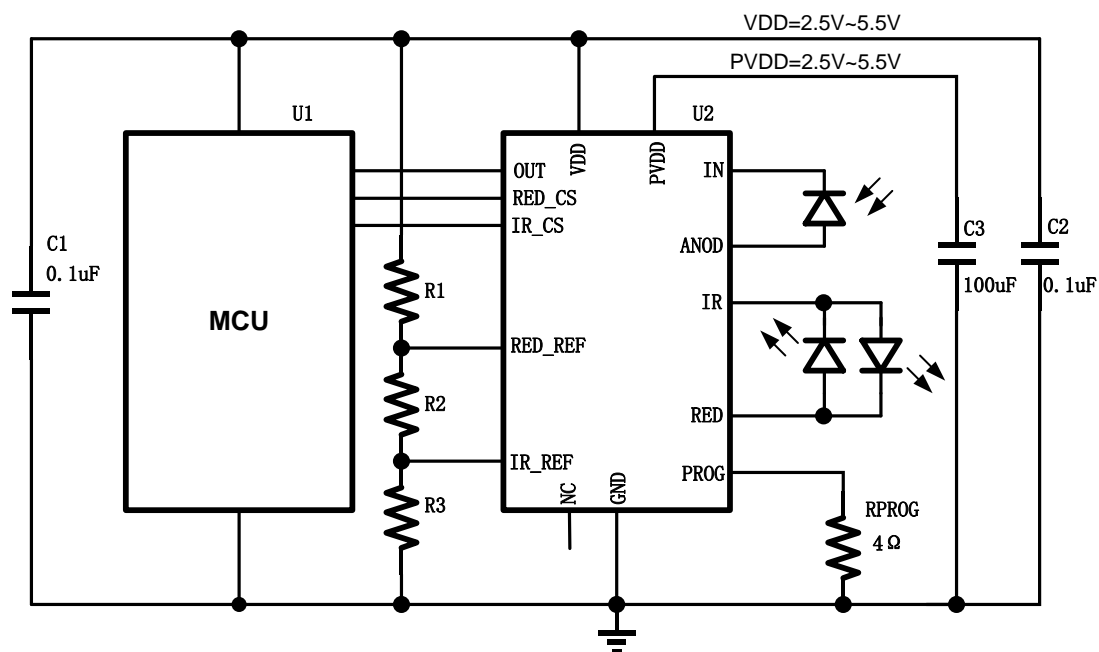
- **Fully-Integrated Analog Front-End for Pulse Oximeter Applications**
- **Receiver:**  
High Accuracy Current to Frequency Converter up to 500KHz
- **Transmitter:**  
Flexible Pulse Sequencing and Timing Control with Integrated LED Driver (H-Bridge)  
95dB Dynamic Range  
LED Currents Programmable with an External Resistor and Analog Input Voltages
- **Power Supplies: 2.5V to 5.5V**  
Low Power: 1.25 mA at 3.3V Supply
- **Specified Temperature Range: -40°C to +85°C**
- **Package: TSSOP14, QFN16**

### 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 TSSOP14 and QFN16 packages and is specified over the operating temperature from -40°C to +85°C.



## Ordering Information

Product	Package-Lead	Package Option	Package Qty.	Operating Temperature Range
TS9514EQR	QFN16	Tape and Reel	2500	-40°C to +85°C
TS9514ETR	TSSOP14	Tape and Reel	2500	-40°C to +85°C

## Absolute Maximum Ratings

Over operating free-air temperature range, unless otherwise noted.

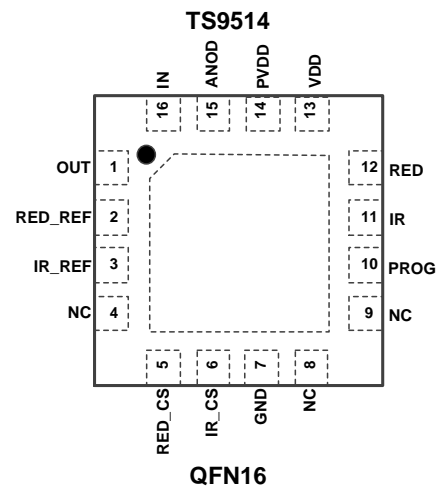
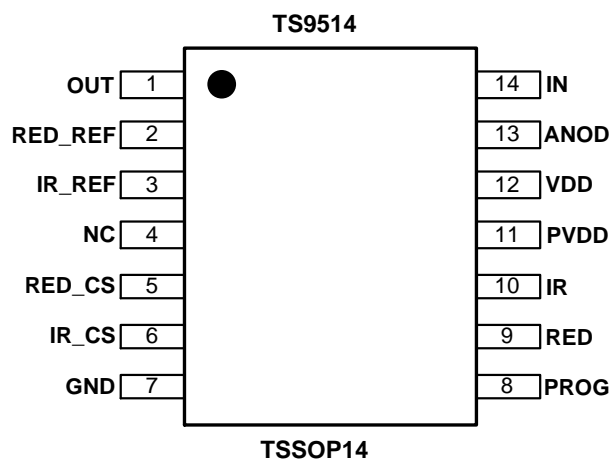
		Value	Unit
VDD to GND		2.5 to 5.5	V
Input current to any pin except supply pins		±10	mA
Input current	Momentary	±50	mA
	Continuous	±10	mA
Operating temperature range		-40 to +85	°C
Storage temperature range		-65 to +150	°C
Maximum junction temperature, T <sub>J</sub>		+125	°C
Electrostatic discharge (ESD) ratings	Human body model (HBM)	±2000	V
	Machine model (MM)	±200	V
	Charge device model (CDM)	±500	V

## 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



**Table 1. PIN Descriptions**

NO. (TSSOP14)	NO. (QFN16)	Name	Function	Description
1	1	OUT	Output	Frequency output
2	2	RED_REF	Input	RED LED driver reference voltage input
3	3	IR_REF	Input	IR LED driver reference voltage input
4	4,8,9	NC	Input	No connection pin
5	5	RED_CS	Input	RED LED control input. High active
6	6	IR_CS	Input	IR LED Control Input. High active
7	7	GND	Supply	Supply ground pin
8	10	PROG	I/O	LED driver current program pin, connect a resistor to this Pin
9	12	RED	Output	RED LED drive output
10	11	IR	Output	IR LED drive output
11	14	PVDD	Supply	LED driver power supply pin
12	13	VDD	Supply	Power supply pin
13	15	ANOD	Input	Current input, connect to PIN diode anode
14	16	IN	Input	Current input, connect to PIN diode cathode

## Electrical Characteristics

Minimum and maximum specification are at  $T_A = -40^\circ\text{C}$  to  $+85^\circ\text{C}$ . Typical specifications are at  $+25^\circ\text{C}$ .

All specifications are at  $V_{DD} = 3.3\text{V}$ , unless otherwise noticed.

Parameter	Test Conditions	Min	Typ	Max	Unit
<b>Performance (Full-Signal Chain)</b>					
$V_{DD}$	Receiver supply voltage	$0^\circ\text{C}$ to $+85^\circ\text{C}$	2.5	5.5	V
		$-40^\circ\text{C}$ to $+85^\circ\text{C}$	2.7	5.5	V
$PV_{DD}$	LED driver supply voltage <sup>1</sup>	2.5	5.5	V	
$I_{DD}$	Supply current	$T_A = 25^\circ\text{C}$ , $V_{DD} = 5.5\text{V}$		1.25	1.7
PRF	Pulse repetition frequency			1000	SPS
<b>I-F Transimpedance Amplifier</b>					
$f_o$	Output frequency	$I_{IN} = 1\mu\text{A}$	100		kHz
	Full-scale frequency		500	1000	kHz
	Nonlinearity	$f_o = 0$ to $100\text{kHz}$	$\pm 1\%$		%FS
$R_e$	Current responsivity		100		kHz/ $\mu\text{A}$
PSRR	Power-supply rejection ratio	$f_o = 100\text{kHz}$	0.3		%/V
<b>Transmitter</b>					
	Full-scale output current <sup>1</sup>	$T_A = 25^\circ\text{C}$ , $V_{DD} = 5\text{V}$ , $R_{PROG} = 4\Omega$ ; $V_{CONTROL} = 0.8\text{V}$		200	mA
$V_{CONTROL}$	Analog input voltage		0	$V_{DD} - 2$	V
	Output current offset	$V_{DD} = 5\text{V}$ , $R_{PROG} = 4\Omega$	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		$\mu\text{s}$
	LED current linearity vs analog input voltage	Percent of full-scale current	1%		
	Output current settling time	From 0 to 50 mA	TBD		$\mu\text{s}$
		From 50 mA to 0	TBD		$\mu\text{s}$
<b>Temperature</b>					
	Specified temperature range		-40	+85	$^\circ\text{C}$
	Storage temperature range		-65	+150	$^\circ\text{C}$

1. 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.

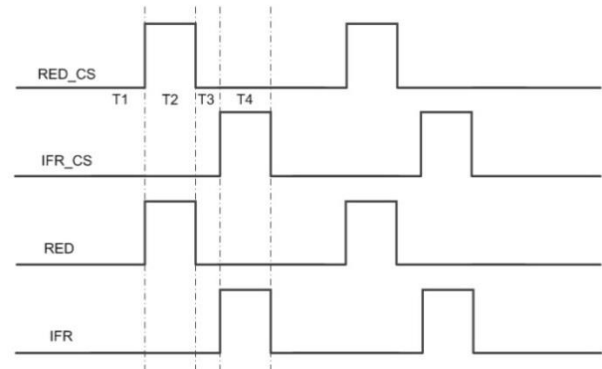


Figure 1. Timing of LED Control.

### 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			$\mu$ s
$t_{IR\_CS}$	Infrared LED on time, active high	50			$\mu$ s
$t_{INT}$	The time interval between Red LED on and IR LED on	50			$\mu$ s

**Application Examples**

Figure 2 and Figure 3 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 VDD and PVDD are interchanged between the two packages.

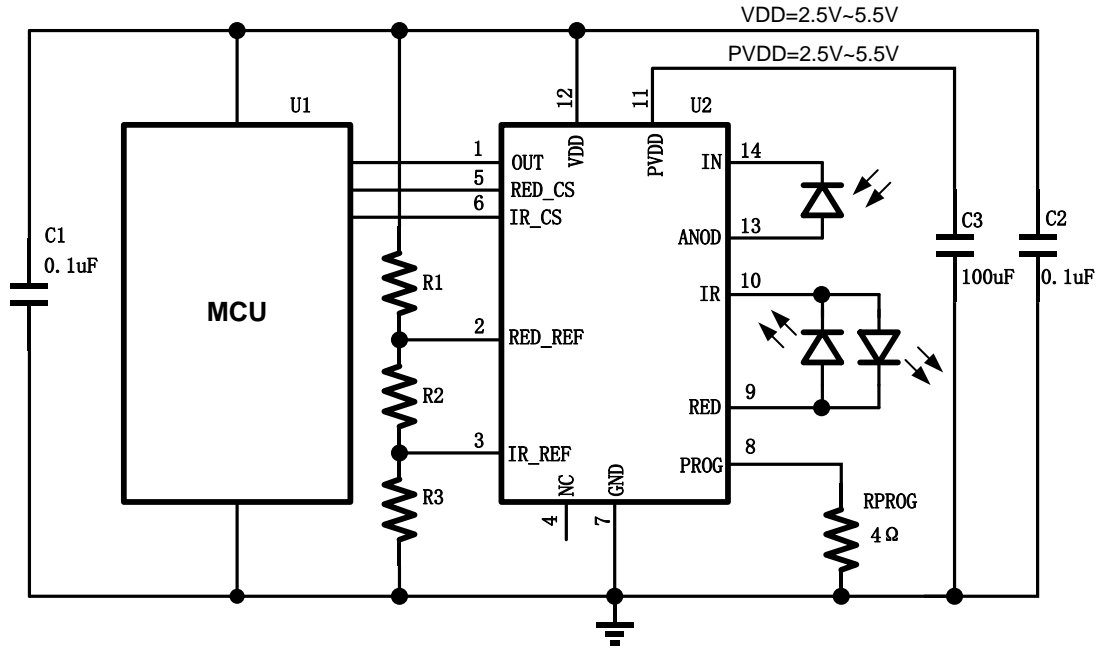


Figure 2. Typical Application of TS9514 in TSSOP14 Package.

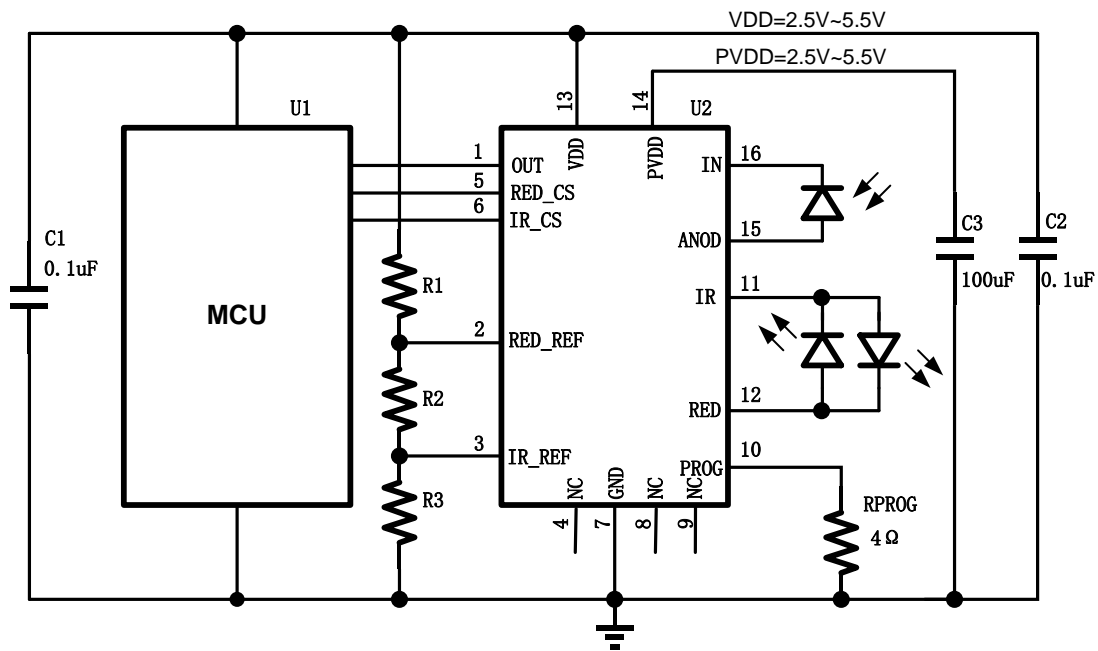
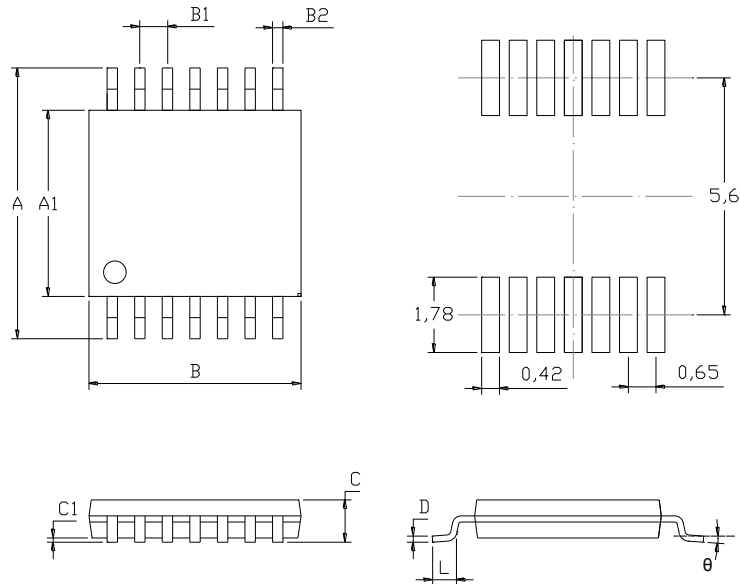


Figure 3. Typical Application of TS9514 in QFN16 Package.

**Mechanical Dimensions**

**TSSOP-14 PACKAGE MECHANICAL DRAWING**

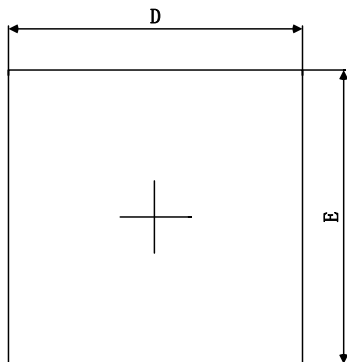


**TSSOP-14 PACKAGE MECHANICAL DATA**

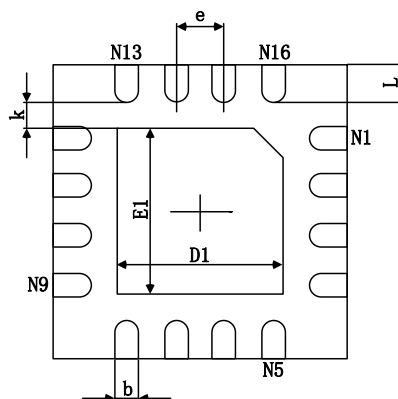
symbol	dimensions			
	millimeters		inches	
	min	max	min	max
A	6.2	6.6	0.2441	0.2598
A1	4.3	4.5	0.1693	0.1772
B	4.9	5.1	0.1929	0.2008
B1	0.65		0.0256	
B2	0.19	0.3	0.0075	0.0118
C	1.20MAX		0.0472MAX	
C1	0.05	0.15	0.0020	0.0059
L	0.5	0.75	0.0197	0.0295
D	0.1	0.2	0.0039	0.0079
θ	0°	8°	0°	8°



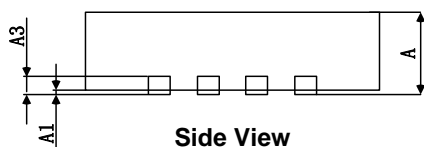
**QFN-16 PACKAGE MECHANICAL DRAWING**



**TOP View**



**Bottom View**



**Side View**

**QFN-16 PACKAGE MECHANICAL DATA**

symbol	dimensions			
	millimeters		inches	
	min	max	min	max
A	0.700/0.800	0.800/0.900	0.028/0.031	0.031/0.035
A1	0.000	0.050	0.000	0.002
A3	0.203REF.		0.008REF.	
D	2.924	3.076	0.115	0.121
E	2.924	3.076	0.115	0.121
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	0.280	0.007	0.011
e	0.500TYP.		0.020TYP.	
L	0.324	0.476	0.013	0.019

## **CONTACT INFORMATION**

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