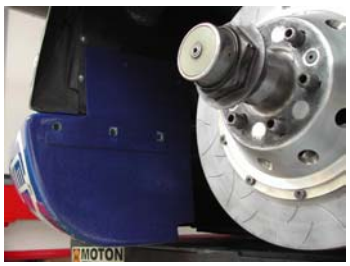
Automotive, Motor-sport, Industrial Infared (IR) thermometer for Remote Temperature Sensing

Features and Benefits

- Remote temperature measurement
- Fully linearized temperature signal
- Analog voltage output
- Factory calibrated
- Custom aperture heat-sink (optic)
- Composite automotive construction
- High impact injection molded automotive casing
- High accuracy thru wide temperature range
- 'PRO' spec – full functional test and re-test by hand on every module
- Features high performance 'MIL' spec PTFE shielded cable

Applications - Automotive

- Automotive Race Tire – remote sensing of tire surface compound temperature
- Open wheel, closed wheel race car or motorcycle applications
- On-board track (surface) temperature measurement

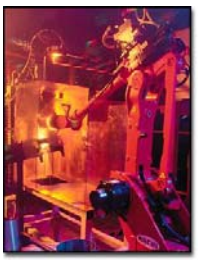


- Transmission system (Race and fluid type) temperature monitoring
- Sump (and Dry-sump) temperature monitoring
- Driver/passenger compartment (cockpit) temperature monitoring
- NOS (Nitrous Oxide – NO2) injection vapor spray instant manifold temperature compensation for horsepower maximization

Automotive, Motor-sport, Industrial Infared (IR) thermometer for Remote Temperature Sensing

Applications - Industrial

- Infared object temperature measurement in harsh environments
- Remote measurement of machine operation and over/under-temperature
- Monitoring of temperature critical processes (e.g. molding, cleaning, finishing etc.,)
- Applications where intermittent exposure to liquids is possible ('water resistant')
- Industrial Air-conditioning remote area/compartment temperature sensing


Industrial examples:

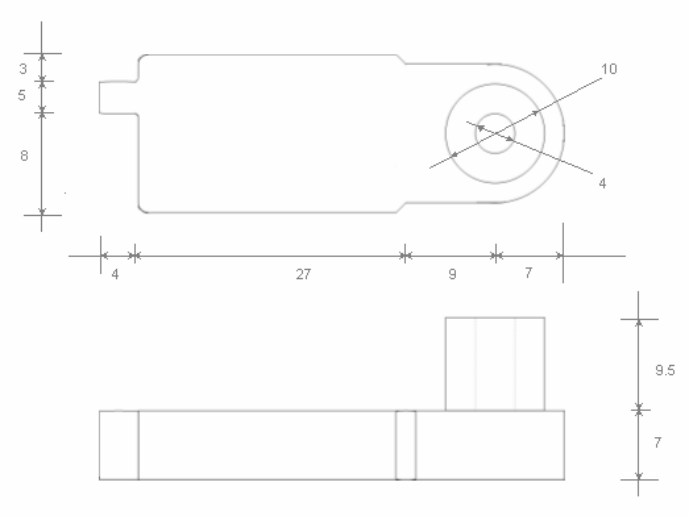
- Space heating - infared
- environmental/facilities monitoring
- paper and textile process control


- plastic molding (moulding) - process temperature monitoring



- Paint and coating oven bake control (infa-red surface temperature monitoring).
- Materials curing and setting – interval management
- Cool-down (annealing) time management

1 Mechanical Diagrams



Note 1: Leads 1m length as supplied: Supply, Ground, Signal.
Note 2: 'PRO' spec fitted with high performance 'MIL' spec PTFE shielded cable

2 Description

The modules are IR thermometer modules, which perform signal conditioning, linearization and ambient temperature compensation. The modules are built around an automotive qualified sensor interface, which uses high performance chopper stabilized amplifiers, providing excellent noise performance. The sensing element is an automotive qualified discrete IR thermopile sensor.
The automotive plastic casing is formed using automotive qualified processing to give a highly temperature stable module.
The modules are delivered factory calibrated. The output signal is 8bit analog voltage output based on 10bit internal process. All output signals are linear with the applied temperature.

The module features a flexible polyamide substrate, making the sensor highly robust for motor-racing, automotive and industrial applications.
The modules have been used successfully by several racing teams in the 2003 season – screen shots of the telemetry data acquired on a race car fitted with SolidStateRacing IR temperature sensors is shown below:

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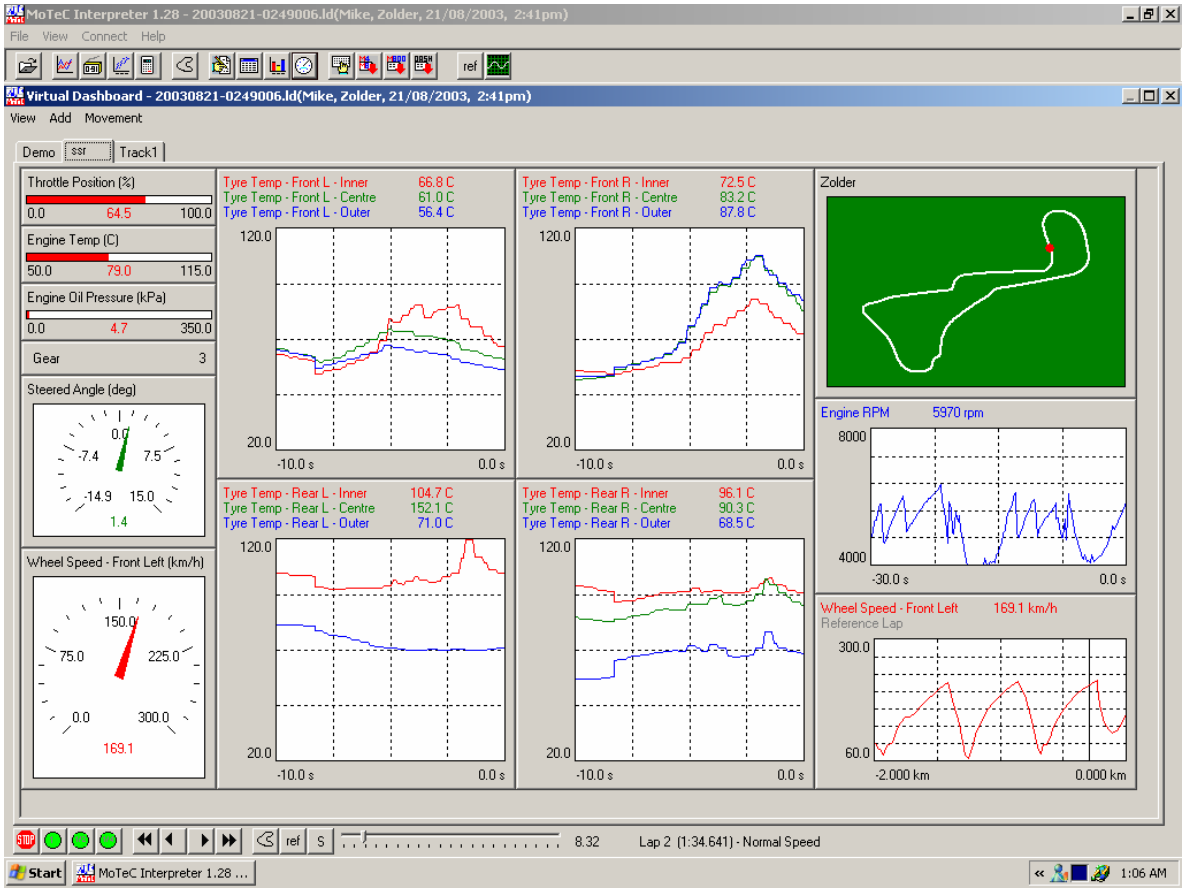

EXAMPLE TEST DATA.

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3 Glossary of Terms

ADC: Analog to Digital Converter

Ambient Compensation: The IR signal captured by a thermopile sensor is not only dependent on the temperature of the object (Tobject) but also on the temperature of the sensor itself. Therefore the IR signal is compensated for this effect by means of the measured sensor temperature (Tambient). This rather complex calculation is performed in the linearization unit of integrated automotive sensor interface.

Chopper Amplifier: Special amplifier configuration aimed at ultra low offset.

DAC: Digital to Analog Converter.

EEPROM: Non-volatile memory that can be electrically erased and rewritten. This type of memory is used to store configuration and calibration data for the module.

ECC: Error Checking and Correction. The EEPROM on board of the integrated automotive sensor interface is equipped with a checking and correction feature based on the Hamming Code method.

IR: Infrared. Every object emits infrared radiation in relation to its temperature. This effect can be used to measure this temperature without the need for physical contact.

Linearization: The signal from a thermopile is not linear with the object temperature. The integrated automotive sensor interface is therefore equipped with a digital calculation unit that produces an output that is linear with the object temperature.

POR: Power-on reset: Reset circuit that starts the digital system in a known state whenever the supply voltage is cycled

PSRR: Power Supply Rejection Ratio: Measure for an amplifier's immunity to disturbances on the supply connections.

PTC: See Thermistor

Ta, Tambient: The temperature of the IR sensor.

Target: or Object: The object the IR module is aimed at.

Thermistor: Temperature dependant resistor. Basically there are 2 types. The types that increase their resistance with rising temperature are PTC (positive thermal coefficient) type. The ones that decrease their resistance with rising temperature we call NTC (negative thermal coefficient) type.

To, Tobject: The temperature of the object one wishes to measure with the module

4 Absolute Maximum Ratings

Flexible modules

Voltage, V_{DD} (over-voltage)	7V
Supply Voltage, V_{DD} (operating)	5.5V
Supply Current, I_{DD}	6mA
Operating Temperature Range, T_A	-40°C / 125°C
ESD Sensitivity (AEC Q100 002)	1kV

Exceeding the absolute maximum ratings may cause permanent damage. Exposure to absolute-maximum rated conditions for extended periods may affect device reliability.

5 General Description

5.1 Theory of operation

The modules are developed especially to make IR temperature sensing easy. All modules have a linearized output signal. Also they are factory calibrated, so making all modules interchangeable. Also this relieves customers from complex calibration procedures.

All modules have an automotive qualified thermopile sensor as IR sensing element. The output of this sensor is a function of both Object (IR) and ambient temperature. Ideally the output voltage of the thermopile sensor is:

$$Vir = \alpha(To^4 - Ta^4)$$

Where To is Object temperature in Kelvin, and Ta is the ambient temperature in Kelvin. Alpha is a device constant. It is clear from above equation that the ambient temperature must be known before the object temperature can be calculated. Therefore the thermopile sensor has a thermistor built-in. SolidStateRacing has integrated the powerful ASIC to perform the signal processing of the thermopile output voltage.
The integrated automotive sensor interface amplifies the signals coming from discrete IR sensing element and converts them to digital by means of two high performance, low noise, chopper stabilized amplifiers and the 12-bit analog to digital converter. The digital unit on the interface then performs the ambient compensation of the IR signal. This results in two temperature signals, one representing the temperature of the object the IR sensor is pointed at (Tobject) and one representing the temperature of the sensor (Tambient). Both signals are then linearised and presented at the outputs in analog of PWM coded form.

The linearisation unit can only operate when both Ta (ambient temperature) and To (object temperature) are both in a distinct calibrated range. This has an important implication for the ambient temperature. When the modules are used outside the calibrated ambient temperature, the object temperature is calculated using a false ambient temperature, resulting in an erroneous output signal.

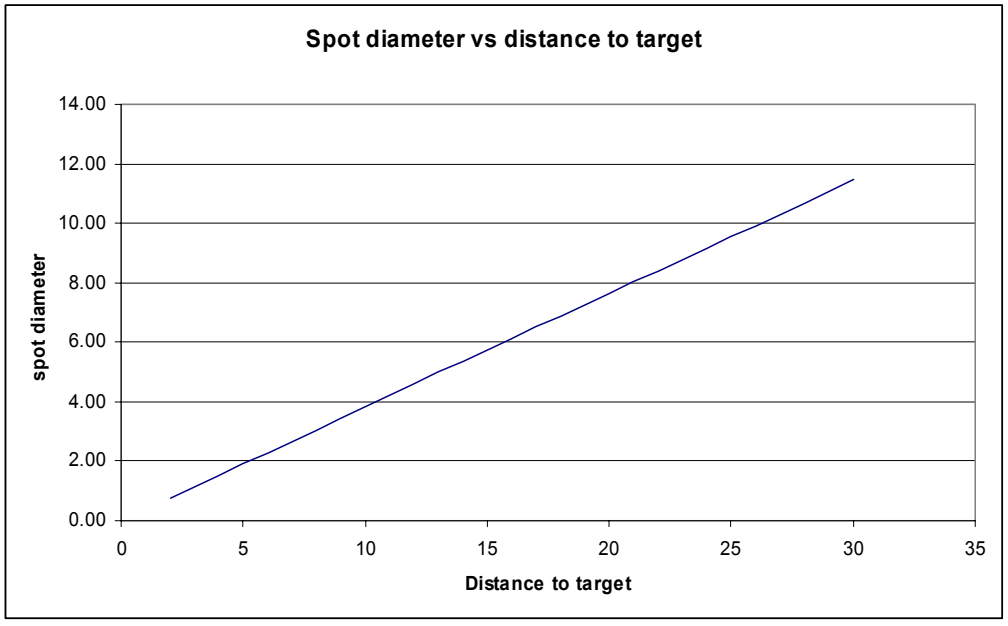
The Custom module for motor-racing applications has a 0 to 150degC range tailored for the applications.

5.2 Sensor characteristics

All modules have the same thermopile sensor. In a calibrated module the linearization unit of integrated automotive sensor interface takes all characteristics of the sensor into account, including all process variations they are subject to.

The TO-39 sensor housing of the thermopile has a 2.5mm diameter aperture and a aluminum bezel giving a field of view (FOV) of 22 degrees. The field of view shape is conical. The distance to spot diameter is defined by:

Spot diameter = 2 * sin(FOV/2) * distance



The silicon filter used as IR-window is treated with an antireflective coating that will pass minimum 75% of IR radiation in the wave length band from 7.5μm to 13.5μm.. Below 5μm, 99.5% of incoming radiation is reflected by the filter. This makes the sensor insensitive to visible light.

6 Motor-racing Custom IR Module

6.1 Key properties

- Automotive use
- analog output signals with 8 bit resolution
- only 3 connections

6.2 General description

The Object temperature information is available at the IROUT pin (BLUE WIRE). The resolution of the output D/A converter is 8bit.

If the ambient temperature is out of the calibrated temperature range, the correct object temperature cannot be calculated. For applications where the ambient temperature can rise above the maximum calibrated temperature, the ambient temperature output must be monitored to make sure the object temperature is valid.

Note that the object temperature range for the custom motor-racing IR module is fixed at 0 to 150degC.

The relation of the output voltage to the temperature is defined as follows:

$$T = \frac{Vout}{4.5} * (Tmax - Tmin) + Tmin$$

where:

T	measured temperature
Vout	analog output voltage on IROUT
Tmin	minimal calibrated temperature ***0degC for motor-racing spec**
Tmax	maximum calibrated temperature ***150degC for motor-racing spec**

A graphical representation with lookup reference is given in appendix A.

6.3 Wiring Information

Description	symbol	Color
Supply	VDD	**RED**
Ground	VSS	**BLACK**
Signal	IROUT	**BLUE**

6.4 Electrical specifications

Parameter	symbol	condition	min	typ	max	unit
Supply Voltage						
Supply voltage range	VDD		4.75	5	6	V
Power consumption	IDD	Ta=25C		5	5.6	mA
Analog outputs IROUT						
D/A converter resolution				8		Bits
Output source current	Iod		1			mA
Output sink current	Ios		20			uA
AC Output impedance	ro				100	Ω
Capacitive load	Cmax				100	nF

6.5 Calibration details

Maximum calibrated object temperature	150°C
Minimum calibrated object temperature	0°C
Object temperature Accuracy (module to module)	±2°C
Object temperature Accuracy (single module repeatability)	<0.5°C
Maximum calibrated ambient temperature	125°C
Minimum calibrated ambient temperature	-10°C
Field of View	22°, conical
Response time	500ms

7 ESD Precautions

Electronic semiconductor products are sensitive to Electro Static Discharge (ESD).
Always observe Electro Static Discharge control procedures whenever handling semiconductor products.

8 FAQ

Q: What is the accuracy?
A: For the standard offered modules the accuracy is ±2°C for the object temperature and ±1°C for the ambient temperature.

Q: Does accuracy increase when the temperature range is decreased?
A: No. The main error comes from limited measurement precision during calibration. These imperfections are the same for all modules.

Q: Are there any special installation requirements or recommendations?
A: For the best performance of your SolidStateRacing IR sensor, always mount the sensor securely

and always by the main composite housing of the module – never by the heat-sink (optic) part of the assembly.
For best response and accuracy, keep the module away from any obvious external or direct heat sources. It is recommended that an air gap or similar insulating layer of 2mm is present around the heat-sink 'tube' (optic).
For the most robust installation, use a SolidStateRacing 'Install Shield' Heat-sink cap!

Q: What is FOV?
A: The FOV or Field Of View is a definition of the area the sensor is 'seeing'. The sensor will detect radiation coming in at an angle, relative to the sensor's central axis, from 0° to 11°. The full viewing angle is thus 22°.

Q: What is the useful temperature range?
A: There are two temperature ranges of interest; the temperature of the object (or target), which you are trying to measure and the temperature of the sensor. The sensor temperature, called Tambient, should be in the calibrated temperature range. See calibration details. Outside this range the ambient temperature compensation will no longer work and calculation of the object's temperature will no longer be correct. The object temperature, called Tobject, should be between 0°C and 150°C. Outside this range the IROUT output will saturate.

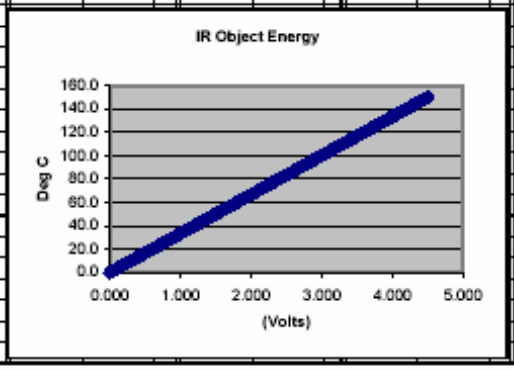
Q: IR radiation is comparable with light. Does my object have to be black?
A: No, the appearance in the visible light spectrum completely differs from the appearance for IR wavelengths. Water and glass for instance, are completely opaque for IR, and thus you can perfectly measure the temperature. Air is transparent for IR and does not influence the measurement. The better name for this property is EMISSIVITY

Q: What is emissivity and how does it affect my measurement?
A: Emissivity is the ratio of the emitted IR energy over the total IR energy that an object has. You can find the value for this property by searching the internet, material data sheets etc. Ice, water, skin, clothes, most non-metallic coatings have an emissivity of 0.90 to 0.99. Emissivity should be close to 1. When measuring objects with low emissivity, reflections of the ambient temperature will come into the thermopile sensor. Therefore there is a measurement error depending on the difference between object and ambient temperature. If the surface of the target has an emissivity lower than 0.7, you can still measure it, but here some tips and tricks are needed. Contact info@solidstateracing.com

Q: How do I clean the module aperture if it exposed to/contaminated by road dirt or tire debris?
A: The IR module aperture can be carefully cleaned using a cotton bud stick (typically used for cleaning out ear wax!) The cotton end should first be gently moistened in pure alcohol as the cleaning solvent. Do not over clean!

9 Custom Module Look-up Reference Table

Output Voltage (V)	Object Temp DegC	Output Voltage (V)	Object Temp DegC	Output Voltage (V)	Object Temp DegC	Output Voltage (V)	Object Temp DegC	Output Voltage (V)	Object Temp DegC
0.000	0.0	1.094	36.5	1.888	62.9	2.682	89.4	3.476	115.9
0.018	0.6	1.112	37.1	1.906	63.5	2.700	90.0	3.494	116.5
0.035	1.2	1.129	37.6	1.924	64.1	2.718	90.6	3.512	117.1
0.053	1.8	1.147	38.2	1.941	64.7	2.735	91.2	3.529	117.6
0.071	2.4	1.165	38.8	1.959	65.3	2.753	91.8	3.547	118.2
0.088	2.9	1.182	39.4	1.976	65.9	2.771	92.4	3.565	118.8
0.106	3.5	1.200	40.0	1.994	66.5	2.788	92.9	3.582	119.4
0.124	4.1	1.218	40.6	2.012	67.1	2.806	93.5	3.600	120.0
0.141	4.7	1.235	41.2	2.029	67.6	2.824	94.1	3.618	120.6
0.159	5.3	1.253	41.8	2.047	68.2	2.841	94.7	3.635	121.2
0.176	5.9	1.271	42.4	2.065	68.8	2.859	95.3	3.653	121.8
0.194	6.5	1.288	42.9	2.082	69.4	2.876	95.9	3.671	122.4
0.212	7.1	1.306	43.5	2.100	70.0	2.894	96.5	3.688	122.9
0.229	7.6	1.324	44.1	2.118	70.6	2.912	97.1	3.706	123.5
0.247	8.2	1.341	44.7	2.135	71.2	2.929	97.6	3.724	124.1
0.265	8.8	1.359	45.3	2.153	71.8	2.947	98.2	3.741	124.7
0.282	9.4	1.376	45.9	2.171	72.4	2.965	98.8	3.759	125.3
0.300	10.0	1.394	46.5	2.188	72.9	2.982	99.4	3.776	125.9
0.318	10.6	1.412	47.1	2.206	73.5	3.000	100.0	3.794	126.5
0.335	11.2	1.429	47.6	2.224	74.1	3.018	100.6	3.812	127.1
0.353	11.8	1.447	48.2	2.241	74.7	3.035	101.2	3.829	127.6
0.371	12.4	1.465	48.8	2.259	75.3	3.053	101.8	3.847	128.2
0.388	12.9	1.482	49.4	2.276	75.9	3.071	102.4	3.865	128.8
0.406	13.5	1.500	50.0	2.294	76.5	3.088	102.9	3.882	129.4
0.424	14.1	1.518	50.6	2.312	77.1	3.106	103.5	3.900	130.0
0.441	14.7	1.535	51.2	2.329	77.6	3.124	104.1	3.918	130.6
0.459	15.3	1.553	51.8	2.347	78.2	3.141	104.7	3.935	131.2
0.476	15.9	1.571	52.4	2.365	78.8	3.159	105.3	3.953	131.8
0.494	16.5	1.588	52.9	2.382	79.4	3.176	105.9	3.971	132.4
0.512	17.1	1.606	53.5	2.400	80.0	3.194	106.5	3.988	132.9
0.529	17.6	1.624	54.1	2.418	80.6	3.212	107.1	4.006	133.5
0.547	18.2	1.641	54.7	2.435	81.2	3.229	107.6	4.024	134.1
0.565	18.8	1.659	55.3	2.453	81.8	3.247	108.2	4.041	134.7
0.582	19.4	1.676	55.9	2.471	82.4	3.265	108.8	4.059	135.3
0.600	20.0	1.694	56.5	2.488	82.9	3.282	109.4	4.076	135.9
0.618	20.6	1.712	57.1	2.506	83.5	3.300	110.0	4.094	136.5
0.635	21.2	1.729	57.6	2.524	84.1	3.318	110.6	4.112	137.1
0.653	21.8	1.747	58.2	2.541	84.7	3.335	111.2	4.129	137.6
0.671	22.4	1.765	58.8	2.559	85.3	3.353	111.8	4.147	138.2
0.688	22.9	1.782	59.4	2.576	85.9	3.371	112.4	4.165	138.8
0.706	23.5	1.800	60.0	2.594	86.5	3.388	112.9	4.182	139.4
0.724	24.1	1.818	60.6	2.612	87.1	3.406	113.5	4.200	140.0
0.741	24.7	1.835	61.2	2.629	87.6	3.424	114.1	4.218	140.6
0.759	25.3	1.853	61.8	2.647	88.2	3.441	114.7	4.235	141.2
0.776	25.9	1.871	62.4	2.665	88.8	3.459	115.3	4.253	141.8
0.794	26.5							4.271	142.4
0.812	27.1							4.288	142.9
0.829	27.6							4.306	143.5
0.847	28.2							4.324	144.1
0.865	28.8							4.341	144.7
0.882	29.4							4.359	145.3
0.900	30.0							4.376	145.9
0.918	30.6							4.394	146.5
0.935	31.2							4.412	147.1
0.953	31.8							4.429	147.6
0.971	32.4							4.447	148.2
0.988	32.9							4.465	148.8
1.006	33.5							4.482	149.4
1.024	34.1							4.500	150.0
1.041	34.7								
1.059	35.3								
1.076	35.9								



10 Disclaimer

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