Hazardous Environment Detection for First Responders Using UAV Platforms

Nicholas Davis

Tufts University

Nicholas.Davis@tufts.edu

Abstract— **In this paper we present a risk detection system using an unmanned aerial vehicle (UAV) platform to capture images, video, and radiation levels. Our approach produces real-time accurate detection of risk throughout the environment allowing the system to be used in real world rescue applications. We present low power radiation detection that enables the system to report accurate radiation levels with a minimal load on the UAV. The system can be used in other robotic platforms. It is highly modular and adaptable to other systems.**

Keywords— Unmanned Aerial System, Risk Detection, Radiation, Robotic Vision

I. Introduction

The site of an emergency is not always accessible or safe for human responders, but there may still be a need to assess the area and determine possible risks or find survivors. In addition to issues of safety and risking the lives of the responders, there may be obstructions such as darkness or smoke that limit human visibility. This UAV system is designed to keep human operators at a safe distance and remotely survey a scene and gather all risk information before sending in personnel. The proposed UAV drone will carry a camera and an array of sensors to relay all information wirelessly to the operator. Real-time information about the site will allow the operator to mark the location of each risk for the team of responders before they enter the potentially hazardous site.

Previous systems developed incorporate image processing and facial recognition to find specific people in low-light low-resolution environments [1]. Because of the highly modular nature of this system, the ability to add this previous work to the current system would be trivial.

II. Background Information

A. UAV System

The UAV platform used for this project was the Draganflyer Guardian made by Draganfly Innovations. This UAV was selected based on its high payload capacity, long battery life, and extremely robust API.

A quadcopter, the Guardian has four rotors extending from the main body. These rotors are mounted on carbon fiber boom arms, and are powered by brushless motors. Four legs extend from the motor housings, which are also made of flexible carbon fiber. The payload assembly is attached underneath the main body of the drone, and is kept in place by four twist-on mechanical connectors, and a pin to lock its orientation. Many options are available for the default payload. The option used for this research included a GoPro Hero3 video camera. This was chosen for its durability, resolution, and light weight. The payload assembly includes a dual-axis gyro-stabilized mount which insures smooth video and constant orientation. This is realized through the use of two brushless motors and a feedback control system to correct the positioning of the camera based on live telemetry readings from the drone. All of the telemetry sensors onboard the drone are housed inside of the main body, where the logic board and communication system are housed. A protective plastic enclosure covers the circuitry from the elements, and is secured to the drone using hex bolts. The Guardian has a total payload capacity of 420 g which leaves 120 g after the default payload to add additional sensors and custom circuitry, which made it the ideal candidate for the intended modifications. Power and weight were the two most important factors in choosing a platform. On-board power must be sufficient enough to supply the additional sensors, because adding battery power would drastically add weight to the system. The Guardian's Li-Po battery not only had excellent lifespan, but the payload assembly had easy access to 5V from the main board.

The Guardian can be operated wirelessly from a handheld controller (HHC), or from a computer using the DraganView software. On the HHC, joysticks control thrust, lateral movement, and yaw. In the center of the controller is a touchscreen which streams live telemetry data from the Guardian, and can be used to configure connection options, such as video channel, and master-slave controller options. The DraganView software is an application used to interface a computer, and control surface which the drone. Whether the operator prefers a joystick, game controller, or some other device, the

DraganView software can interface with the device, and convert the input data into meaningful commands and send those commands to the Guardian.

B. Geiger-Müller Tube

A Geiger-Müller tube is the device within a Geiger counter that detects radiation particles. Depending on the type of Geiger-Müller tube, it can detect alpha or beta particles, gamma rays, or a combination of the three. In order to detect this radiation, the tube is filled with a low-pressure inert gas. There are two electrodes, and when the device is activated, there is a very high potential difference between the two. For the specific tube used for this research, the T2417AC from Canberra Industries, that potential difference is on the order of 600 volts. Depending on the sensitivity of the device, and the type of particles it detects, the operating range of a Geiger-Müller tube can be on the order of 1 kV. When ionizing radiation of the correct type hits the tube, molecules of the inert gas are ionized, and an electron is emitted. Due to the strong electric field being produced between the two electrodes, the negative and positive ion pairs separate toward the anode and the cathode respectively. As the electron gets close to the anode, it produces more ion pairs. This is because the original electron gains energy as it moves closer to the anode, and eventually has enough energy to ionize nearby molecules. This causes a significant output pulse to be detected at the anode of the device, which is considered a detection of a particle. The T2417AC was chosen based on its high sensitivity, low weight, and compact form factor. At 4 cm long and 1 cm in diameter, the tube weighs only 8 g. This is well within the 120 g margin available for the Guardian's payload. As shown in Figure 1, the T2417AC has two tin wraps along the tube, which causes only a small surface area of the tube to actually be exposed. These wraps, called energy wraps, effectively filter out lower energy radiation, which reduces background noise, and maintains a consistent output count for any energy of radiation. This is important because counts per minute (cpm) is the measure of the total amount of radiation occurring, and will be the units used to determine whether the environment is safe for first responders or not. A dose amount; which is measured in grays (Gy) and sieverts (Sv) can only be measured by a dosimeter[1] [2][4].

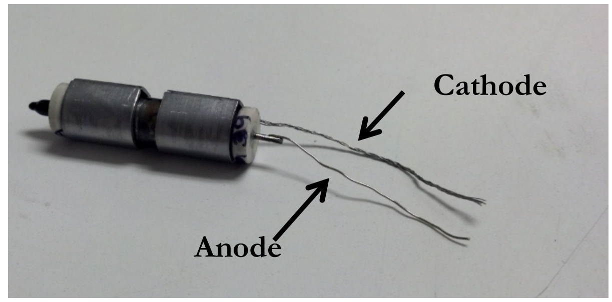


Figure 1: T2417AC Geiger-Müller Tube

The T2417AC's ideal operating conditions consist of an operating voltage of 575 V and room temperature. At these conditions, the tube has a sensitivity of 450 cpm in a radiative field of 1 milliRoentgen per hour (mR/hr) as produced by cesium-137 (^{137}Cs). Sensitivity is a measurement of radiation over time that can be converted into cpm. For example: the rating of 450 means that in a radiative field of 1 mR/hr, the T2417AC produces a count of 450 cpm. This measurement is linear, so in a field of 2 mR/hr, the output would be 900 cpm. This sensitivity gives good reading in a wide range of radiative field strengths. At low radiation levels, the tube will still pick up measurements, and at extremely high levels (up to 6.9 million cpm) the Geiger-Müller tube can still give distinguishable readings. Over a time period of 1 hour, 6.9 million cpm equates to 135.5 Gy/hr[3]. For comparison, 5 Gy absorbed instantly through air is lethal to an average human being [2][3]. Because the measurements of the system are in terms of radiation over time, 135.5 Gy/hr is lethal in even 10 minutes of exposure. This gives operators an understanding of the environment, and how long they can potentially enter an area before it is unsafe. This, along with the use of personal dosimeter badges, can keep responders safe. Another advantage of giving readings in radiation over time is in triaging disaster survivors remotely. If an injured person is found in an area with 135.5 Gr/hr, and the incident occurred 10 minutes prior, then that patient will be assigned a red tag in triage [5].

C. High Voltage Kickback Generator

In order to operate the Geiger-Müller tube from the 5V available on the Guardian, a variable high voltage kickback generator was needed. This circuit was created around a 555 timer. The timer functions as a pulse generator, through the use of the trigger (TRIG) pin. When TRIG is brought to logical low (0V), a logical high (5V) square pulse is generated on the output pin (OUT). When the discharge pin (DIS) is brought to logical high OUT then becomes low again. If the reset (RESET) pin is enabled by a logical low signal, the timer resets the OUT pin to low.

1 See http://www.remm.nlm.gov/civilian.htm for information on dosimeters

2 See http://www.firstresponder.gov/Saver/RadiationDosimeters_TN.pdf for information on first responder dosimeters

3 Background information obtained from http://www.epa.gov/radiation/

High voltage is generated by beginning with OUT and TRIG of the 555 timer at logical low. Because TRIG is low, OUT will begin to rise to high, which allows current to flow through R3, D2, and R1, which in turn brings TRIG high preventing another output pulse. When OUT is high, the threshold voltage of Q1 is met, and the transistor is turned on. Current then can flow through Q1 to L1, and when enough current has flowed through L1, a voltage is effected on R5. This voltage will turn on Q2, which will in turn cause RESET to go low, turning off the 555 timer. With no voltage at OUT, current no longer flows to L1, which causes the electromagnetic field stored in the inductor to flow to the capacitance of Q1. Once the inductor is drained completely, the voltage drop across D1 is enough for it to operate in forward bias mode. Current then flows through D1 into C2. The pulses from the 555 timer are only milliseconds long, which in turn means that very high voltage is created by L1. This voltage is then stored in C2, and when discharged, powers the Geiger-Müller tube. The schematic for the high voltage kickback generator is shown in figure 2.

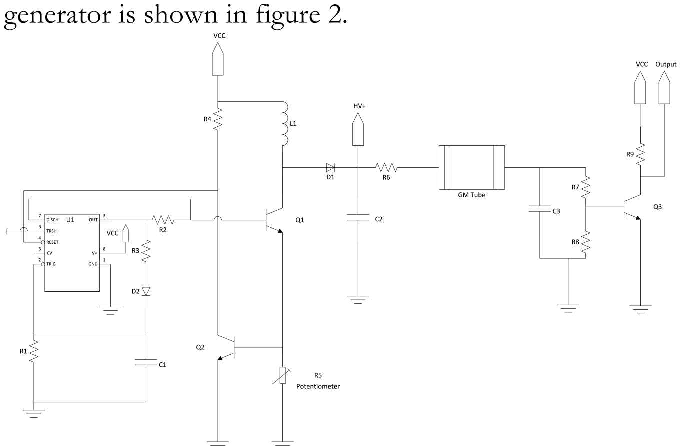


Figure 2: High Voltage Kickback Generator Schematic

D. *Software*

The DraganView software in its entirety is a separate program that can be included with the system at additional cost. Included with the system was an API example program with all of the barebones functionality of the DraganView software. This included telemetry streaming, device input translation, and access to the encryption format of the messages sent between the Guardian and the computer. This API is covered under a non-disclosure agreement (NDA) signed by all members of the research team and Draganfly Innovations. Because of this, the specifics of the API and the communication protocol of the drone are not under the scope of this paper. In general, messages sent and received are encrypted to ensure only the operator can read, modify, or send messages between the Guardian and the software. These messages also have a parity check to make sure the data was not altered or lost during transmission. Because of this, the communication between the drone and the operator is extremely robust. All communication is done using XBee-Pro modules. XBee-Pro modules use the IEEE 802.15.4[4] protocol to communicate at distances of approximately 1 mile. In order for the software to send and receive communication to and from the drone, an XBee-Pro module is connected to the computer via a USB VCP device created by Draganfly. Once the XBee-Pro transceivers are paired, communication between them begins. Encryption and decryption happens end-to-end, leaving no space for a man-in-the-middle attack (MITM). In the same fashion, the parity check is calculated after the message payload has been created and checked end-to-end.

In order to create a graphical user interface (GUI), the Qt framework is used. Qt is a UI framework for C++ which makes use of a special code generator called the Meta Object Compiler (moc). Along with special macros, Qt makes writing UI elements extremely easy. Qt uses signals and slots in its architecture. A signal is emitted when an event occurs, and a slot is a function called in response to a specific signal. This type of architecture is extremely efficient for building UIs but can also be used for asynchronous I/O. In a way, coding with Qt in C++ makes the language feel almost object oriented. Each class can be instantiated multiple times, and has signals and slots associated with each instantiation. Through very clear documentation, the API was used to create a new real-time data UI element very similar to the way telemetry data is presented. In the background, much extra infrastructure was added. In order to handle the new messages, code was added to the message parser, so the program understood what it was receiving. This was done through manipulation of the proprietary message format of the Draganflyer System. Once the software understood the messages it was receiving, logic was added to drop any duplicate messages in the pipeline. This was a crucial step, because radiation data is transmitted in counts per second (cps), and duplicate transmissions could skew results, leading to a misrepresentation of the environment. After the uniqueness of the message was checked, a signal was sent with the data from the message, and the slot in the UI picked up the data, and replaced the information on screen with the most current version. This UI is shown in figure 3. In order for this to work, a new struct was designed to match the information in the message, and display it in a human readable format.

[4] http://standards.ieee.org/about/get/802/802.15.html

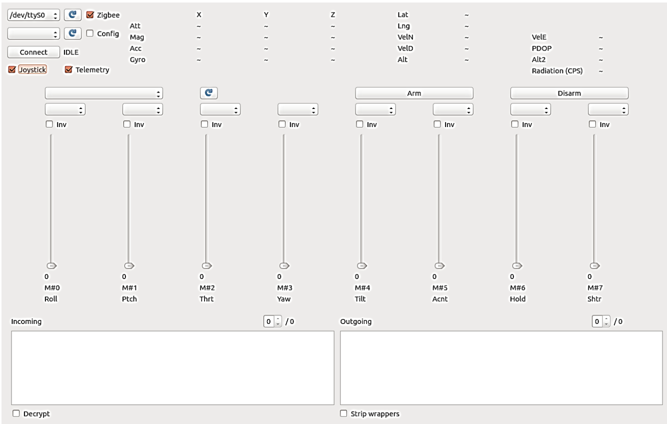


Figure 3: DraganView API Example UI

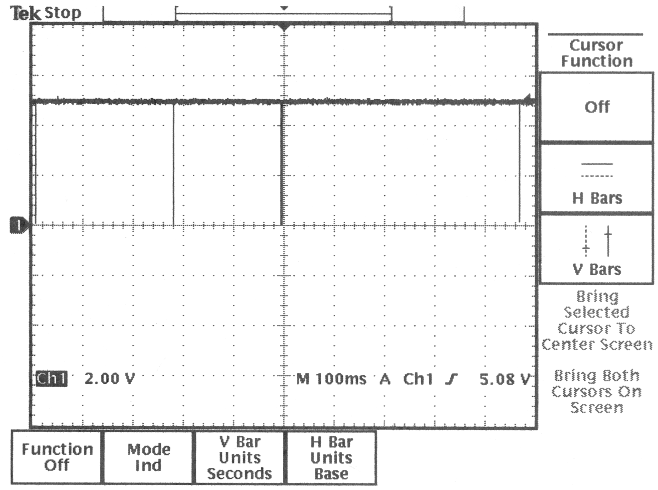


Figure 4: Oscilloscope Reading for SBM-20 Testing

III. EXPERIMENTAL RESULTS

The final revision of the design used the high voltage kickback generator shown in figure 2. This circuit has an excellent variable range capable of producing anything from 180 – 960 V. Because of this, multiple different Geiger-Müller tubes can be accommodated. In previous revisions, the kickback generator was only capable of generating up to 400 V, which severely limited the type of tubes it could power. This was due to the use of smaller inductors and slower transistors. Once the inductor was changed from 10mH to 15 mH, and the transistors were changed to faster versions, the generator was able to achieve the desired operating ranges.

Once a revision with stable operating voltages was created, the circuit was tested with an initial less sensitive Geiger-Müller tube. Due to delays from Canberra Industries, the T2417AC was unavailable for this stage of testing, so a soviet era SBM-20 was obtained for initial acceptance testing. This tube was low-cost, durable, and needed a lower operating voltage than the T2417AC. The SBM-20 also only detects beta radiation; so neither alpha particles, nor gamma rays were tested in this revision. Because of the lack of sensitivity, and the large form factor of the tube, it was not to be used in the final revision. Using a small sample of Americium-241 (^{241}Am) the full circuit was tested, using an oscilloscope to capture the output from the tube. As shown in figure 4, when detection occurs, there is a spike of low voltage. This is exactly how we would expect the tube to behave. The count of particles on the SBM-20 is lower than that of the T2417AC because the SBM-20 has a worse sensitivity. The background radiation from everyday sources is counted even at very low energy, causing the readings to be less accurate as well.

The next revision was able to generate 575 V, and with access to the T2417AC, true acceptance testing was performed. Using the same ^{241}Am, the T2417AC was tested under the same conditions. The results showed a higher count at a much more stable rate, as can be seen in figure 5. This showed that the tube operated correctly with the kickback generator, and had a stable sensitivity. Because of the energy wrap, the readings are more accurate as well because any low-energy background radiation is filtered.

In order to test the software to its limits, a method was devised by which we could reach the limits of the message bandwidth. In order to do this, an input pin on the payload assembly (a spare JP12 connector unused by the normal operation of the drone) was attached to a function generator. Because the signal from the tube is counted by a falling edge, we could simulate the serial input of the tube at high frequency without exposing the team to possibly lethal doses of radiation. With the function generator connected to the Guardian, we began to test the communication. In order for the radiation readings to be sent back to the control software, a message has to first be sent to the drone telling it that the software is ready to receive the data. In order to eliminate timeout errors, this message is sent on a timer in order to keep the connection alive. The messages were able to send up to a 10kHz count. This far exceeds the range where it would be safe for humans to enter the area, which ensures that the system will operate in all necessary conditions.

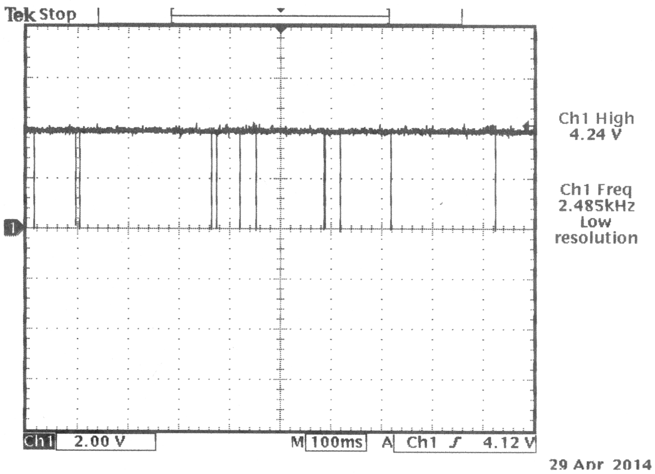


Figure 5: Oscilloscope Reading from T2417AC Testing

IV. CONCLUSION AND FUTURE WORK

This system shows how highly modular sensor networks can be added to COTS platforms to create powerful tools in security and emergency response spaces. The sensor package designed for this system can detect and transmit radiation data back to the operator in real-time, providing a means of gaining actionable intelligence about an environment for operators in a potentially life threatening scenario. This system can easily be expanded to include other sensors, and the message format is very robust and can handle many different types of data. Because of the encryption, this system is ideal for secure applications. The Draganflyer Guardian loaded with full payload assembly and custom radiation sensor package can fly for approximately 30 minutes based on weather conditions. With this flight time, the system can be used to remotely investigate hazardous environment with little or no risk to the operator. Analog video can be streamed live from the GoPro Hero3 which can allow the operator to pilot the drone out of line of sight. While this is not recommended, it is possible and can be useful in specific scenarios.

Future work for this project will include adding facial recognition algorithms to the system. In particular, facial recognition using human visual systems will be added as per Davis Pittaluga and Panetta [1].

ACKNOWLEDGMENT

Special thanks to Andrew Schweig my project partner who worked tirelessly with me to complete this project, Dr. Karen Panetta the project sponsor, my advisor and trusted mentor, and Greg Wood an engineer from Draganfly without whom this would not have been possible. Thanks to Canberra Industries for their help in acquiring the correct Gieger-Müller tube.

REFERENCES

[1] N. Davis, F. Pittaluga, and K. Panetta, "Facial Recognition Using Human Visual System Algorithms for Robotic and UAV Platforms," *2013 IEEE International Conference on Technologies for Practical Robot Applications (TePRA),* Apr 2013.

[2] F, Ballarini, S. Altieri, S. Bortolussi, M. Carante, E. Giroletti, and N. Protti, "The BIANCA Model/Code for Radiation-Induced Cell Death: Application to Human Cells Exposed to Different Radiation Types," *Radiation and Environmental Biophysics,* Mar 2014.

[3] E. Donnelly, J. Nemhauser, J. Smith, Z. Kazzi, E. Farfán, A. Chang, and S. Naeem, "Acute Radiation Syndrome: Assessment and Management," *Southern Medical Journal, 103(6),* 541-546, June 2010

[4] P. Bailey, "A First Responders Guide to Purchasing Personal Radiation Detectors (PRDs) for Homeland Security Purposes," *New York: Environmental Measurement Laboratory, U.S. Department of Homeland Security,* Nov 2004

[5] Department of Health and & Senior Services, New jersey Office of Medical Services, "New Jersey Disaster Triage Tag", *http://www.state.nj.us/health/ems/documents/njdisastertag.pdf*

APPENDIX

Part 1: Component Specifications

DraganFly Innovations, Inc. DraganFlyer Guardian:

Dimensions	
Width x Length	47 x 47 cm
Diameter	71 cm
Height	25 cm
Weight/Payload	
Drone Weight	900 g
Max Payload	420 g
Flight Capabilities	
Max Climb Rate	2 m/s
Max Descent Rate	2 m/s
Max Turn Rate	90 deg/s
Air Speed Min-Max	0-50 km/hr
Max Altitude	2438 m
Battery	14.8 V 2100 mAh rechargeable LiPo 30 min charge time

Motor Type	Four 14.8 V brushless DC
Safety	Two red/green identifier 1 W LEDs Two white rear 1 W LEDs Low battery auto-land and shut-off
Safe Operating Temperature	-25-75 C
Max Operating Humidity	90%
Max Tested Safe Operating Windspeed	10 mph

Communication

Wireless Connections	XBee-PRO SE on drone XBee-PRO and VCP board connected to computer
Frequency Band	IEEE802.15.4 protocol, 11 channels
Wireless Baud Rate	250 kbps
Transmission Power	100 mW
Receiver Sensitivity	-1000 dBm
Wired Connections	Half duplex serial Tx/Rx 8-pin payload (camera) serial control Asynchronous serial read
Wired Baud Rate	115200 bps
Video Connection	5.8 GHz DraganEye analog video up/downlink

Controller

Inputs	Two self-centering dual-axis gimbals Arming toggle Training mode button Four trim switches for gimbals On/Off switch TFT touchscreen Camera shutter button Camera zoom toggle Camera tilt knob
Information Displayed	Connectivity, roll, pitch, yaw, altitude, drone S/N
Frequency Band	IEEE 802.15.4 protocol
Transmission Power	100 mW
Wireless Baud Rate	250 kbps
Receiver Sensitivity	-1000 dBm
Battery	11.1 V 2000 mAh rechargeable LiPo 30 min recharge time

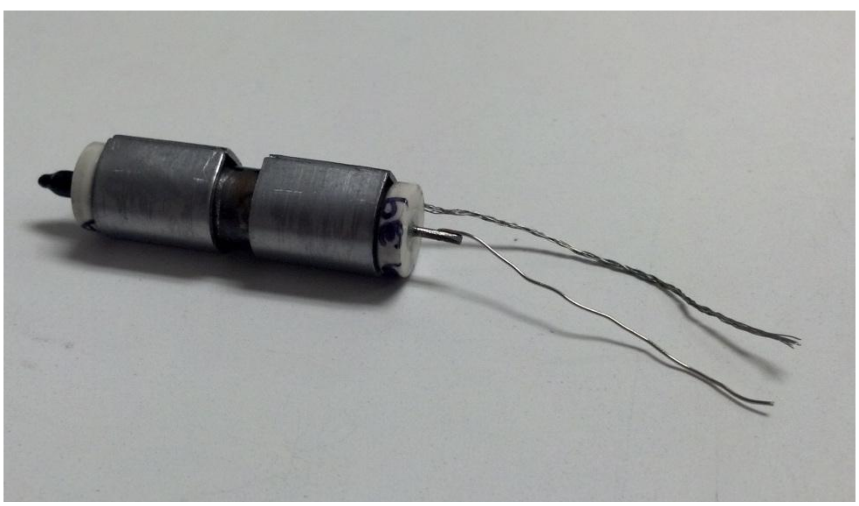
DraganView Software

Min Hardware Requirements	Intel Core2 1.8 GHz, AMD Athalon 64 2.4 GHz 1 GB RAM 1 GB base plus additional data storage NVidia Geforce 6200, ATI Radeon 9550
Operating System	Ubuntu 13.04
Compiling Software	Qt 4.8.5

GoPro Hero 3+ Black Edition

Weight	73.7 g
Height x Length x Depth	3.9 x 5.8 x 2.0 cm
FOV	170˚ and 120˚
Video Resolution	WVGA-4K
Video Aspect Ratio	4:3, 16:9, and 17:9
Video Frame Rate	12-240 fps, depending on resolution
Video Format	NTSC and PAL
Battery	3.7 V 1180 mAh rechargeable Li-Ion
Audio	Mono, unsupported by DraganFly
Storage	Up to 64 GB microSD
Communication/Transfer	Mini USB: video streaming, digital I/O, file transfer
	Micro HDMI: video streaming
	WiFi: digital I/O with remote

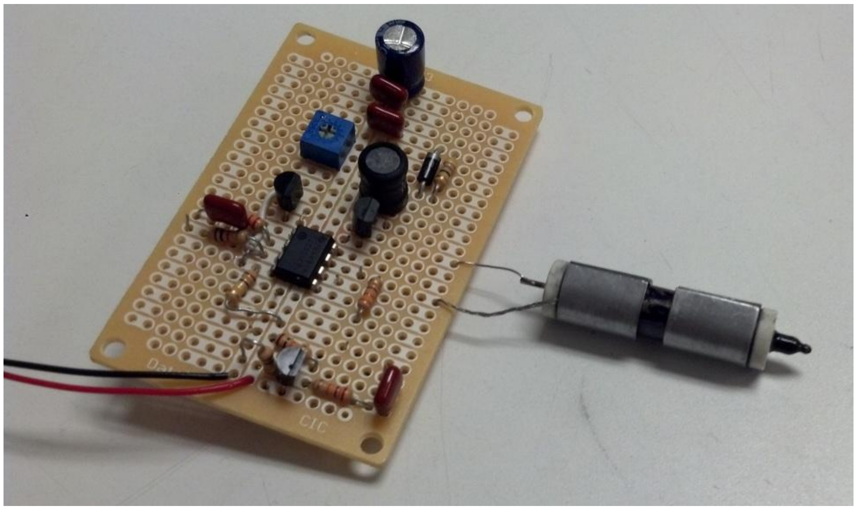
Canberra Industries T2417AC Geiger-Müller Tube:



Weight	8.0 g
Height x Diameter	4.6 x 0.9 cm
Tube Material	Cr, Fe
Operating Voltage	575 V

Sensitivity	450 cpm for ^{137}Cs, 1 mR/hr
Detection Type	β-particles, γ-rays
Max Detection	80 million cpm
Max Background Radiation	5 cpm
Safe Operating Temperature	-40-75 C

Geiger Counter



Weight	24.0 g
Length x Width	3.8 x 7.6 cm
Mounting Material	PCB
Operating Voltage	5.0 V
Outputs	180-960 V high voltage power supply Radiation in counts (5-to-0 V drop)
Detection Source	Canberra Industries T2417AC tube

Part 2: Geiger Counter Bill of Materials and Circuit

Bill of Materials:

Part Name/Number	Listing (see fig. 1)
220 kΩ	R1
330 Ω	R2
1 kΩ	R3
100 kΩ	R4
25 Ω potentiometer	R5
4.7 MΩ	R6
22 kΩ	R7
100 kΩ	R8
10 kΩ	R9
1 nF	C1
0.01 μF	C2
220 pF	C3
15 mH	L1
BUL7420	Q1
2N4401	Q2
2N3904	Q3
UF4007	D1
1N4148	D2
TLC555CP	U1

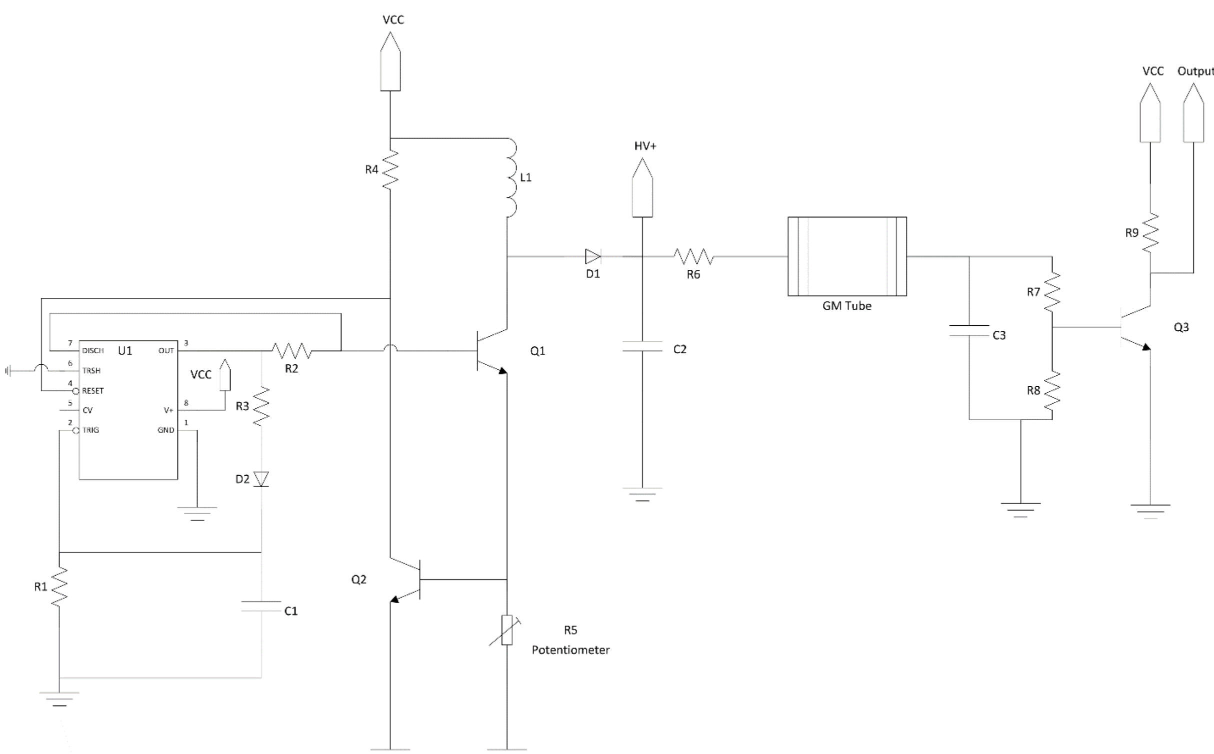
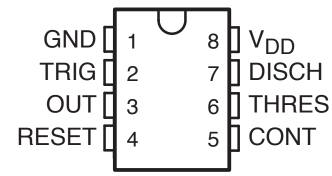


Fig. 1: High-voltage kickback generator and Geiger counter schematic

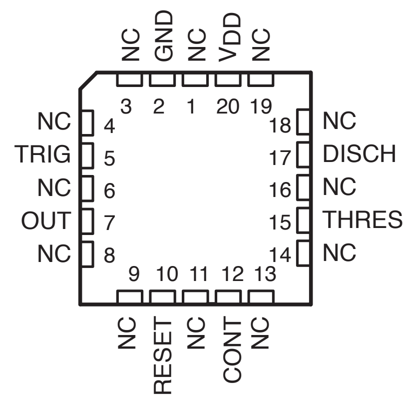
Part 3: Product Datasheets

- **Very Low Power Consumption**
  – 1 mW Typ at V_{DD} = 5 V
- **Capable of Operation in Astable Mode**
- **CMOS Output Capable of Swinging Rail to Rail**
- **High Output-Current Capability**
  – Sink 100 mA Typ
  – Source 10 mA Typ
- **Output Fully Compatible With CMOS, TTL, and MOS**
- **Low Supply Current Reduces Spikes During Output Transitions**
- **Single-Supply Operation From 2 V to 15 V**
- **Functionally Interchangeable With the NE555; Has Same Pinout**
- **ESD Protection Exceeds 2000 V Per MIL-STD-883C, Method 3015.2**
- **Available in Q-Temp Automotive**
  High Reliability Automotive Applications
  Configuration Control/Print Support
  Qualification to Automotive Standards

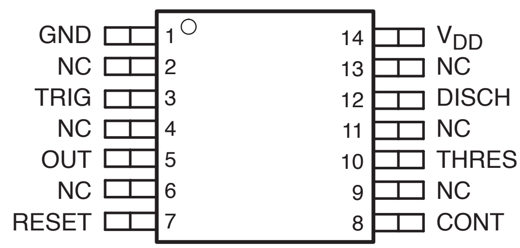
D, DB, JG, OR P PACKAGE
(TOP VIEW)



FK PACKAGE
(TOP VIEW)



PW PACKAGE
(TOP VIEW)



NC – No internal connection

description

The TLC555 is a monolithic timing circuit fabricated using the TI LinCMOS™ process. The timer is fully compatible with CMOS, TTL, and MOS logic and operates at frequencies up to 2 MHz. Because of its high input impedance, this device uses smaller timing capacitors than those used by the NE555. As a result, more accurate time delays and oscillations are possible. Power consumption is low across the full range of power supply voltage.

Like the NE555, the TLC555 has a trigger level equal to approximately one-third of the supply voltage and a threshold level equal to approximately two-thirds of the supply voltage. These levels can be altered by use of the control voltage terminal (CONT). When the trigger input (TRIG) falls below the trigger level, the flip-flop is set and the output goes high. If TRIG is above the trigger level and the threshold input (THRES) is above the threshold level, the flip-flop is reset and the output is low. The reset input (RESET) can override all other inputs and can be used to initiate a new timing cycle. If RESET is low, the flip-flop is reset and the output is low. Whenever the output is low, a low-impedance path is provided between the discharge terminal (DISCH) and GND. All unused inputs should be tied to an appropriate logic level to prevent false triggering.

While the CMOS output is capable of sinking over 100 mA and sourcing over 10 mA, the TLC555 exhibits greatly reduced supply-current spikes during output transitions. This minimizes the need for the large decoupling capacitors required by the NE555.

description (continued)

The TLC555C is characterized for operation from 0°C to 70°C. The TLC555I is characterized for operation from –40°C to 85°C. The TLC555Q is characterized for operation over the automotive temperature range of –40°C to 125°C. The TLC555M is characterized for operation over the full military temperature range of –55°C to 125°C.

AVAILABLE OPTIONS†

		PACKAGED DEVICES					
T_A	V_{DD} RANGE	SMALL OUTLINE (D)‡	SSOP (DB)‡	CHIP CARRIER (FK)	CERAMIC DIP (JG)	PLASTIC DIP (P)	TSSOP (PW)‡
0°C to 70°C	2 V to 15 V	TLC555CD	TLC555CDB	—	—	TLC555CP	TLC555CPW
–40°C to 85°C	3 V to 15 V	TLC555ID	—	—	—	TLC555IP	—
–40°C to 125°C	5 V to 15 V	TLC555QD	—	—	—	—	—
–55°C to 125°C	5 V to 15 V	TLC555MD	—	TLC555MFK	TLC555MJG	TLC555MP	—

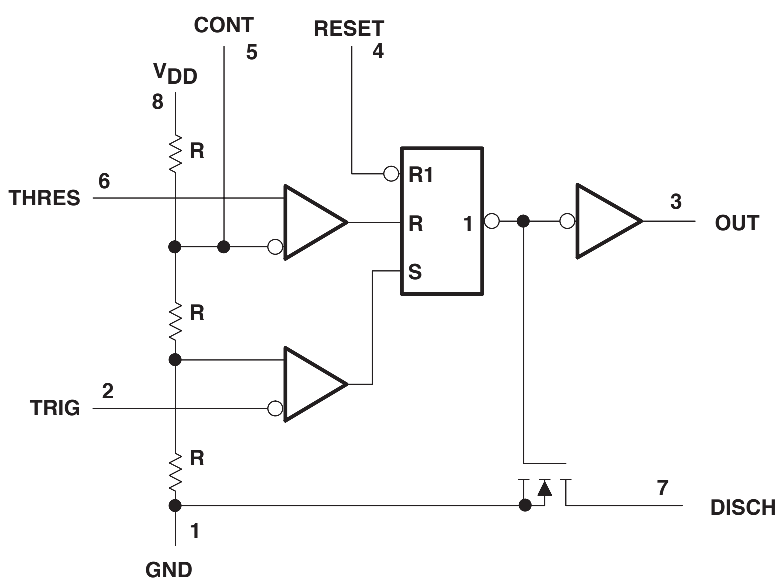
† For the most current package and ordering information, see the Package Option Addendum at the end of this document, or see the TI web site at www.ti.com.
‡ This package is available taped and reeled. Add the R suffix to device type (e.g., TLC555CDR).

FUNCTION TABLE

RESET VOLTAGE‡	TRIGGER VOLTAGE‡	THRESHOLD VOLTAGE‡	OUTPUT	DISCHARGE SWITCH
<MIN	Irrelevant	Irrelevant	L	On
>MAX	<MIN	Irrelevant	H	Off
>MAX	>MAX	>MAX	L	On
>MAX	>MAX	<MIN	As previously established	

‡ For conditions shown as MIN or MAX, use the appropriate value specified under electrical characteristics.

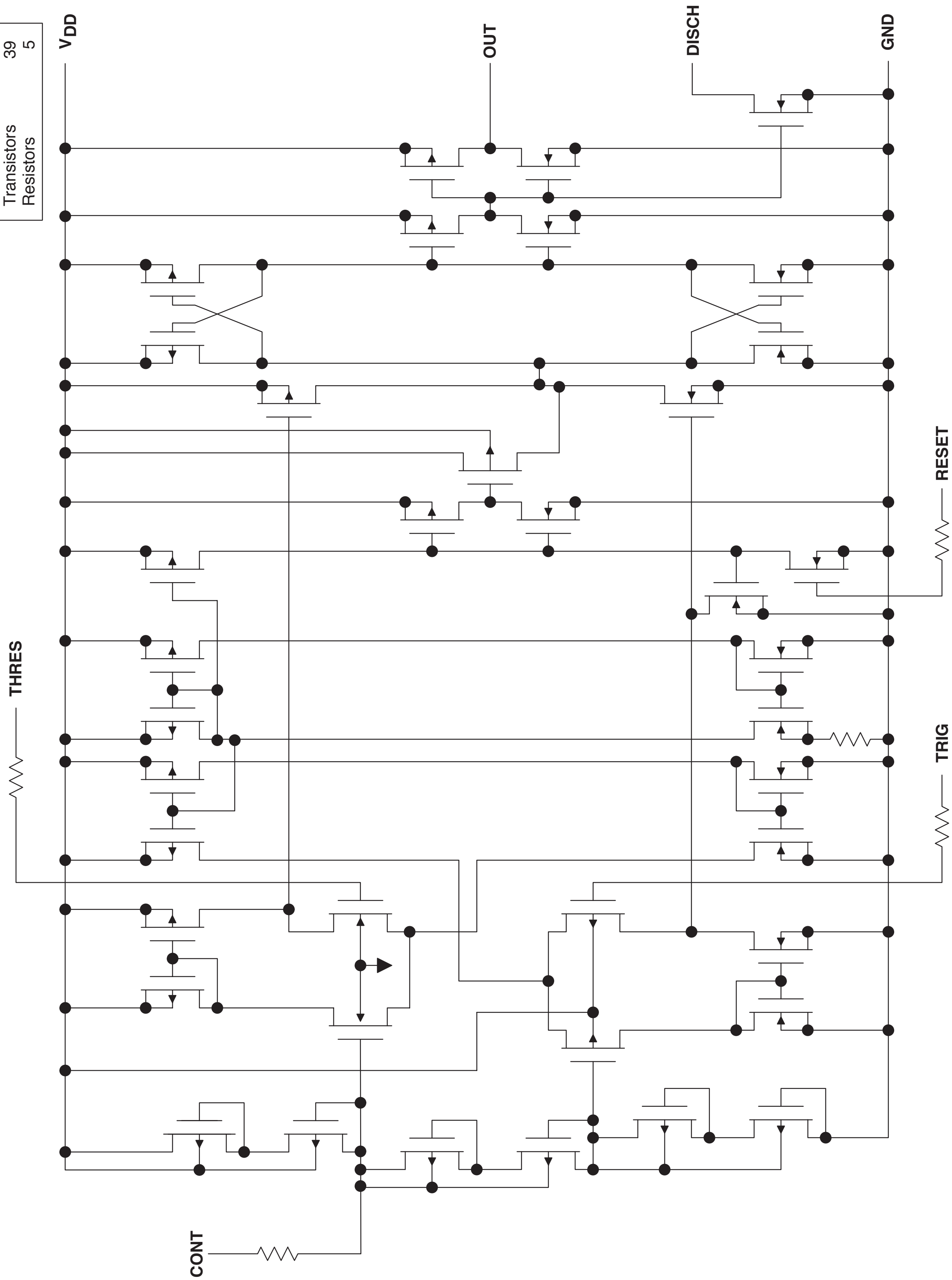
functional block diagram



Pin numbers are for all packages except the FK package. RESET can override TRIG, which can override THRES.

equivalent schematic (each channel)

COMPONENT COUNT	
Transistors	39
Resistors	5



absolute maximum ratings over operating free-air temperature range (unless otherwise noted)†

Supply voltage, V_{DD} (see Note 1) . . . . 18 V
Input voltage range, V_I (any input) . . . . −0.3 to V_{DD}
Sink current, discharge or output . . . . 150 mA
Source current, output, I_O . . . . 15 mA
Continuous total power dissipation . . . . See Dissipation Rating Table
Operating free-air temperature range, T_A: C-suffix . . . . 0°C to 70°C
I-suffix . . . . −40°C to 85°C
Q-suffix . . . . −40°C to 125°C
M-suffix . . . . −55°C to 125°C
Storage temperature range . . . . −65°C to 150°C
Case temperature for 60 seconds: FK package . . . . 260°C
Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds: JG package . . . . 300°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds: D, DB, P, or PW package . . . . 260°C

† Stresses beyond those listed under “absolute maximum ratings” may cause permanent damage to the device. These are stress ratings only and functional operation of the device at these or any other conditions beyond those indicated under “recommended operating conditions” is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

NOTE 1: All voltage values are with respect to network GND.

DISSIPATION RATING TABLE

PACKAGE	$T_A \leq 25°C$ POWER RATING	DERATING FACTOR ABOVE $T_A = 25°C$	$T_A = 70°C$ POWER RATING	$T_A = 85°C$ POWER RATING	$T_A = 125°C$ POWER RATING
D	725 mW	5.8 mW/°C	464 mW	377 mW	145 mW
DB	525 mW	4.2 mW/°C	336 mW	273 mW	105 mW
FK	1375 mW	11.0 mW/°C	880 mW	715 mW	275 mW
JG	1050 mW	8.4 mW/°C	672 mW	546 mW	210 mW
P	1000 mW	8.0 mW/°C	640 mW	520 mW	200 mW
PW	525 mW	4.2 mW/°C	336 mW	273 mW	105 mW

recommended operating conditions

		MIN	MAX	UNIT
Supply voltage, V_{DD}		2	15	V
Operating free-air temperature range, T_A	TLC555C	0	70	°C
	TLC555I	–40	85	
	TLC555Q	–40	125	
	TLC555M	–55	125	

electrical characteristics at specified free-air temperature, V_{DD} = 2 V for TLC555C, V_{DD} = 3 V for TLC555I

PARAMETER		TEST CONDITIONS	T_A†	TLC555C			TLC555I			UNIT
				MIN	TYP	MAX	MIN	TYP	MAX	
V_{IT}	Threshold voltage		25°C	0.95	1.33	1.65	1.6		2.4	V
			Full range	0.85		1.75	1.5		2.5	
I_{IT}	Threshold current		25°C		10			10		pA
			MAX		75			150		
$V_{I(TRIG)}$	Trigger voltage		25°C	0.4	0.67	0.95	0.71	1	1.29	V
			Full range	0.3		1.05	0.61		1.39	
$I_{I(TRIG)}$	Trigger current		25°C		10			10		pA
			MAX		75			150		
$V_{I(RESET)}$	Reset voltage		25°C	0.4	1.1	1.5	0.4	1.1	1.5	V
			Full range	0.3		2	0.3		1.8	
$I_{I(RESET)}$	Reset current		25°C		10			10		pA
			MAX		75			150		
	Control voltage (open circuit) as a percentage of supply voltage		MAX		66.7%			66.7%		
	Discharge switch on-stage voltage	I_{OL} = 1 mA	25°C		0.03	0.2		0.03	0.2	V
			Full range			0.25			0.375	
	Discharge switch off-stage current		25°C		0.1			0.1		nA
			MAX		0.5			120		
V_{OH}	High-level output voltage	I_{OH} = −300 μA	25°C	1.5	1.9		2.5	2.85		V
			Full range	1.5			2.5			
V_{OL}	Low-level output voltage	I_{OL} = 1 mA	25°C		0.07	0.3		0.07	0.3	V
			Full range			0.35			0.4	
I_{DD}	Supply current	See Note 2	25°C			250			250	μA
			Full range			400			500	

† Full range is 0°C to 70°C for the TLC555C and –40°C to 85°C for the TLC555I. For conditions shown as MAX, use the appropriate value specified in the recommended operating conditions table.

NOTE 2: These values apply for the expected operating configurations in which THRES is connected directly to DISCH or to TRIG.

electrical characteristics at specified free-air temperature, V_{DD} = 5 V

PARAMETER		TEST CONDITIONS	T_A†	TLC555C			TLC555I			TLC555Q, TLC555M			UNIT
				MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
V_{IT}	Threshold voltage		25°C	2.8	3.3	3.8	2.8	3.3	3.8	2.8	3.3	3.8	V
			Full range	2.7		3.9	2.7		3.9	2.7		3.9	
I_{IT}	Threshold current		25°C		10			10			10		pA
			MAX		75			150			5000		
$V_{I(TRIG)}$	Trigger voltage		25°C	1.36	1.66	1.96	1.36	1.66	1.96	1.36	1.66	1.96	V
			Full range	1.26		2.06	1.26		2.06	1.26		2.06	
$I_{I(TRIG)}$	Trigger current		25°C		10			10			10		pA
			MAX		75			150			5000		
$V_{I(RESET)}$	Reset voltage		25°C	0.4	1.1	1.5	0.4	1.1	1.5	0.4	1.1	1.5	V
			Full range	0.3		1.8	0.3		1.8	0.3		1.8	
$I_{I(RESET)}$	Reset current		25°C		10			10			10		pA
			MAX		75			150			5000		
	Control voltage (open circuit) as a percentage of supply voltage		MAX		66.7%			66.7%			66.7%		
	Discharge switch on-state voltage	I_{OL} = 10 mA	25°C		0.14	0.5		0.14	0.5		0.14	0.5	V
			Full range			0.6			0.6			0.6	
	Discharge switch off-state current		25°C		0.1			0.1			0.1		nA
			MAX		0.5			120			120		
V_{OH}	High-level output voltage	I_{OH} = − 1 mA	25°C	4.1	4.8		4.1	4.8		4.1	4.8		V
			Full range	4.1			4.1			4.1			
V_{OL}	Low-level output voltage	I_{OL} = 8 mA	25°C		0.21	0.4		0.21	0.4		0.21	0.4	V
			Full range			0.5			0.5			0.6	
		I_{OL} = 5 mA	25°C		0.13	0.3		0.13	0.3		0.13	0.3	
			Full range			0.4			0.4			0.45	
		I_{OL} = 3.2 mA	25°C		0.08	0.3		0.08	0.3		0.08	0.3	
			Full range			0.35			0.35			0.4	
I_{DD}	Supply current	See Note 2	25°C		170	350		170	350		170	350	µA
			Full range			500			600			700	

† Full range is 0°C to 70°C the for TLC555C, −40°C to 85°C for the TLC555I, −40°C to 125°C for the TLC555Q, and −55°C to 125°C for the TLC555M. For conditions shown as MAX, use the appropriate value specified in the recommended operating conditions table.

NOTE 2: These values apply for the expected operating configurations in which THRES is connected directly to DISCH or TRIG.

electrical characteristics at specified free-air temperature, V_{DD} = 15 V

PARAMETER		TEST CONDITIONS	T_A†	TLC555C			TLC555I			TLC555Q, TLC555M			UNIT
				MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
V_{IT}	Threshold voltage		25°C	9.45	10	10.55	9.45	10	10.55	9.45	10	10.55	V
			Full range	9.35		10.65	9.35		10.65	9.35		10.65	
I_{IT}	Threshold current		25°C		10			10			10		pA
			MAX		75			150			5000		
$V_{I(TRIG)}$	Trigger voltage		25°C	4.65	5	5.35	4.65	5	5.35	4.65	5	5.35	V
			Full range	4.55		5.45	4.55		5.45	4.55		5.45	
$I_{I(TRIG)}$	Trigger current		25°C		10			10			10		pA
			MAX		75			150			5000		
$V_{I(RESET)}$	Reset voltage		25°C	0.4	1.1	1.5	0.4	1.1	1.5	0.4	1.1	1.5	V
			Full range	0.3		1.8	0.3		1.8	0.3		1.8	
$I_{I(RESET)}$	Reset current		25°C		10			10			10		pA
			MAX		75			150			5000		
	Control voltage (open circuit) as a percentage of supply voltage		MAX		66.7%			66.7%			66.7%		
	Discharge switch on-state voltage	I_{OL} = 100 mA	25°C		0.77	1.7		0.77	1.7		0.77	1.7	V
			Full range			1.8			1.8			1.8	
	Discharge switch off-state current		25°C		0.1			0.1			0.1		nA
			MAX		0.5			120			120		
V_{OH}	High-level output voltage	I_{OH} = – 10 mA	25°C	12.5	14.2		12.5	14.2		12.5	14.2		V
			Full range	12.5			12.5			12.5			
		I_{OH} = – 5 mA	25°C	13.5	14.6		13.5	14.6		13.5	14.6		
			Full range	13.5			13.5			13.5			
		I_{OH} = – 1 mA	25°C	14.2	14.9		14.2	14.9		14.2	14.9		
			Full range	14.2			14.2			14.2			
V_{OL}	Low-level output voltage	I_{OL} = 100 mA	25°C		1.28	3.2		1.28	3.2		1.28	3.2	V
			Full range			3.6			3.7			3.8	
		I_{OL} = 50 mA	25°C		0.63	1		0.63	1		0.63	1	
			Full range			1.3			1.4			1.5	
		I_{OL} = 10 mA	25°C		0.12	0.3		0.12	0.3		0.12	0.3	
			Full range			0.4			0.4			0.45	
I_{DD}	Supply current	See Note 2	25°C		360	600		360	600		360	600	µA
			Full range			800			900			1000	

† Full range is 0°C to 70°C for TLC555C, –40°C to 85°C for TLC555I, –40°C to 125°C for the TLC555Q, and –55°C to 125°C for TLC555M. For conditions shown as MAX, use the appropriate value specified in the recommended operating conditions table.

NOTE 2: These values apply for the expected operating configurations in which THRES is connected directly to DISCH or TRIG.

operating characteristics, V_{DD} = 5 V, T_A = 25°C (unless otherwise noted)

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
	Initial error of timing interval‡	V_{DD} = 5 V to 15 V, C_T = 0.1 μF,	R_A = R_B = 1 kΩ to 100 kΩ, See Note 3		1%	3%	
	Supply voltage sensitivity of timing interval				0.1	0.5	%/V
t_r	Output pulse rise time	R_L = 10 MΩ,	C_L = 10 pF		20	75	ns
t_f	Output pulse fall time				15	60	
f_{max}	Maximum frequency in astable mode	R_A = 470 Ω, C_T = 200 pF,	R_B = 200 Ω, See Note 3	1.2	2.1		MHz

‡ Timing interval error is defined as the difference between the measured value and the average value of a random sample from each process run.

NOTE 3: R_A, R_B, and C_T are as defined in Figure 1.

electrical characteristics at V_{DD} = 5 V, T_A = 25°C

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
V_{IT}	Threshold voltage		2.8	3.3	3.8	V
I_{IT}	Threshold current			10		pA
$V_{I(TRIG)}$	Trigger voltage		1.36	1.66	1.96	V
$I_{I(TRIG)}$	Trigger current			10		pA
$V_{I(RESET)}$	Reset voltage		0.4	1.1	1.5	V
$I_{I(RESET)}$	Reset current			10		pA
	Control voltage (open circuit) as a percentage of supply voltage			66.7%		
	Discharge switch on-state voltage	I_{OL} = 10 mA		0.14	0.5	V
	Discharge switch off-state current			0.1		nA
V_{OH}	High-level output voltage	I_{OH} = – 1 mA	4.1	4.8		V
V_{OL}	Low-level output voltage	I_{OL} = 8 mA		0.21	0.4	V
		I_{OL} = 5 mA		0.13	0.3	
		I_{OL} = 3.2 mA		0.08	0.3	
I_{DD}	Supply current	See Note 2		170	350	μA

NOTE 2: These values apply for the expected operating configurations in which THRES is connected directly to DISCH or TRIG.

TYPICAL CHARACTERISTICS

DISCHARGE SWITCH ON-STATE RESISTANCE vs FREE-AIR TEMPERATURE

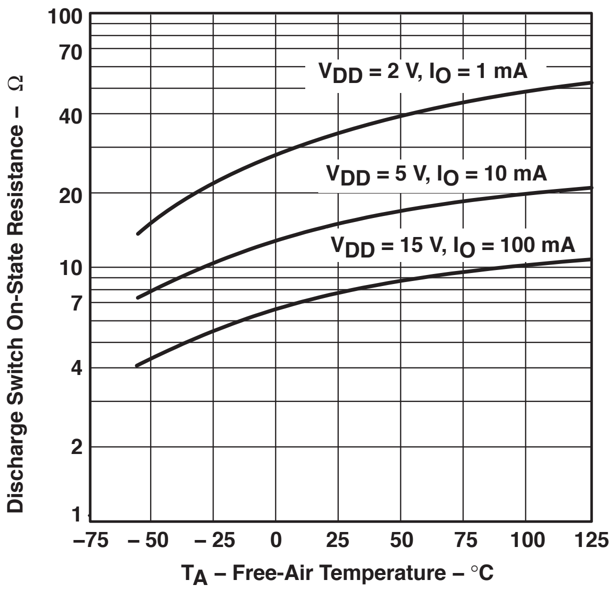
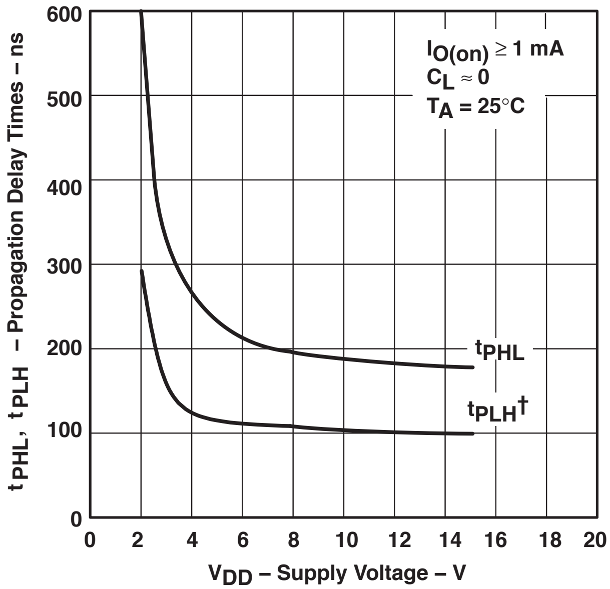


Figure 1

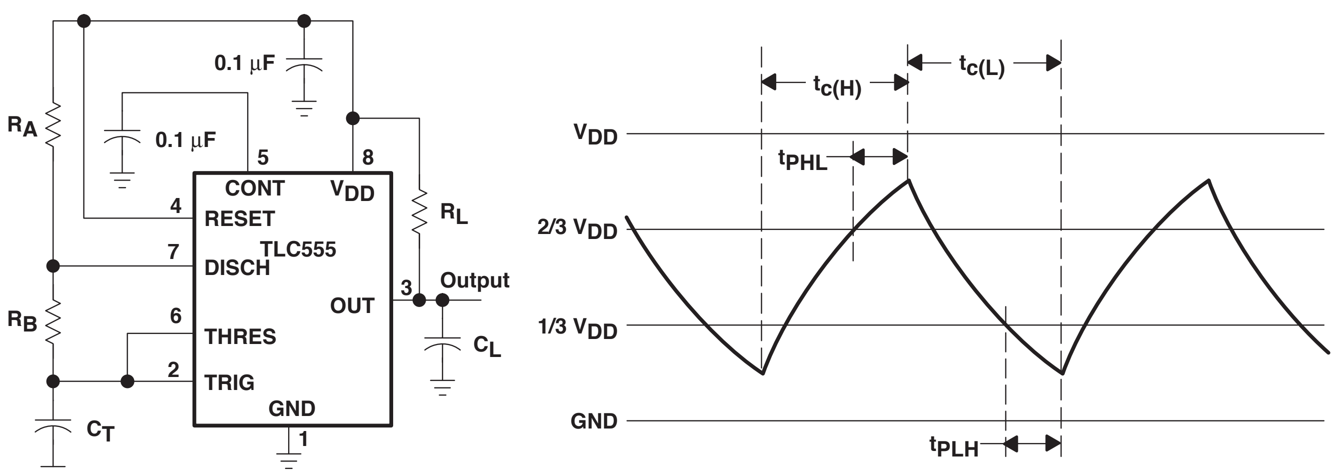
PROPAGATION DELAY TIMES TO DISCHARGE OUTPUT FROM TRIGGER AND THRESHOLD SHORTED TOGETHER vs SUPPLY VOLTAGE



† The effects of the load resistance on these values must be taken into account separately.

Figure 2

APPLICATION INFORMATION



Pin numbers shown are for all packages except the FK package.

CIRCUIT

TRIGGER AND THRESHOLD VOLTAGE WAVEFORM

Figure 3. Astable Operation

APPLICATION INFORMATION

Connecting TRIG to THRES, as shown in Figure 3, causes the timer to run as a multivibrator. The capacitor C_T charges through R_A and R_B to the threshold voltage level (approximately 0.67 V_{DD}) and then discharges through R_B only to the value of the trigger voltage level (approximately 0.33 V_{DD}). The output is high during the charging cycle ($t_{c(H)}$) and low during the discharge cycle ($t_{c(L)}$). The duty cycle is controlled by the values of R_A, R_B, and C_T as shown in the equations below.

$$t_{c(H)} \approx C_T (R_A + R_B) \ln 2 \quad (\ln 2 = 0.693)$$

$$t_{c(L)} \approx C_T R_B \ln 2$$

$$\text{Period} = t_{c(H)} + t_{c(L)} \approx C_T (R_A + 2R_B) \ln 2$$

$$\text{Output driver duty cycle} = \frac{t_{c(L)}}{t_{c(H)} + t_{c(L)}} \approx 1 - \frac{R_B}{R_A + 2R_B}$$

$$\text{Output waveform duty cycle} = \frac{t_{c(H)}}{t_{c(H)} + t_{c(L)}} \approx \frac{R_B}{R_A + 2R_B}$$

The 0.1-µF capacitor at CONT in Figure 3 decreases the period by about 10%.

The formulas shown above do not allow for any propagation delay times from the TRIG and THRES inputs to DISCH. These delay times add directly to the period and create differences between calculated and actual values that increase with frequency. In addition, the internal on-state resistance r_{on} during discharge adds to R_B to provide another source of timing error in the calculation when R_B is very low or r_{on} is very high.

The equations below provide better agreement with measured values.

$$t_{c(H)} = C_T (R_A + R_B) \ln \left[3 - \exp\left(\frac{-t_{PLH}}{C_T (R_B + r_{on})} \right) \right] + t_{PHL}$$

$$t_{c(L)} = C_T (R_B + r_{on}) \ln \left[3 - \exp\left(\frac{-t_{PHL}}{C_T (R_A + R_B)} \right) \right] + t_{PLH}$$

These equations and those given earlier are similar in that a time constant is multiplied by the logarithm of a number or function. The limit values of the logarithmic terms must be between ln 2 at low frequencies and ln 3 at extremely high frequencies. For a duty cycle close to 50%, an appropriate constant for the logarithmic terms can be substituted with good results. Duty cycles less than 50% $\frac{t_{c(H)}}{t_{c(H)} + t_{c(L)}}$ require that $\frac{t_{c(H)}}{t_{c(L)}} < 1$ and possibly $R_A \le r_{on}$. These conditions can be difficult to obtain.

In monostable applications, the trip point on TRIG can be set by a voltage applied to CONT. An input voltage between 10% and 80% of the supply voltage from a resistor divider with at least 500-µA bias provides good results.

PACKAGING INFORMATION

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead/Ball Finish	MSL Peak Temp (3)	Op Temp (°C)	Top-Side Markings (4)	Samples
5962-89503012A	ACTIVE	LCCC	FK	20	1	TBD	Call TI	Call TI	-55 to 125	5962-89503012A TLC555MFKB	Samples
5962-8950301PA	ACTIVE	CDIP	JG	8	1	TBD	Call TI	Call TI	-55 to 125	8950301PA TLC555M	Samples
TLC555CD	ACTIVE	SOIC	D	8	75	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	0 to 70	TL555C	Samples
TLC555CDG4	ACTIVE	SOIC	D	8	75	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	0 to 70	TL555C	Samples
TLC555CDR	ACTIVE	SOIC	D	8	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	0 to 70	TL555C	Samples
TLC555CDRG4	ACTIVE	SOIC	D	8	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	0 to 70	TL555C	Samples
TLC555CP	ACTIVE	PDIP	P	8	50	Pb-Free (RoHS)	CU NIPDAU	N / A for Pkg Type	0 to 70	TLC555CP	Samples
TLC555CPE4	ACTIVE	PDIP	P	8	50	Pb-Free (RoHS)	CU NIPDAU	N / A for Pkg Type	0 to 70	TLC555CP	Samples
TLC555CPSR	ACTIVE	SO	PS	8	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	0 to 70	P555	Samples
TLC555CPSRG4	ACTIVE	SO	PS	8	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	0 to 70	P555	Samples
TLC555CPW	ACTIVE	TSSOP	PW	14	90	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	0 to 70	P555	Samples
TLC555CPWG4	ACTIVE	TSSOP	PW	14	90	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	0 to 70	P555	Samples
TLC555CPWR	ACTIVE	TSSOP	PW	14	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	0 to 70	P555	Samples
TLC555CPWRG4	ACTIVE	TSSOP	PW	14	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	0 to 70	P555	Samples
TLC555ID	ACTIVE	SOIC	D	8	75	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	-40 to 85	TL555I	Samples
TLC555IDG4	ACTIVE	SOIC	D	8	75	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	-40 to 85	TL555I	Samples

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead/Ball Finish	MSL Peak Temp (3)	Op Temp (°C)	Top-Side Markings (4)	Samples
TLC555IDR	ACTIVE	SOIC	D	8	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	-40 to 85	TL555I	Samples
TLC555IDRG4	ACTIVE	SOIC	D	8	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	-40 to 85	TL555I	Samples
TLC555IP	ACTIVE	PDIP	P	8	50	Pb-Free (RoHS)	CU NIPDAU	N / A for Pkg Type	-40 to 85	TLC555IP	Samples
TLC555IPE4	ACTIVE	PDIP	P	8	50	Pb-Free (RoHS)	CU NIPDAU	N / A for Pkg Type	-40 to 85	TLC555IP	Samples
TLC555MFKB	ACTIVE	LCCC	FK	20	1	TBD	POST-PLATE	N / A for Pkg Type	-55 to 125	5962-89503012A TLC555MFKB	Samples
TLC555MJG	ACTIVE	CDIP	JG	8	1	TBD	A42	N / A for Pkg Type	-55 to 125	TLC555MJG	Samples
TLC555MJGB	ACTIVE	CDIP	JG	8	1	TBD	A42	N / A for Pkg Type	-55 to 125	8950301PA TLC555M	Samples
TLC555MP	OBSOLETE	PDIP	P	8		TBD	Call TI	Call TI	-55 to 125		
TLC555QDR	ACTIVE	SOIC	D	8	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	-40 to 125	TL555Q	Samples
TLC555QDRG4	ACTIVE	SOIC	D	8	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM		TL555Q	Samples

(1) The marketing status values are defined as follows:
ACTIVE: Product device recommended for new designs.
LIFEBUY: TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.
NRND: Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.
PREVIEW: Device has been announced but is not in production. Samples may or may not be available.
OBSOLETE: TI has discontinued the production of the device.

(2) Eco Plan - The planned eco-friendly classification: Pb-Free (RoHS), Pb-Free (RoHS Exempt), or Green (RoHS & no Sb/Br) - please check http://www.ti.com/productcontent for the latest availability information and additional product content details.
TBD: The Pb-Free/Green conversion plan has not been defined.
Pb-Free (RoHS): TI's terms "Lead-Free" or "Pb-Free" mean semiconductor products that are compatible with the current RoHS requirements for all 6 substances, including the requirement that lead not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, TI Pb-Free products are suitable for use in specified lead-free processes.
Pb-Free (RoHS Exempt): This component has a RoHS exemption for either 1) lead-based flip-chip solder bumps used between the die and package, or 2) lead-based die adhesive used between the die and leadframe. The component is otherwise considered Pb-Free (RoHS compatible) as defined above.
Green (RoHS & no Sb/Br): TI defines "Green" to mean Pb-Free (RoHS compatible), and free of Bromine (Br) and Antimony (Sb) based flame retardants (Br or Sb do not exceed 0.1% by weight in homogeneous material)

[(3)] MSL, Peak Temp. -- The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

[(4)] Only one of markings shown within the brackets will appear on the physical device.

Important Information and Disclaimer: The information provided on this page represents TI's knowledge and belief as of the date that it is provided. TI bases its knowledge and belief on information provided by third parties, and makes no representation or warranty as to the accuracy of such information. Efforts are underway to better integrate information from third parties. TI has taken and continues to take reasonable steps to provide representative and accurate information but may not have conducted destructive testing or chemical analysis on incoming materials and chemicals. TI and TI suppliers consider certain information to be proprietary, and thus CAS numbers and other limited information may not be available for release.

In no event shall TI's liability arising out of such information exceed the total purchase price of the TI part(s) at issue in this document sold by TI to Customer on an annual basis.

OTHER QUALIFIED VERSIONS OF TLC555, TLC555M :

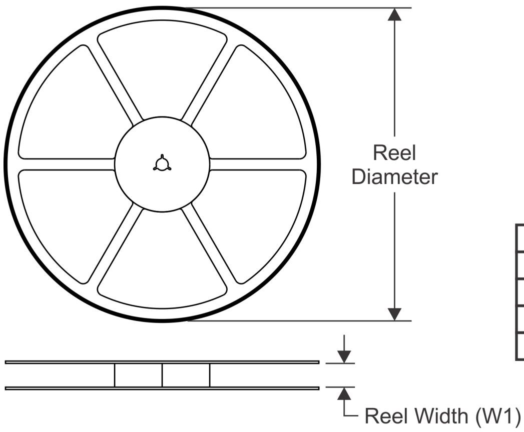
- Catalog: TLC555
- Automotive: TLC555-Q1, TLC555-Q1
- Military: TLC555M

NOTE: Qualified Version Definitions:

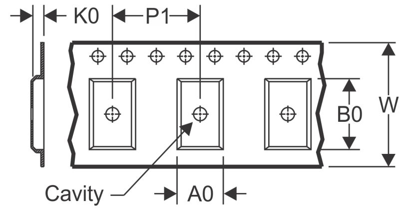
- Catalog - TI's standard catalog product
- Automotive - Q100 devices qualified for high-reliability automotive applications targeting zero defects
- Military - QML certified for Military and Defense Applications

TAPE AND REEL INFORMATION

REEL DIMENSIONS

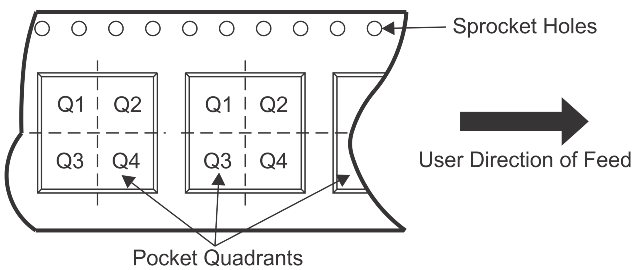


TAPE DIMENSIONS



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

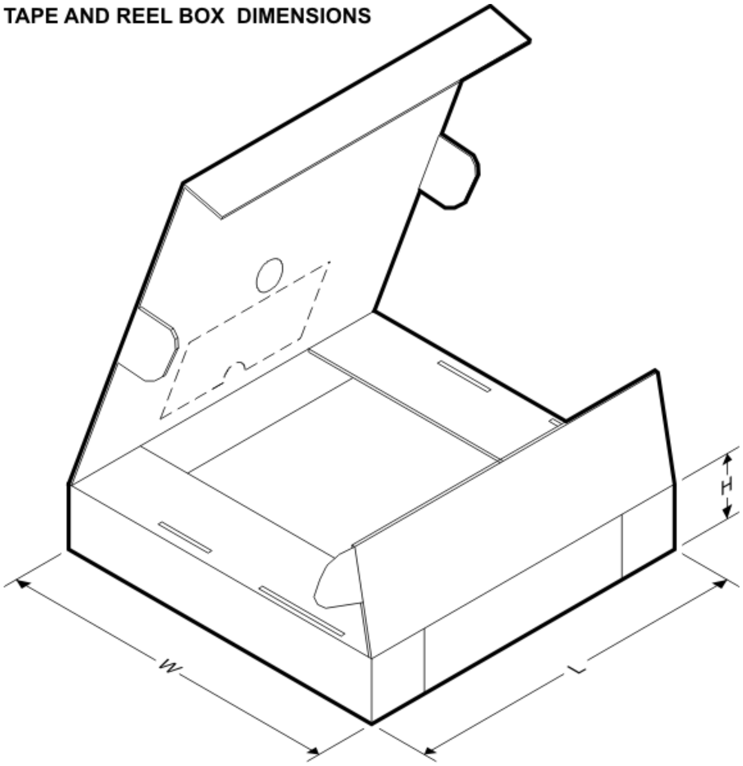
QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE



*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Reel Diameter (mm)	Reel Width W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P1 (mm)	W (mm)	Pin1 Quadrant
TLC555CDR	SOIC	D	8	2500	330.0	12.4	6.4	5.2	2.1	8.0	12.0	Q1
TLC555CPSR	SO	PS	8	2000	330.0	16.4	8.2	6.6	2.5	12.0	16.0	Q1
TLC555CPWR	TSSOP	PW	14	2000	330.0	12.4	6.9	5.6	1.6	8.0	12.0	Q1
TLC555IDR	SOIC	D	8	2500	330.0	12.4	6.4	5.2	2.1	8.0	12.0	Q1
TLC555QDR	SOIC	D	8	2500	330.0	12.4	6.4	5.2	2.1	8.0	12.0	Q1
TLC555QDRG4	SOIC	D	8	2500	330.0	12.4	6.4	5.2	2.1	8.0	12.0	Q1

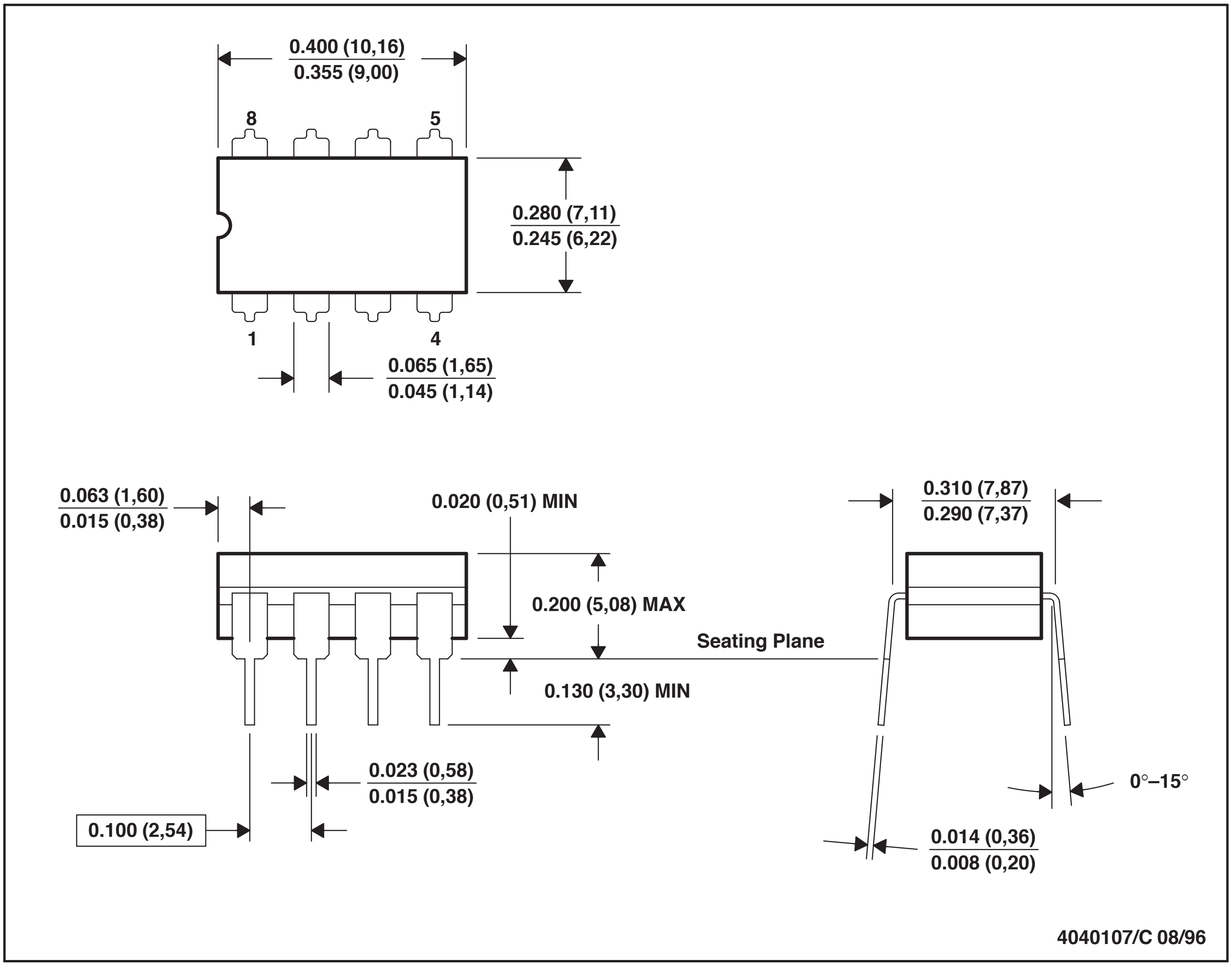
TAPE AND REEL BOX DIMENSIONS



*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
TLC555CDR	SOIC	D	8	2500	340.5	338.1	20.6
TLC555CPSR	SO	PS	8	2000	367.0	367.0	38.0
TLC555CPWR	TSSOP	PW	14	2000	367.0	367.0	35.0
TLC555IDR	SOIC	D	8	2500	340.5	338.1	20.6
TLC555QDR	SOIC	D	8	2500	367.0	367.0	35.0
TLC555QDRG4	SOIC	D	8	2500	367.0	367.0	35.0

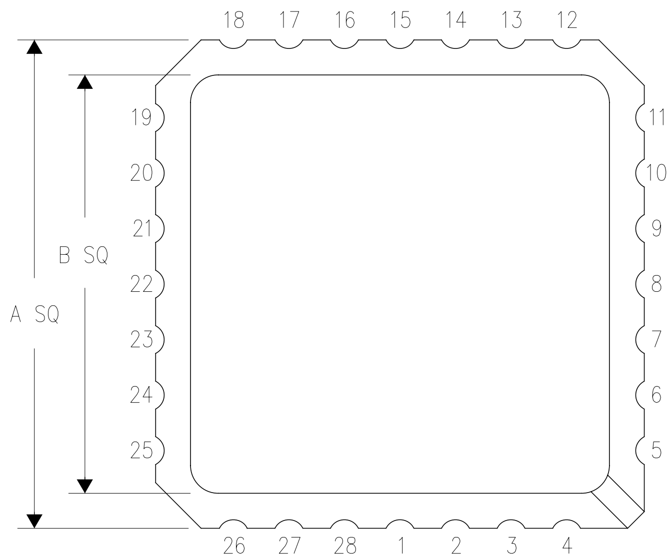
JG (R-GDIP-T8) **CERAMIC DUAL-IN-LINE**



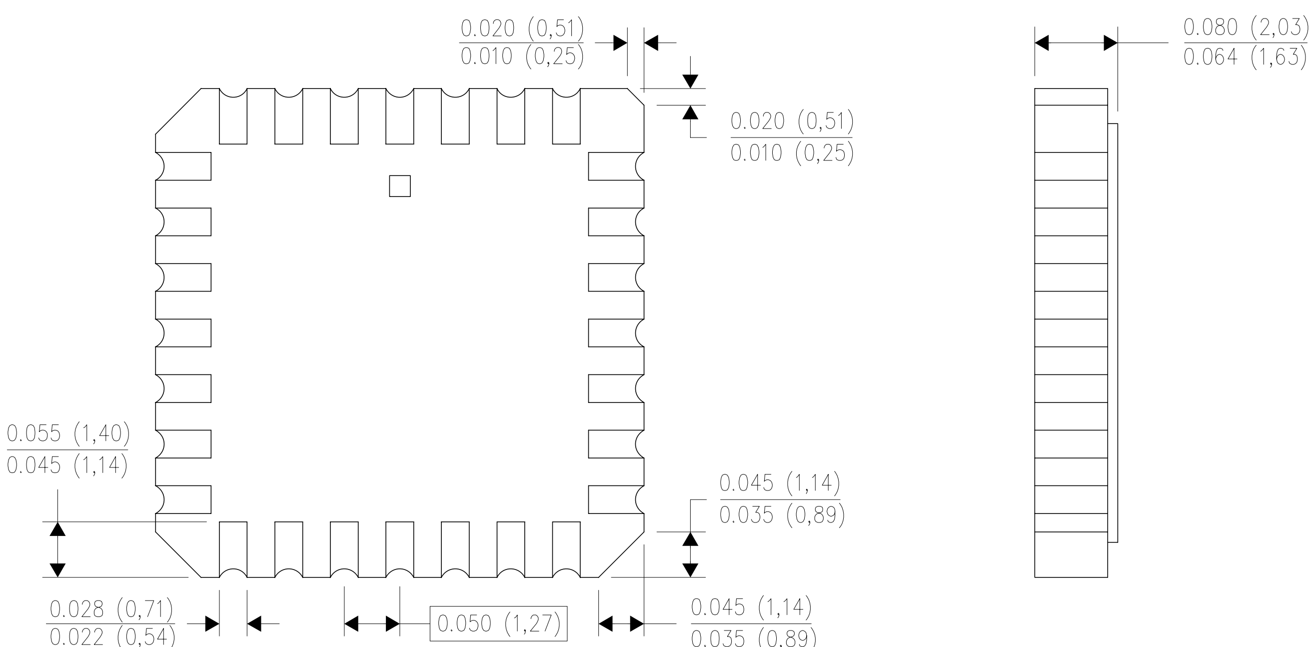
NOTES:
- A. All linear dimensions are in inches (millimeters).
- B. This drawing is subject to change without notice.
- C. This package can be hermetically sealed with a ceramic lid using glass frit.
- D. Index point is provided on cap for terminal identification.
- E. Falls within MIL STD 1835 GDIP1-T8

FK (S-CQCC-N**) LEADLESS CERAMIC CHIP CARRIER

28 TERMINAL SHOWN



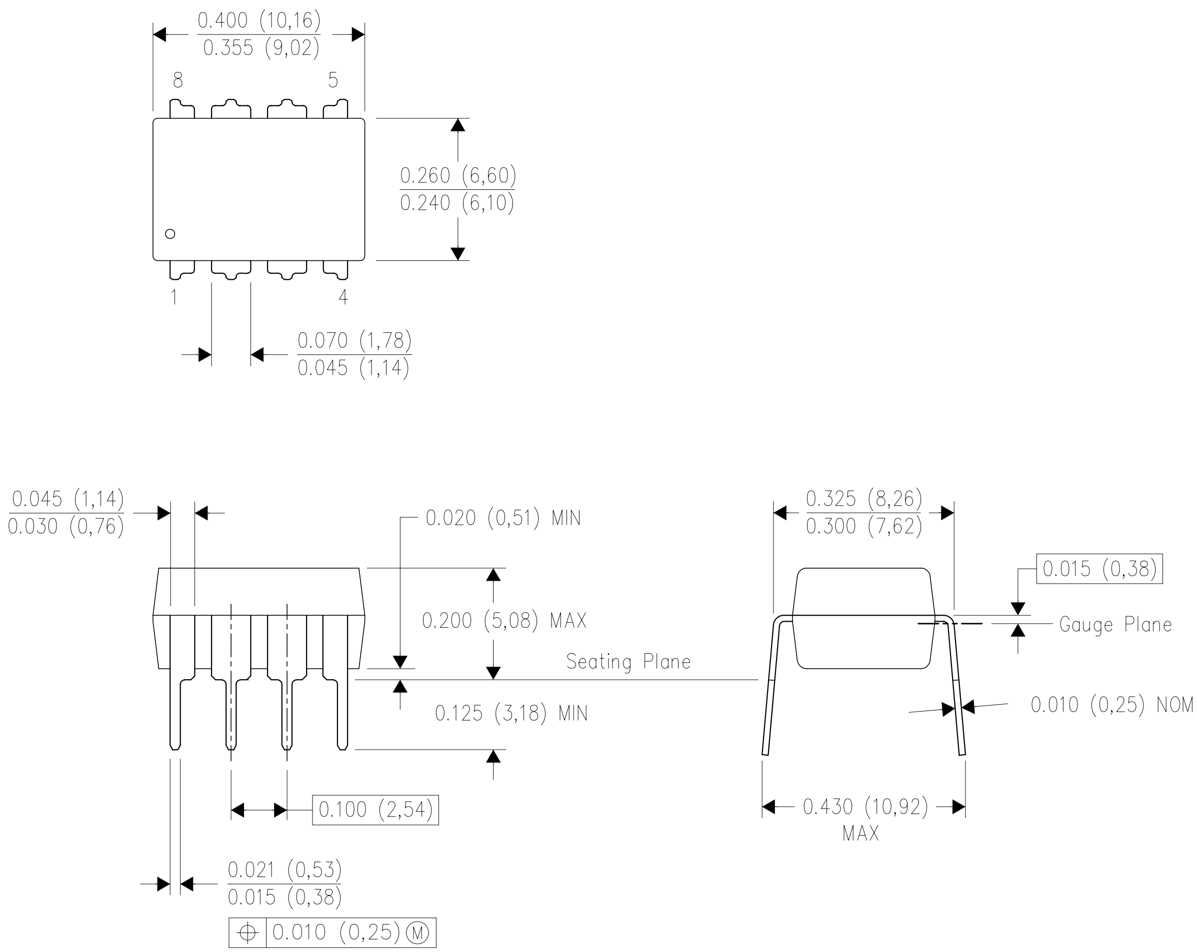
NO. OF TERMINALS **	A		B	
	MIN	MAX	MIN	MAX
20	0.342 (8,69)	0.358 (9,09)	0.307 (7,80)	0.358 (9,09)
28	0.442 (11,23)	0.458 (11,63)	0.406 (10,31)	0.458 (11,63)
44	0.640 (16,26)	0.660 (16,76)	0.495 (12,58)	0.560 (14,22)
52	0.740 (18,78)	0.761 (19,32)	0.495 (12,58)	0.560 (14,22)
68	0.938 (23,83)	0.962 (24,43)	0.850 (21,6)	0.858 (21,8)
84	1.141 (28,99)	1.165 (29,59)	1.047 (26,6)	1.063 (27,0)



4040140/D 01/11

NOTES:
- A. All linear dimensions are in inches (millimeters).
- B. This drawing is subject to change without notice.
- C. This package can be hermetically sealed with a metal lid.
- D. Falls within JEDEC MS-004

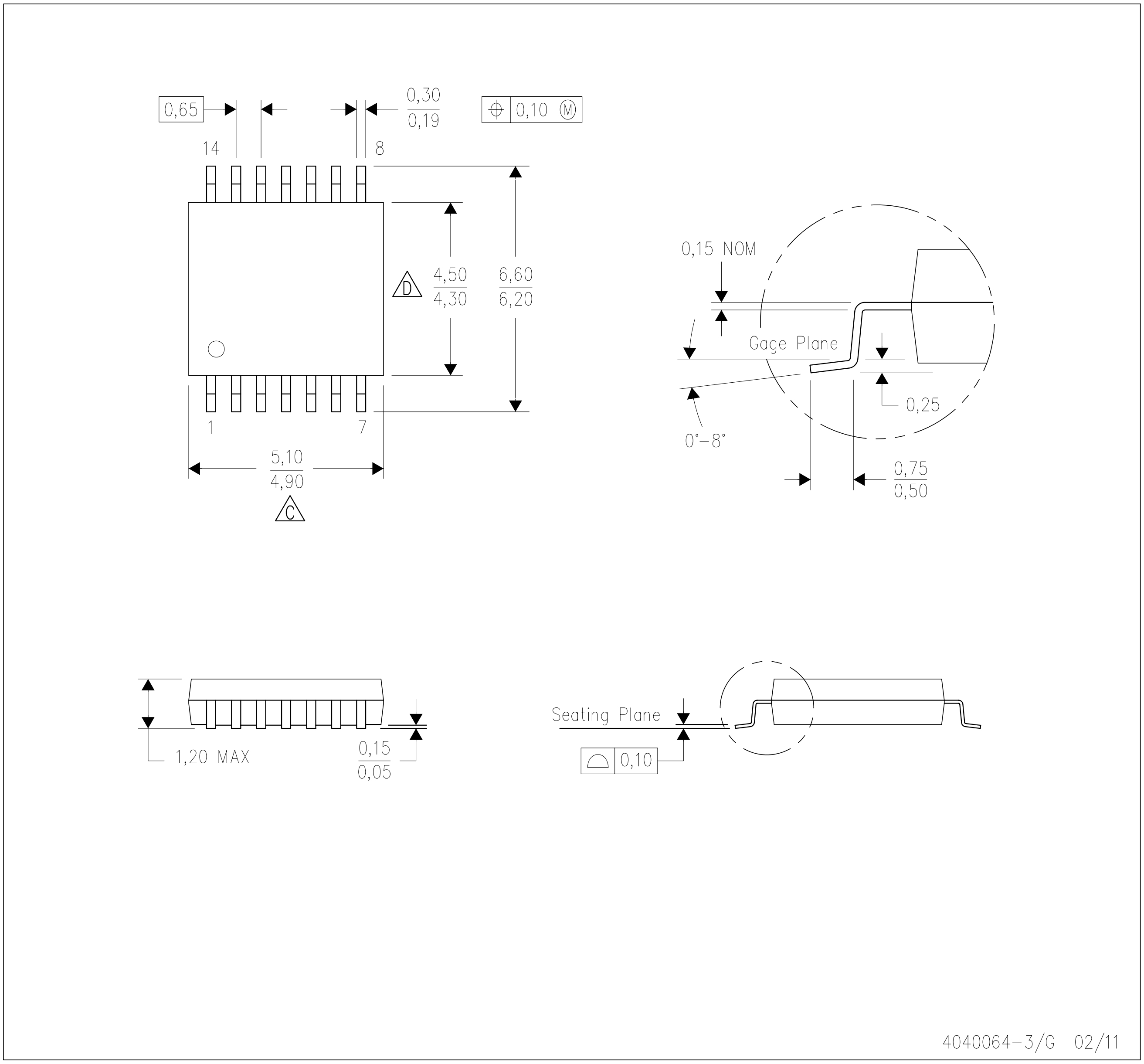
P (R–PDIP–T8) PLASTIC DUAL–IN–LINE PACKAGE



4040082/E 04/2010

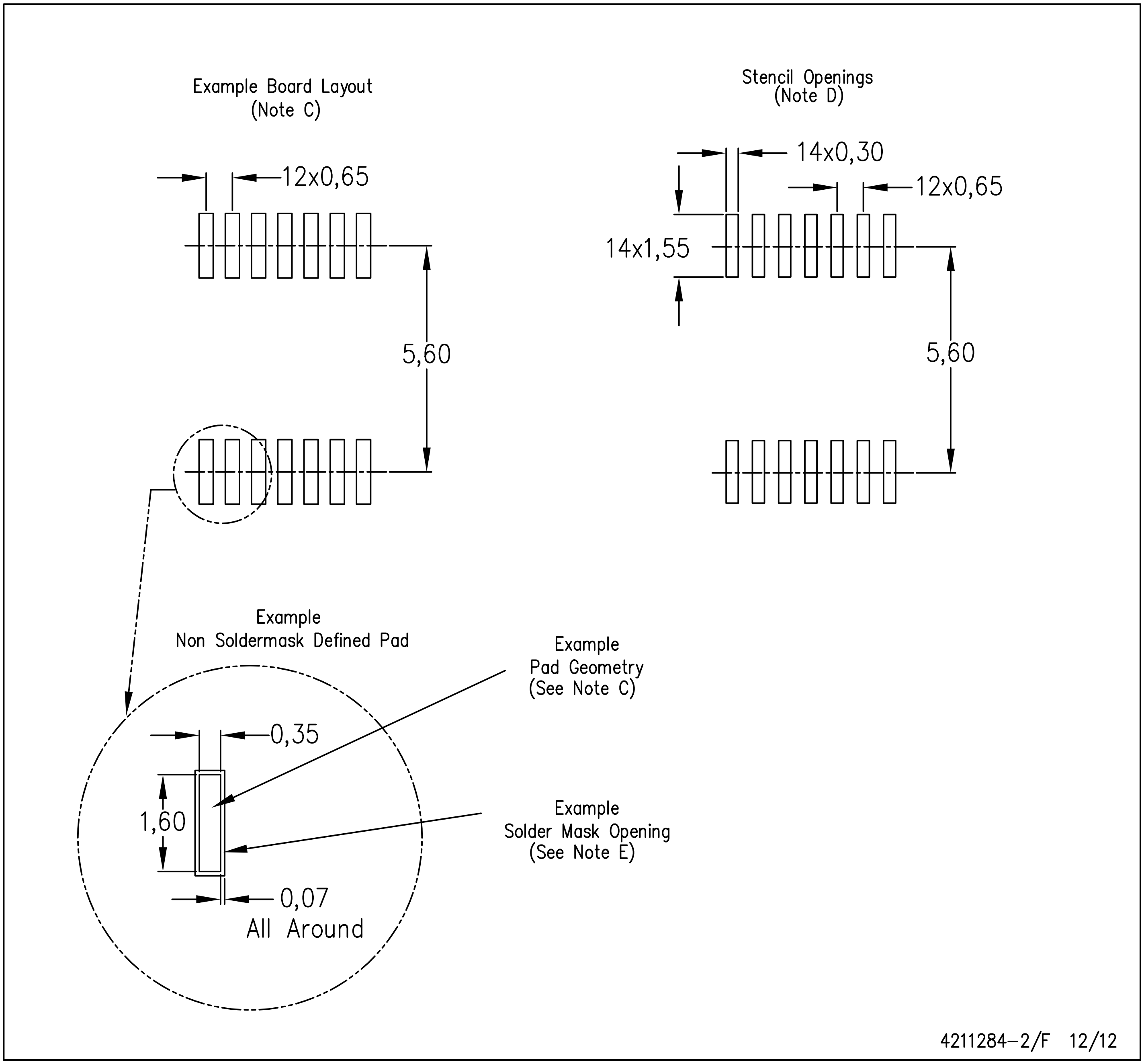
NOTES:
A. All linear dimensions are in inches (millimeters).
B. This drawing is subject to change without notice.
C. Falls within JEDEC MS–001 variation BA.

PW (R-PDSO-G14) PLASTIC SMALL OUTLINE



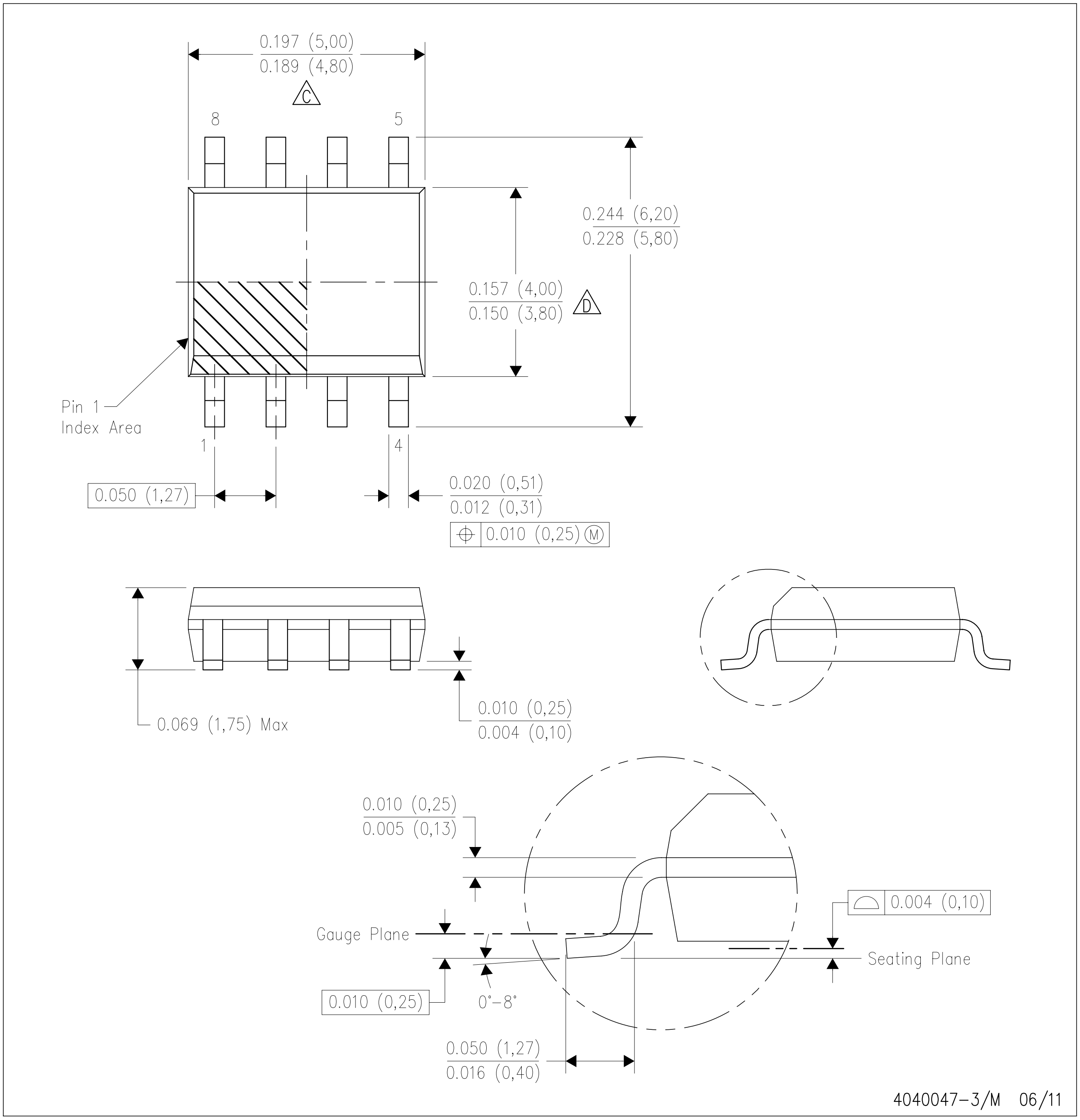
NOTES:
A. All linear dimensions are in millimeters. Dimensioning and tolerancing per ASME Y14.5M-1994.
B. This drawing is subject to change without notice.
C. Body length does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0,15 each side.
D. Body width does not include interlead flash. Interlead flash shall not exceed 0,25 each side.
E. Falls within JEDEC MO-153

PW (R–PDSO–G14) PLASTIC SMALL OUTLINE



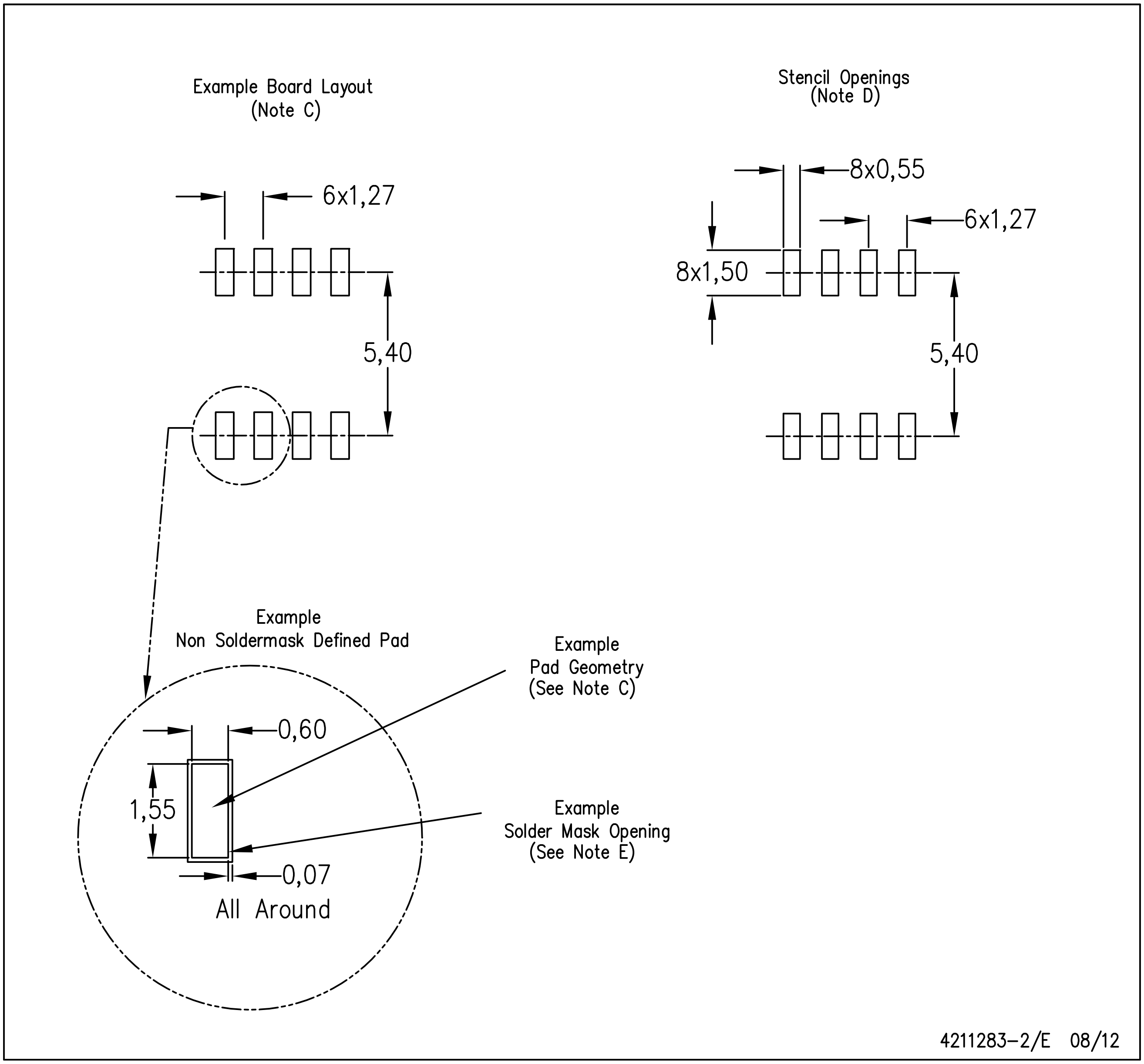
NOTES:
- A. All linear dimensions are in millimeters.
- B. This drawing is subject to change without notice.
- C. Publication IPC–7351 is recommended for alternate designs.
- D. Laser cutting apertures with trapezoidal walls and also rounding corners will offer better paste release. Customers should contact their board assembly site for stencil design recommendations. Refer to IPC–7525 for other stencil recommendations.
- E. Customers should contact their board fabrication site for solder mask tolerances between and around signal pads.

D (R–PDSO–G8) PLASTIC SMALL OUTLINE



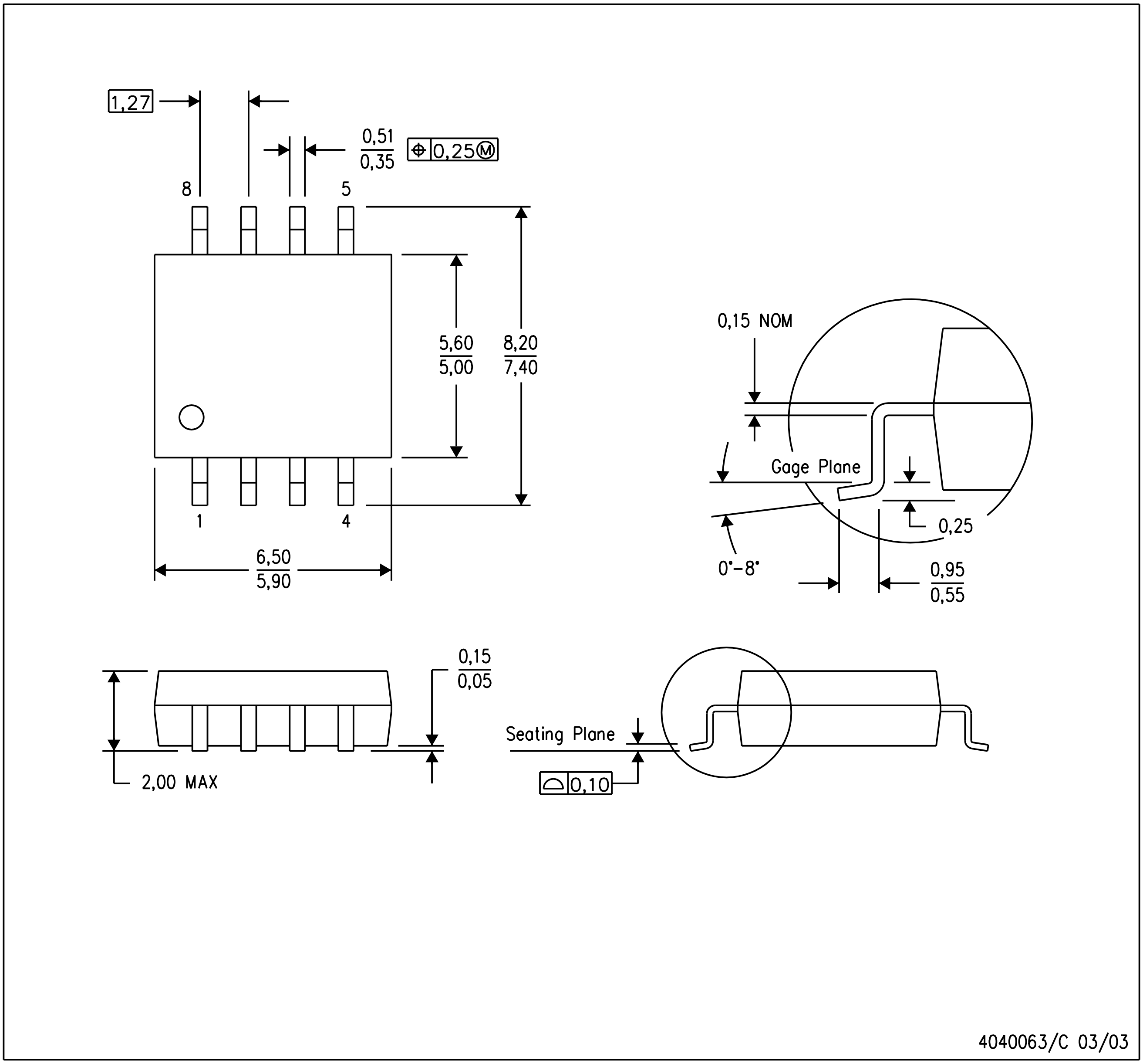
NOTES:
- A. All linear dimensions are in inches (millimeters).
- B. This drawing is subject to change without notice.
- C. Body length does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.006 (0,15) each side.
- D. Body width does not include interlead flash. Interlead flash shall not exceed 0.017 (0,43) each side.
- E. Reference JEDEC MS-012 variation AA.

D (R-PDSO-G8) PLASTIC SMALL OUTLINE



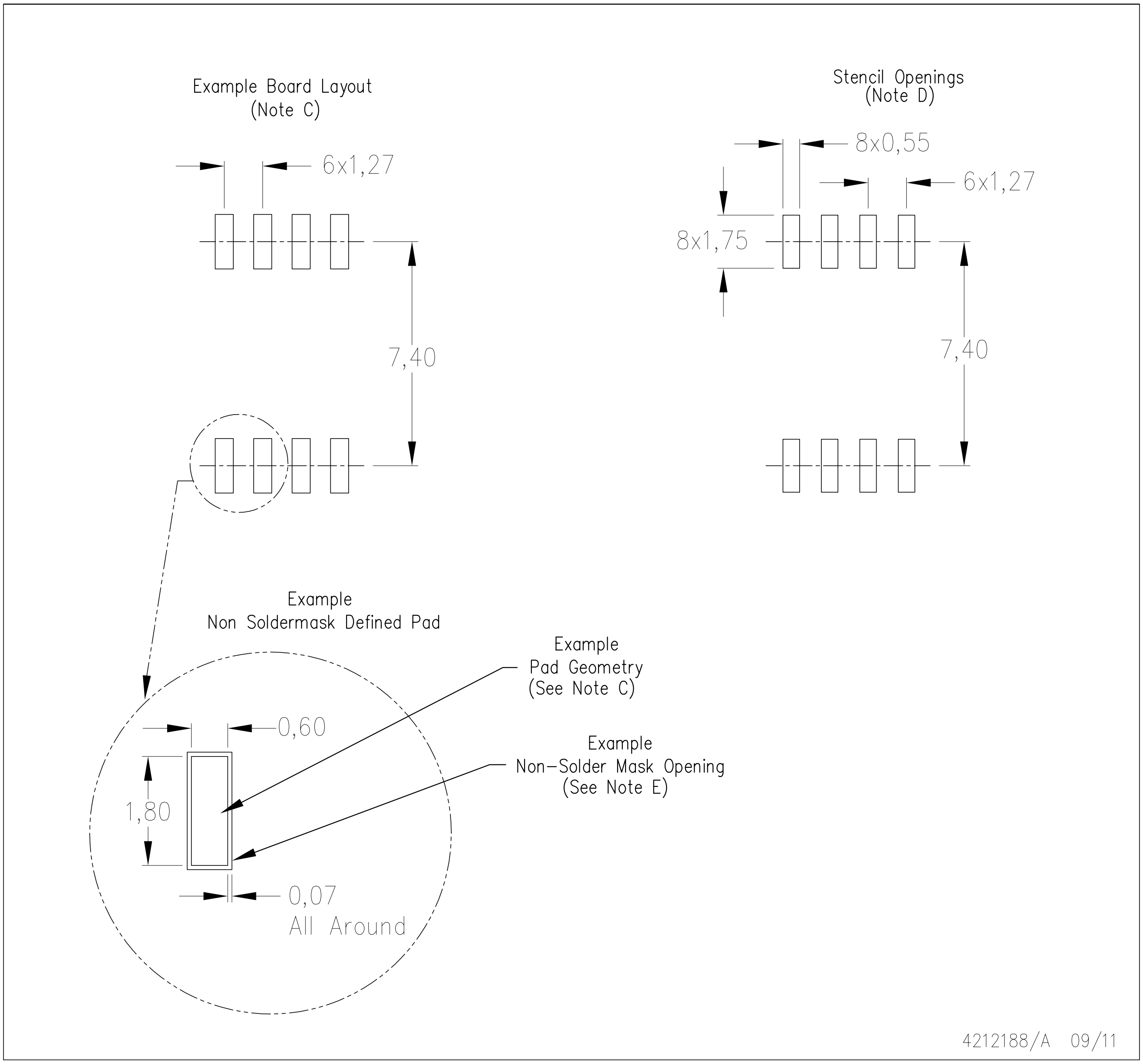
NOTES:
A. All linear dimensions are in millimeters.
B. This drawing is subject to change without notice.
C. Publication IPC-7351 is recommended for alternate designs.
D. Laser cutting apertures with trapezoidal walls and also rounding corners will offer better paste release. Customers should contact their board assembly site for stencil design recommendations. Refer to IPC-7525 for other stencil recommendations.
E. Customers should contact their board fabrication site for solder mask tolerances between and around signal pads.

PS (R-PDSO-G8) **PLASTIC SMALL-OUTLINE PACKAGE**



NOTES: A. All linear dimensions are in millimeters.
B. This drawing is subject to change without notice.
C. Body dimensions do not include mold flash or protrusion, not to exceed 0,15.

PS (R-PDSO-G8) PLASTIC SMALL OUTLINE



NOTES:
- A. All linear dimensions are in millimeters.
- B. This drawing is subject to change without notice.
- C. Publication IPC-7351 is recommended for alternate designs.
- D. Laser cutting apertures with trapezoidal walls and also rounding corners will offer better paste release. Customers should contact their board assembly site for stencil design recommendations. Refer to IPC-7525 for other stencil recommendations.
- E. Customers should contact their board fabrication site for solder mask tolerances between and around signal pads.

IMPORTANT NOTICE

Texas Instruments Incorporated and its subsidiaries (TI) reserve the right to make corrections, enhancements, improvements and other changes to its semiconductor products and services per JESD46, latest issue, and to discontinue any product or service per JESD48, latest issue. Buyers should obtain the latest relevant information before placing orders and should verify that such information is current and complete. All semiconductor products (also referred to herein as “components”) are sold subject to TI’s terms and conditions of sale supplied at the time of order acknowledgment.

TI warrants performance of its components to the specifications applicable at the time of sale, in accordance with the warranty in TI’s terms and conditions of sale of semiconductor products. Testing and other quality control techniques are used to the extent TI deems necessary to support this warranty. Except where mandated by applicable law, testing of all parameters of each component is not necessarily performed.

TI assumes no liability for applications assistance or the design of Buyers’ products. Buyers are responsible for their products and applications using TI components. To minimize the risks associated with Buyers’ products and applications, Buyers should provide adequate design and operating safeguards.

TI does not warrant or represent that any license, either express or implied, is granted under any patent right, copyright, mask work right, or other intellectual property right relating to any combination, machine, or process in which TI components or services are used. Information published by TI regarding third-party products or services does not constitute a license to use such products or services or a warranty or endorsement thereof. Use of such information may require a license from a third party under the patents or other intellectual property of the third party, or a license from TI under the patents or other intellectual property of TI.

Reproduction of significant portions of TI information in TI data books or data sheets is permissible only if reproduction is without alteration and is accompanied by all associated warranties, conditions, limitations, and notices. TI is not responsible or liable for such altered documentation. Information of third parties may be subject to additional restrictions.

Resale of TI components or services with statements different from or beyond the parameters stated by TI for that component or service voids all express and any implied warranties for the associated TI component or service and is an unfair and deceptive business practice. TI is not responsible or liable for any such statements.

Buyer acknowledges and agrees that it is solely responsible for compliance with all legal, regulatory and safety-related requirements concerning its products, and any use of TI components in its applications, notwithstanding any applications-related information or support that may be provided by TI. Buyer represents and agrees that it has all the necessary expertise to create and implement safeguards which anticipate dangerous consequences of failures, monitor failures and their consequences, lessen the likelihood of failures that might cause harm and take appropriate remedial actions. Buyer will fully indemnify TI and its representatives against any damages arising out of the use of any TI components in safety-critical applications.

In some cases, TI components may be promoted specifically to facilitate safety-related applications. With such components, TI’s goal is to help enable customers to design and create their own end-product solutions that meet applicable functional safety standards and requirements. Nonetheless, such components are subject to these terms.

No TI components are authorized for use in FDA Class III (or similar life-critical medical equipment) unless authorized officers of the parties have executed a special agreement specifically governing such use.

Only those TI components which TI has specifically designated as military grade or “enhanced plastic” are designed and intended for use in military/aerospace applications or environments. Buyer acknowledges and agrees that any military or aerospace use of TI components which have ***not*** been so designated is solely at the Buyer's risk, and that Buyer is solely responsible for compliance with all legal and regulatory requirements in connection with such use.

TI has specifically designated certain components as meeting ISO/TS16949 requirements, mainly for automotive use. In any case of use of non-designated products, TI will not be responsible for any failure to meet ISO/TS16949.

Products		**Applications**	
Audio	www.ti.com/audio	Automotive and Transportation	www.ti.com/automotive
Amplifiers	amplifier.ti.com	Communications and Telecom	www.ti.com/communications
Data Converters	dataconverter.ti.com	Computers and Peripherals	www.ti.com/computers
DLP® Products	www.dlp.com	Consumer Electronics	www.ti.com/consumer-apps
DSP	dsp.ti.com	Energy and Lighting	www.ti.com/energy
Clocks and Timers	www.ti.com/clocks	Industrial	www.ti.com/industrial
Interface	interface.ti.com	Medical	www.ti.com/medical
Logic	logic.ti.com	Security	www.ti.com/security
Power Mgmt	power.ti.com	Space, Avionics and Defense	www.ti.com/space-avionics-defense
Microcontrollers	microcontroller.ti.com	Video and Imaging	www.ti.com/video
RFID	www.ti-rfid.com		
OMAP Applications Processors	www.ti.com/omap	**TI E2E Community**	e2e.ti.com
Wireless Connectivity	www.ti.com/wirelessconnectivity		

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265