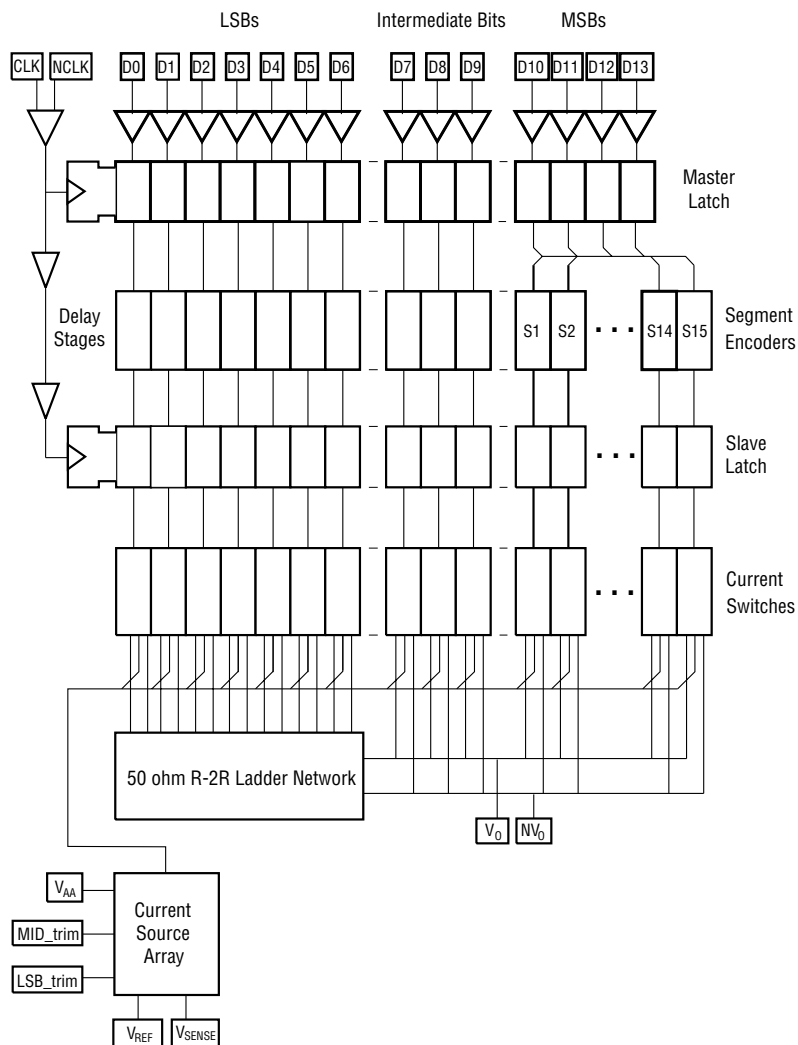


The TQ6124 is a 14-bit monolithic digital-to-analog converter. The TQ6124 achieves conversion accuracy by using a segmented architecture, precision current sources, and on-chip nichrome resistors. The only external components required are an external reference and loop control amplifier.

The TQ6124 is ideally suited for applications in direct digital synthesis, pixel generation for high-resolution monitors, broadband video generation, and high-speed arbitrary waveform generators.

**Figure 1. TQ6124 Block Diagram**



## TQ6124

### **1 Giga-sample/sec, 14-bit Digital-to-Analog Converter**

#### **Features**

- 1Gs/s aggregate bandwidth
- 14-bit resolution
- RF front end
- ECL-compatible inputs
- 0.026% DC differential non-linearity
- 0.035% DC integral non-linearity
- SFDR: 52 dBc @  $F_{OUT} = 75$  MHz  
48 dBc @  $F_{OUT} = 148$  MHz  
45 dBc @  $F_{OUT} = 199$  MHz
- 1.4 W power dissipation
- 44-pin ceramic QFP package or die only

#### **Applications**

- Direct Digital Synthesis
- Pixel generation for workstations and high-end monitors
- Direct-generation of broadband video for cable TV
- High-speed arbitrary waveform generators

## Functional Description

The TQ6124 registers incoming bits in a master latch array. The value of the four most-significant bits is encoded into an n-of-15 thermometer code while the ten low-order bits pass through an equalizing delay stage. All 25 bits are re-registered in a 25-wide slave latch array which drives a set of 25 differential pair switches. These switches steer the corresponding segment and bit currents into the true ( $V_O$ ) and complementary ( $NV_O$ ) outputs. This architecture minimizes glitch impulses by eliminating large mid-scale current transitions.

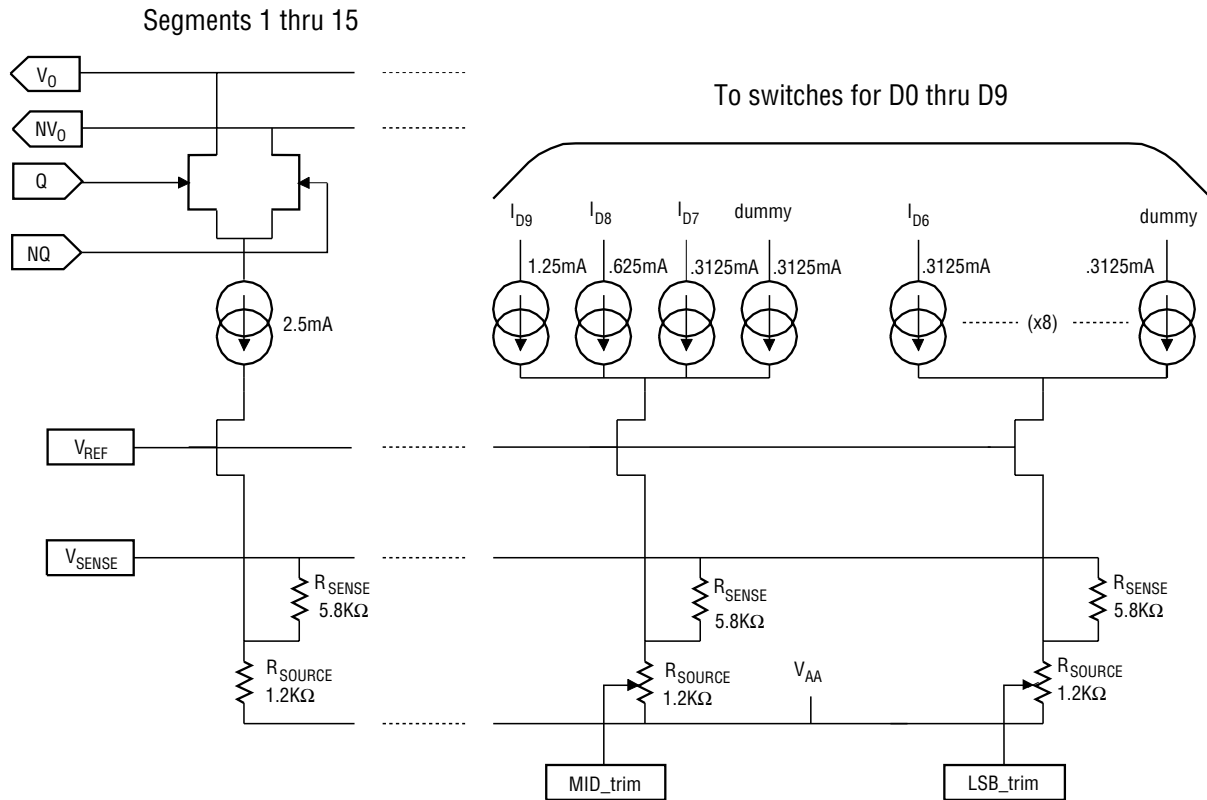
The most-significant bits generate the segment currents, which are of equal weight at  $1/16$  of the full-scale output ( $I_{FS}$ ). The ten lower-order bits are divided into two subgroups. The three intermediate bits steer

binary-weighted currents of magnitude  $I_{FS}/32$ ,  $I_{FS}/64$  and  $I_{FS}/128$  to the outputs. The seven least-significant bits steer identical  $I_{FS}/128$  currents into a differential R-2R ladder to generate effective bit currents of  $I_{FS}/256$  to  $I_{FS}/16384$ . The DAC output is the sum of the outputs of the segments and the low-order bits.

Clock and data inputs are ECL-compatible. The outputs are designed to operate into a  $50\Omega$  load, with internal reverse termination to ground being provided by the R-2R network.

External compensation is utilized to minimize the effects of device mismatch. An external op amp senses the sum of the segment, the intermediate bit, and the LSB currents.

**Figure 2. TQ6124 Currents**



## Electrical Specifications

**Table 1. Recommended Operating Conditions**

Symbol	Parameter	Min.	Nom.	Max.	Unit
V <sub>SS</sub>	Negative Power Supply	−5.25	−5.0	−4.75	V
V <sub>AA</sub>	Analog Power Supply	−15.5	−12	−11.5	V
T <sub>C</sub>	Case Temperature	−20		85	°C

**Table 2. DC Operating Characteristics**

Unless otherwise specified, measured over Recommended Operating Conditions with balanced 50Ω loads, V<sub>FS</sub> = 1.0 V.

Symbol	Parameter	Condition	Min.	Nom.	Max.	Unit
I <sub>AA</sub>	V <sub>AA</sub> Supply Current			−75	−90	mA
I <sub>SS</sub>	V <sub>SS</sub> Supply Current			−285	−450	mA
V <sub>REF</sub>	Reference Voltage		V <sub>AA</sub> + 2.5	V <sub>AA</sub> + 3.0	V <sub>AA</sub> + 3.75	V
I <sub>REF</sub>	Reference input current		−25		25	mA
V <sub>IH</sub>	ECL Input High Voltage	V <sub>REF</sub> = −1.3 V	−1.1		−0.6	V
V <sub>IL</sub>	ECL Input Low Voltage	V <sub>REF</sub> = −1.3 V	−2.5		−1.5	V
I <sub>I</sub>	ECL Input Current		−25		25	mA
V <sub>EREF</sub>	ECL Reference Voltage	V <sub>SS</sub> = −5.0 V		−1.34		V
R <sub>EREF</sub>	ECL Reference Resistance			400		ohms
DNL	Differential non-linearity	(Note 2)	−0.05	0.026	0.05	%F.S.
INL	Integral non-linearity	(Note 2)	−0.05	0.035	0.05	%F.S.
	Full-scale symmetry	(Note 1)	−8	2	8	mV
V <sub>FS</sub>	Full-scale output voltage	R <sub>L</sub> = 50 ohms		−1.0	−1.125	V
R <sub>OUT</sub>	V <sub>O</sub> , NV <sub>O</sub> , output resistance		44	50.9	57	ohms
	R <sub>OUT</sub> Matching		−2.5	0.15	2.5	%
V <sub>O</sub> , NV <sub>O</sub>	Output Voltage		−1.125		0	V
V <sub>ZS</sub>	Zero Scale Voltage		−50	−40	0	mV
V <sub>SENSE</sub>	Sense output voltage		V <sub>AA</sub> + 2.5		V <sub>AA</sub> + 3.75	V
θ <sub>JC</sub>	Thermal Impedance			15		°C/W

Notes: 1. Full-scale symmetry is a measure of the balance between V<sub>O</sub> and NV<sub>O</sub>. For a full-scale output transition, the change in V<sub>O</sub> will match the change in NV<sub>O</sub> to within the specified amount. Any imbalance in the output loads will affect symmetry.

2. Linearity can be interpreted as 10 bits at 1/2 LSB or as 11 bits at 1 LSB. The device is monotonic to 10 bits. Linearity is tested with the Mid\_trim set for optimal DNL, with the LSB\_trim pin open.

**Table 3. AC Operating Characteristics**

Unless otherwise noted, measured over DC operating characteristics with balanced 50Ω loads,  
 $V_{FS} = 0.8V$ ,  $V_{IN} = 0.8V_{P-P}$ , input rise and fall times  $\leq 300$  ps.

Symbol	Parameter	Condition	Min.	Typ.	Max.	Unit
$F_{CLK}$	Clock Frequency		50		1000	MHz
$t_R, t_F$	At full scale	10% to 90%			350	ps
$t_{DS}$	Data Setup Time		200			ps
$t_{DH}$	Data Hold Time		300			ps
$t_{CLKHI}$	Clock High Time		400			ps
$t_{CLKLO}$	Clock Low Time		400			ps
SFDR*	Spurious free dynamic range	$F_{OUT} = 75$ MHz	45	52		dBc
		$F_{OUT} = 148$ MHz	45	52		dBc
		$F_{OUT} = 199$ MHz	45	49		dBc

\*Note: SFDR testing performed at  $F_{CLK} = 600$  MHz only.

**Table 4. Absolute Maximum Ratings**

Symbol	Parameter	Min.	Max.	Unit
$V_{SS}$	Digital Supply	-7.0		V
$V_{AA}$	Analog Supply	-16.0		V
$V_O, NV_O$	Analog Output Voltage	-2.0	2.0	V
$V_I$	Digital Input Voltage	$V_{SS} - 0.5$	+0.5	V
$I_I$	Digital Input Current	-1.0	+1.0	mA
$V_{REF}$	Reference Voltage	$V_{AA} - 2$	0	V
$I_{REF}$	Reference Current	-1	1	mA
	Power Dissipation		5	W
$T_{STG}$	Storage Temperature	-65	150	°C
$T_J$	Operating Junction Temperature		150	°C

Note: Absolute Maximum Ratings are those beyond which the integrity of the device cannot be guaranteed.  
 If the device is subjected to the limits in the absolute maximum ratings, its reliability may be impaired.  
 The Electrical Specifications tables provide conditions for actual device operation.

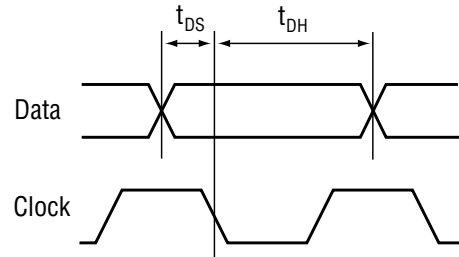
The low-going transition of CLK latches the data. Production SFDR testing is performed with the clock transitioning in the center of the data eye. The timing of the clock transition with respect to the data can improve SFDR performance. Systems working to optimize SFDR can 'tune' this phase relationship to optimize the desired characteristic.

## Operating Notes

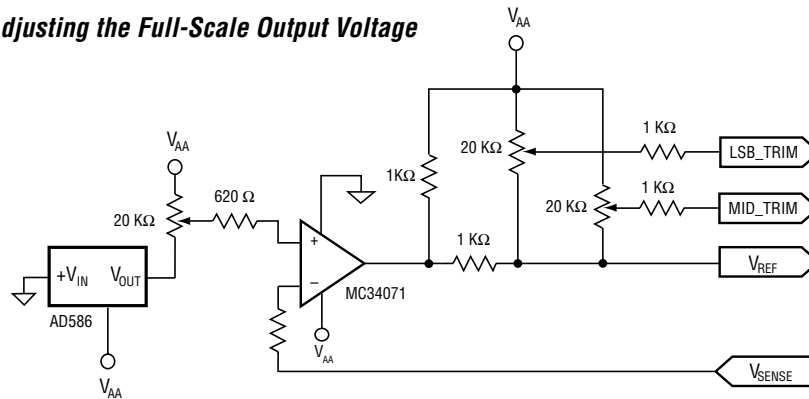
### Current Source Control Loop

The full scale output voltage is set through the use of an external op amp, as shown in Figure 4. Nominal full scale output voltage can be achieved by using a voltage source. With this, control voltages on the op amp of

**Figure 3. AC Timing Relationships**



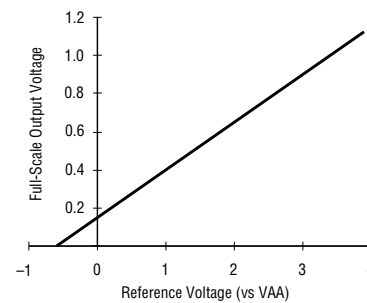
**Figure 4. Adjusting the Full-Scale Output Voltage**



### V<sub>REF</sub> Adjustment Range

The output full scale voltage range can be set through the  $V_{REF}$  input. Figure 5 shows the approximate relationship between  $V_{REF}$  and  $V_{FS}$ .

**Figure 5. Full-Scale Output Voltage vs.  $V_{REF}$**



## Operating Notes (continued)

### Power Supplies

Optimized performance depends on clean supplies. Utilize very low impedance negative supplies that are decoupled over a wide frequency range. The analog and digital grounds should be isolated at the chip, connecting to a single point ground on the circuit board.

### ECL Reference

The single-ended data inputs switch against an internal reference of -1.3V (nominal). Variations among input

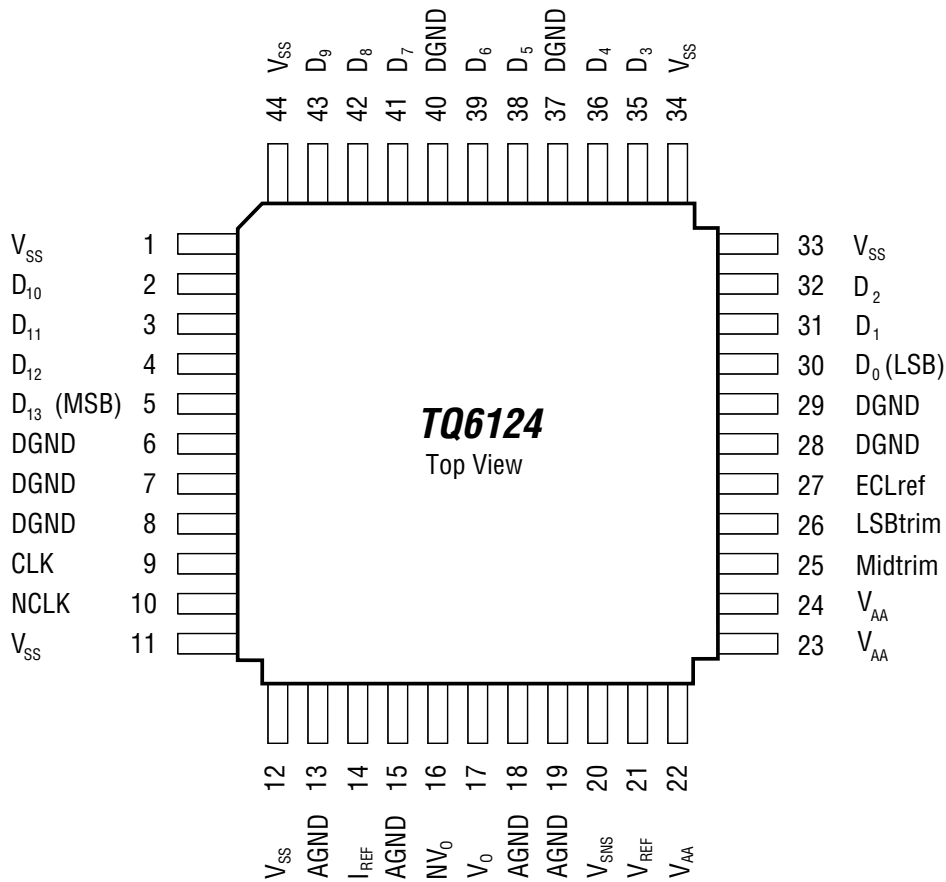
buffers, or in  $V_{TT}$ , may benefit from adjustments in the reference. The ECL reference pin may be driven externally. Its equivalent load is 400 ohms to -1.3V (nominal).

### Trim Adjustments

The external trim adjustments for the midrange bits and the LSBs is optional. Trimming is performed by monitoring the attribute of greatest concern (INL, DNL, Spurious levels) while minimizing the unwanted effects. Trim inputs should be left open if not used.

## Signals

Figure 6. TQ6124 Pinout



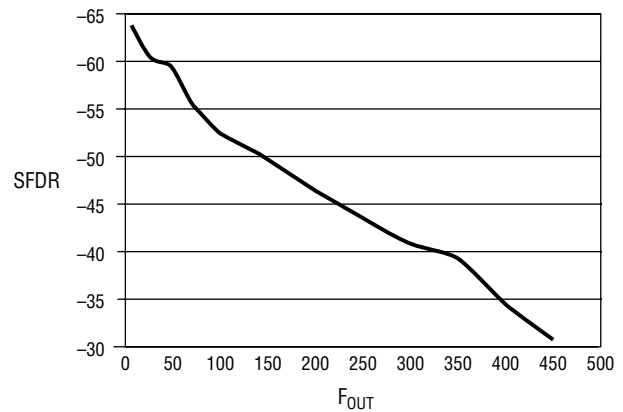
**Table 5. Signal-Pin Descriptions**

<b>Signal</b>	<b>Pin(s)</b>	<b>Description</b>
DGND	6, 7, 8, 28, 29, 37, 40	Ground connection for digital circuitry.
AGND	13, 15, 18, 19	Ground connection for analog circuitry.
D <sub>0</sub> thru D <sub>13</sub>	30, 31, 32, 35, 36, 38, 39, 41, 42, 43, 2, 3, 4, 5	Data inputs. D <sub>0</sub> is the least significant bit. ECL levels.
V <sub>O</sub> , NV <sub>O</sub>	17, 16	True and complementary analog outputs.
CLK, NCLK	9, 10	True and complementary clock inputs. ECL levels.
I <sub>REF</sub>	14	Connect to AGND. Source of dummy currents in the switch array.
V <sub>SENSE</sub>	20	Sense Output.
V <sub>REF</sub>	21	Reference Input.
V <sub>SS</sub>	1, 11, 12, 33, 34, 44	Digital negative power supply.
V <sub>AA</sub>	22, 23, 24	Analog negative power supply.
Mid_trim	25	Trim terminal for mid range bits.
LSB_trim	26	Trim terminal for LSB range bits.
ECLref	27	Optional ECL reference level adjustment. Thevinin equivalent is 1.3V nominally into 400 ohms. Equivalent voltage tracks with digital supply.

### Typical Performance Data

The graph in Figure 7 shows representative performance data of spurious free dynamic range (SFDR) vs. output frequency performance measured from TQ6124 devices.

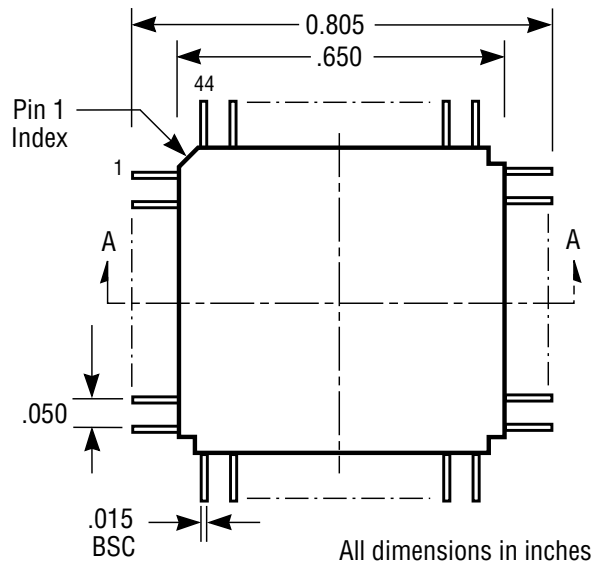
Data was collected at room temperature; note, however, that SFDR is not strongly dependent on temperature. Optimum performance is obtained by utilizing as high a clock rate as practical.

**Figure 7. SFDR vs. Output Frequency**

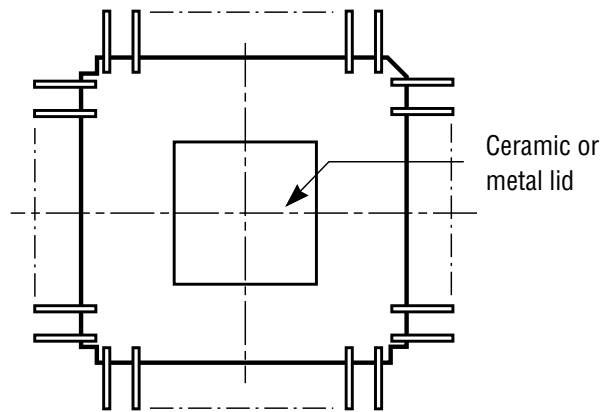
## Packaging

Figure 8. 44-pin QFP Package Dimensions

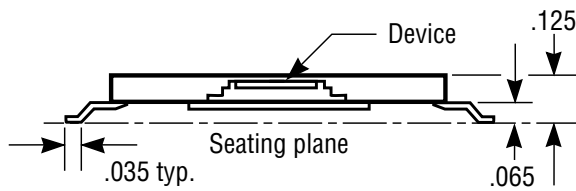
### Top View



### Bottom View



### Section A-A





***Ordering Information***

<b>TQ6124-CM</b>	<i>1 GS/s 14-bit DAC in 44-pin ceramic QFP</i>
<b>TQ6124-CD</b>	<i>1 GS/s 14-bit DAC — die only</i>
<b>ETF6124</b>	<i>Engineering Test Fixture with TQ6124 device</i>

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