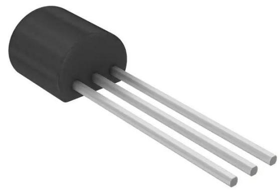
LM35

High-precision Celsius temperature sensor

General Description



TO92

The LM35 series are precision integrated-circuit temperature devices with an output voltage linearly proportional to the Centigrade temperature. The LM35 device has an advantage over linear temperature sensors calibrated in Kelvin, as the user is not required to subtract a large constant voltage from the output to obtain convenient Centigrade scaling. The LM35 device does not require any external calibration or trimming to provide typical accuracies of ±0.5℃ at room temperature and ±1.5℃ over a full -40℃ to 125℃ temperature range. Lower cost is assured by trimming and calibration at the wafer level. The low-output impedance, linear output, and precise inherent calibration of the LM35 device makes interfacing to readout or control circuitry especially easy. The device is used with single power supplies, or with plus and minus supplies. As the LM35 device draws only 60 µA from the supply, it has very low self-heating of less than 0.1°C in still air.

The LM35 device is available in TO92 packaging.

Features

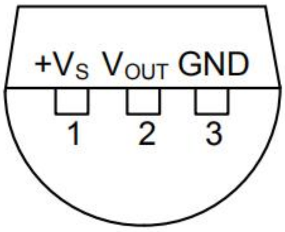
- Calibrated Directly in Celsius (Centigrade)
- Linear + 10 mV / °C Scaling Factor
- 0.5°C Ensured Accuracy (at 25°C)
- Rated temperature ranges from -40°C to 125°C
- Suitable for Remote Applications
- Low-Cost Due to Wafer-Level Trimming
- Operates From 4 V to 30 V
- Less Than 60-µA Current Drain
- Low Self-Heating, 0.08°C in Still Air
- Low-Impedance Output, 0.1 Ω for 1-mA Load

Package Information

Part NO.	Order NO.	Package Description	Package Marking	Package Option
LM35	LM35	TO92	SXXXX LM35 XZ	1000/Bag 2000/Tape

LM35:Part NO. “X”refer to C or D SXXXX:Lot NO.

Pin Connection



LM35X(TO92)

(Bottom View)

Pin Functions

PIN		TYPE	DESCRIPTION
NAME	TO92		
V_{OUT}	2	O	Temperature Sensor Analog Output
GND	3	GROUND	Device ground pin, connect to power supply negative terminal
$+V_S$	1	POWER	Positive power supply pin

Applications

- Power Supplies
- Battery Management
- HVAC
- Electrical Equipment

Absolute Maximum Ratings

（over operating free-air temperature range (unless otherwise noted)[(1)]）

		MIN	MAX	UNIT
Supply voltage		–0.2	35	V
Output voltage		–1	6	V
Output current			10	mA
Maximum Junction Temperature, $T_J$max			150	°C
Storage Temperature, Tstg	TO92	–60	150	°C

(1)Absolute Maximum Ratings indicate limits beyond which damage to the device may occur. DC and AC electrical specifications do not apply when operating the device beyond its rated operating conditions.

ESD Ratings

			VALUE	UNIT
$V_{(ESD)}$	Electrostatic discharge	Human-body model (HBM)	±2500	V

Recommended Operating Conditions

over operating free-air temperature range (unless otherwise noted)

		MIN	MAX	UNIT
Specified operating temperature: TMIN to TMAX	LM35C	-40	125	°C
	LM35D	0	100	°C
Supply Voltage (+V_S)		4	30	V

Electrical Characteristics:LM35C, LM35D Limits

Unless otherwise noted, these specifications apply: −40°C ≤ T_J ≤ 125°C for the LM35C; and 0°C ≤ T_J ≤ 100°C for the LM35D. V_S = 5Vdc and I_{LOAD} = 50 µA, in the circuit of Full-Range Centigrade Temperature Sensor. These specifications also apply from 2°C to T_{MAX} in the circuit of Figure 1.

PARAMETER	TEST CONDITIONS	LM35C, LM35D			UNIT
		TYP	TESTED LIMIT(1)	DESIGN LIMIT(2)	
Accuracy,LM35C(3)	T_A = 25°C	±0.4	±1		°C
	T_A = –10°C	±0.5		±1.5	
	$T_A = T_{MAX}$	±0.8		±1.5	
	$T_A = T_{MIN}$	±0.8		±2	
Accuracy, LM35D (3)	T_A = 25°C	±0.6	±1.5		°C
	$T_A = T_{MAX}$	±0.9		±2	
	$T_A = T_{MIN}$	±0.9		±2	
Nonlinearity(4)	$T_{MIN} \le T_A \le T_{MAX}$, –40°C ≤ T_J ≤ 125°C	±0.2		±0.5	°C
Sensor gain (average slope)	$T_{MIN} \le T_A \le T_{MAX}$, –40°C ≤ T_J ≤ 125°C	10		9.8	mV/°C
		10		10.2	
Load regulation(5) 0 ≤ I_L ≤ 1 mA	T_A = 25°C	±0.4	±2		mV/mA
	$T_{MIN} \le T_A \le T_{MAX}$, –40°C ≤ T_J ≤ 125°C	±0.5		±5	
Line regulation(5)	T_A = 25°C	±0.01	±0.1		mV/V
	4 V ≤ V_S ≤ 30 V, –40°C ≤ T_J ≤ 125°C	±0.02		±0.2	
Quiescent current(6)	V_S = 5 V, 25°C	56	80		µA
	V_S = 5 V, –40°C ≤ T_J ≤ 125°C	91		138	
	V_S = 30 V, 25°C	56.2	82		
	V_S = 30 V, –40°C≤T_J ≤ 125°C	91.5		141	
Change of quiescent current(5)	4 V ≤ V_S ≤ 30 V, 25°C	0.2	2		µA
	4 V ≤ V_S ≤ 30 V, –40°C ≤ T_J ≤ 125°C	0.5		3	
Temperature coefficient of quiescent current	–40°C ≤ T_J ≤ 125°C	0.39		0.7	µA/°C
Minimum temperature for rate accuracy	In circuit of Figure 1, I_L = 0	1.5		2	°C
Long term stability	$T_J = T_{MAX}$, for 1000 hours	±0.08			°C

(1) Tested Limits are ensured and 100% tested in production.

(2) Design Limits are ensured (but not 100% production tested) over the indicated temperature and supply voltage ranges. These limits are not used to calculate outgoing quality levels.

(3) Accuracy is defined as the error between the output voltage and 10 mv/°C times the case temperature of the device, at specified conditions of voltage, current, and temperature (expressed in °C).

(4) Non-linearity is defined as the deviation of the output-voltage-versus-temperature curve from the best-fit straight line, over the rated temperature range of the device.

(5) Regulation is measured at constant junction temperature, using pulse testing with a low duty cycle. Changes in output due to heating effects can be computed by multiplying the internal dissipation by the thermal resistance.

(6) Quiescent current is defined in the circuit of Figure 1.

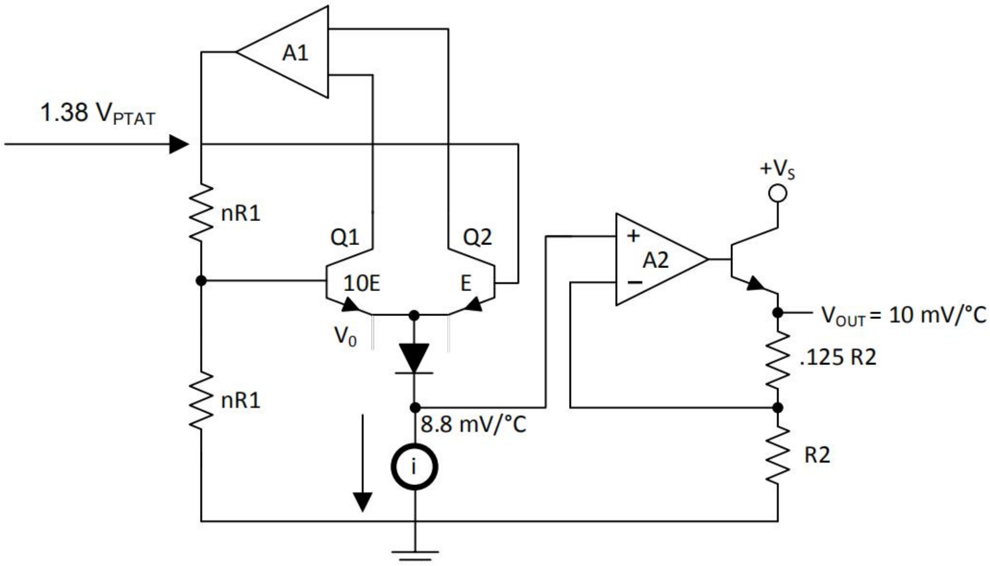
Detailed Description

Overview

The LM35-series devices are precision integrated-circuit temperature sensors, with an output voltage linearly proportional to the Centigrade temperature. The LM35 device has an advantage over linear temperature sensors calibrated in Kelvin, as the user is not required to subtract a large constant voltage from the output to obtain convenient Centigrade scaling. The LM35 device does not require any external calibration or trimming to provide typical accuracies of ± 0.5 °C at room temperature and ± 1.5 °C over a full temperature range.Lower cost is assured by trimming and calibration at the wafer level. The low output impedance, linear output, and precise inherent calibration of the LM35 device makes interfacing to readout or control circuitry especially easy. The device is used with single power supplies, or with plus and minus supplies. As the LM35 device draws only 60 µA from the supply, it has very low self-heating of less than 0.1°C in still air. The temperature-sensing element is comprised of a delta-V BE architecture.

The temperature-sensing element is then buffered by an amplifier and provided to the VOUT pin. The amplifier has a simple class A output stage with typical 0.5-Ω output impedance as shown in the Functional Block Diagram. Therefore the LM35 can only source current and it's sinking capability is limited to 1 µA.

Functional Block Diagram



Feature Description

LM35 Transfer Function

The accuracy specifications of the LM35 are given with respect to a simple linear transfer function:

VOUT = 10 mV/°C × T

where

- VOUT is the LM35 output voltage
- T is the temperature in °C (1)

Device Functional Modes

The only functional mode of the LM35 is that it has an analog output directly proportional to temperature.

Typical Application

Basic Centigrade Temperature Sensor

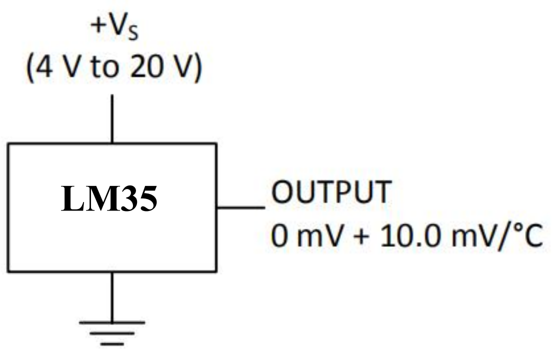


Figure 1. Basic Centigrade Temperature Sensor (2°C to 150 °C)

System Examples

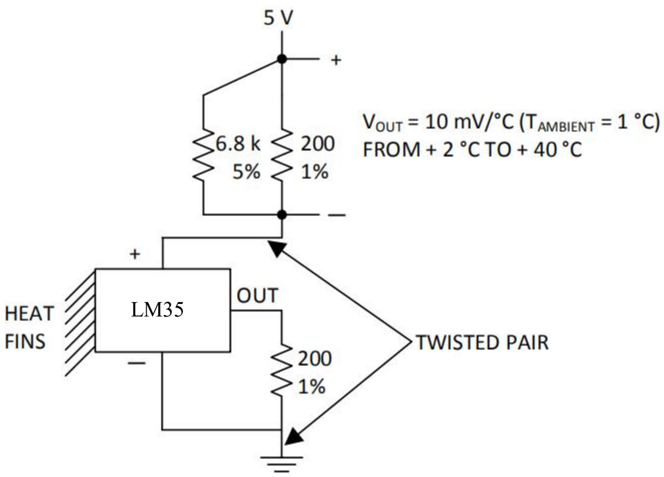


Figure 2. Two-Wire Remote Temperature Sensor
(Grounded Sensor)

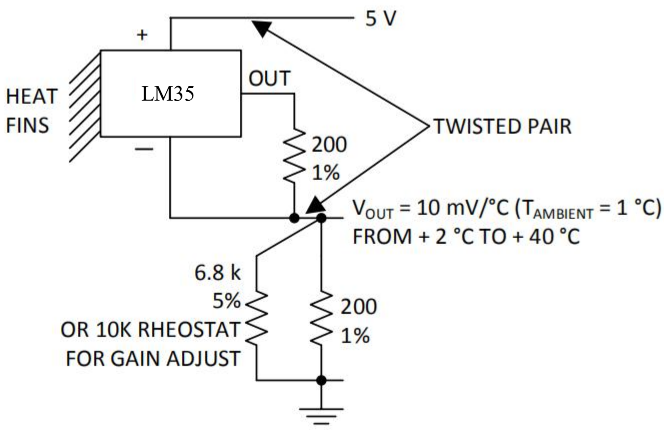


Figure 3. Two-Wire Remote Temperature Sensor
(Output Referred to Ground)

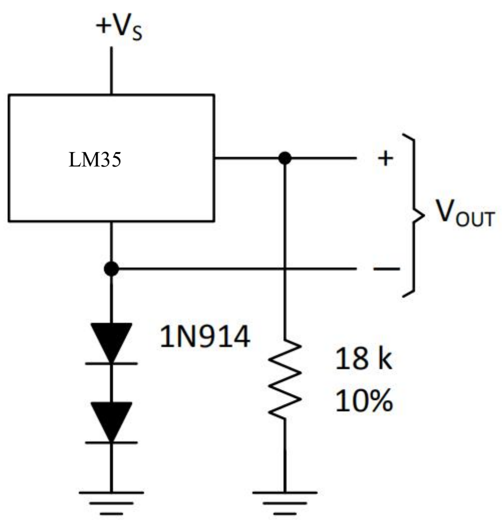


Figure 4. Temperature Sensor, Single Supply
(−40°C to +125°C)

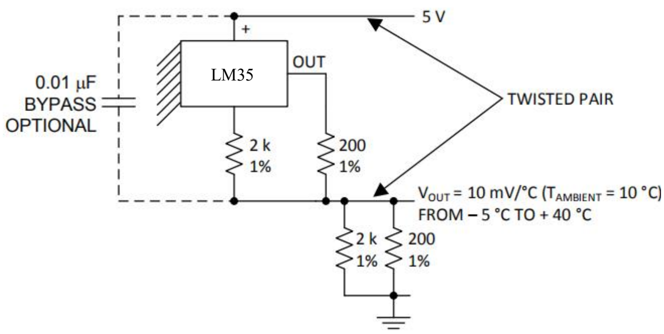


Figure 5. Two-Wire Remote Temperature Sensor
(Output Referred to Ground)

System Examples (continued)

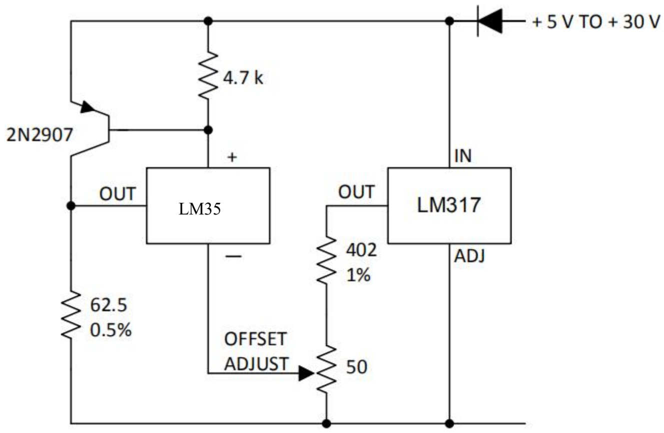


Figure 6. 4-To-20 mA Current Source

(0°C to 100°C)

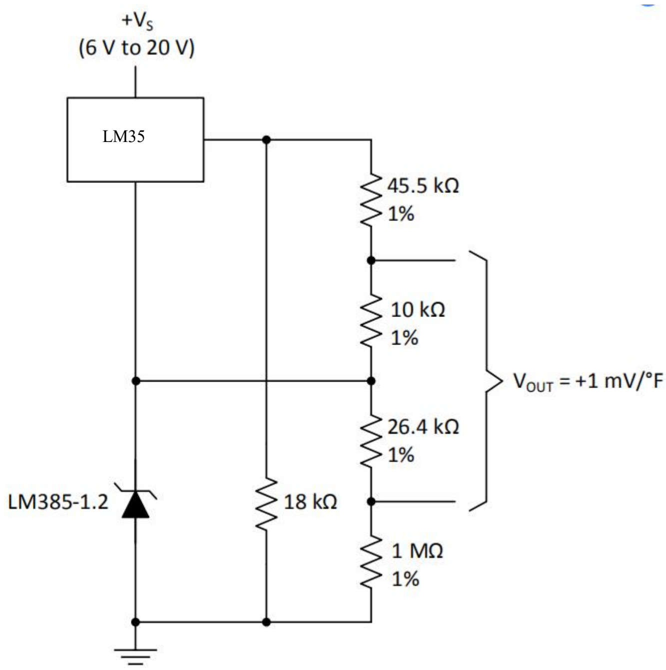


Figure7. Fahrenheit Thermometer

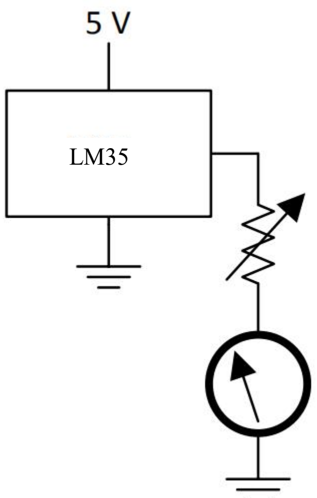


Figure 8. Centigrade Thermometer

(Analog Meter)

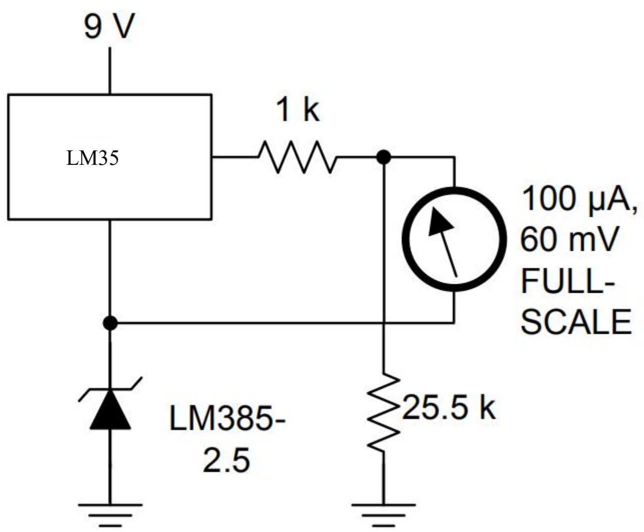


Figure 9. Fahrenheit Thermometer, Expanded Scale Thermometer

(50°F to 80°F, for Example Shown)

System Examples (continued)

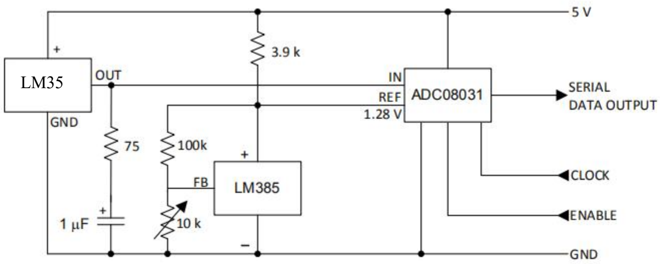


Figure 10. Temperature to Digital Converter

(Serial Output)

(128℃Full Scale)

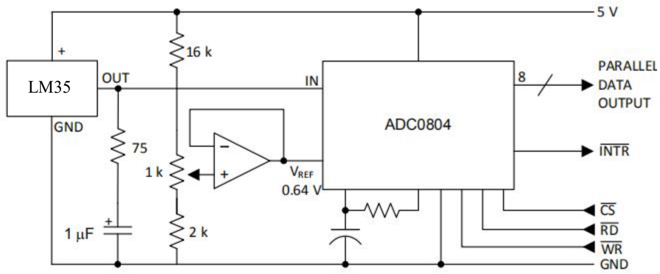
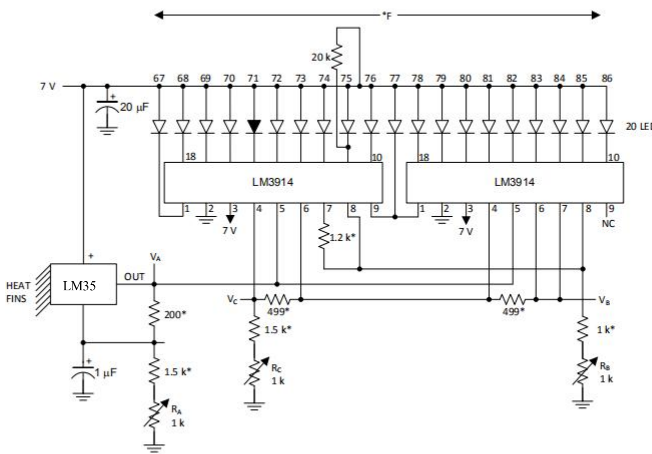


Figure 11. Temperature to Digital Converter

(Parallel TRI-STATE Outputs for Standard Data Bus

to µP Interface)

(128℃Full Scale)



*=1% or 2% film resistor

Trim RB for VB = 3.075 V

Trim RC for VC = 1.955 V

Trim RA for VA = 0.075 V + 100 mV/℃ ×Tambient

Example, VA = 2.275 V at 22℃

Figure 12. Bar-Graph Temperature Display

(Dot Mode)

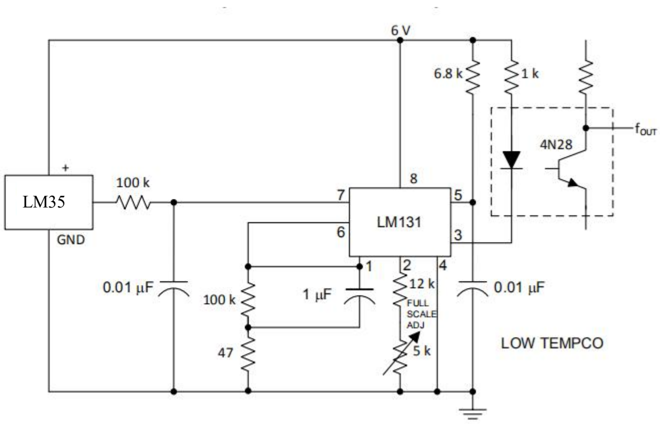


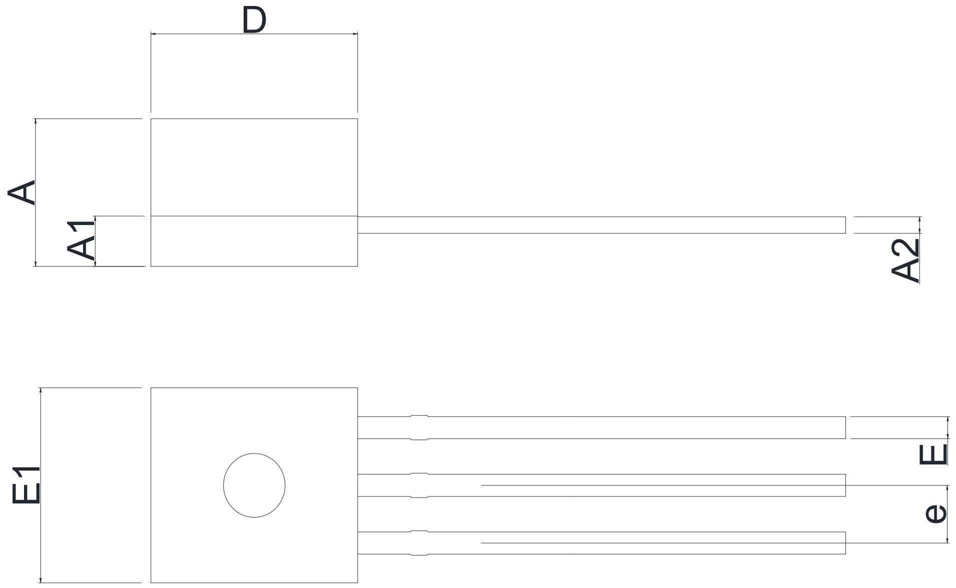
Figure 13. LM35 With Voltage-To-Frequency

Converter and Isolated Output

(2°C to 150°C; 20 to 1500 Hz)

Outline Dimensions

TO92



Symbol	Dimensions In Millimeters		Dimensions In Inches	
	Min	Max	Min	Max
A	3.300	3.700	0.130	0.146
A1	1.100	1.400	0.043	0.055
A2	0.280	0.510	0.011	0.020
D	4.300	4.700	0.169	0.185
E	0.360	0.560	0.014	0.022
E1	4.300	4.700	0.169	0.185
e	1.270（BSC）		0.050（BSC）	

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