Automated Threat Detection for Disaster Response Teams Using UAV Platforms

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***Abstract* – In this paper, we present a sensor system, mountable on a commercially available quadcopter unmanned aerial vehicle (UAV). The system comprises of real-time video, radiation detection, and vehicle telemetry. We present methods of integrating sensor hardware and software with existing frameworks. The system is intended for use by disaster first response teams to prevent injury or loss of human life during site surveillance.**

I. Introduction

At a disaster site, the first responders must identify potential hazards before moving in to rescue survivors or attempt hazard containment/clean-up. Without advance knowledge of the site, responders are presented with many unseen threats, including chemical and radiological sources. A UAV can navigate these dangerous sites and relay information to the responders before any humans enter the site. Previous systems incorporate static images or real-time video only. Previous research in 2013 by Davis, Pittaluga, and Panetta [1] provided the starting point for this project by using video detection algorithms for facial recognition. Additional information of radiation sources adds an additional layer of safety.

II. Background Information

A. *Geiger-Müller Tube*

Geiger-Müller tubes are devices used within a Geiger-Müller instrument (Geiger counter) to detect alpha- or beta-particles and gamma-rays. The tube is constructed of metal filled with inert gas. The tube has wire leads or end terminals that function as cathode and anode; however, some tubes can be operated in either orientation. The Canberra Industries T2417AC[1] tube used in our sensor is unidirectional, with the anode at the core of the device and the cathode lead connected to the tube exterior. The T2417AC tube (fig. 1) was chosen for its high sensitivity and low weight and size. The tube has a 4 cm long, 1 cm diameter cylindrical detection window and weighs 8.0 g. Attached are two aluminum bars known as “energy wraps.” These bars filter out lower energy particles to maintain a consistent count output for any energy of radiative particles/rays. This is desirable, since counts per minute (cpm) is an effective measure of total amount of radiation occurring, rather than dose amount. Dosimeters or radiation badges are necessary to measure dosage.[2]

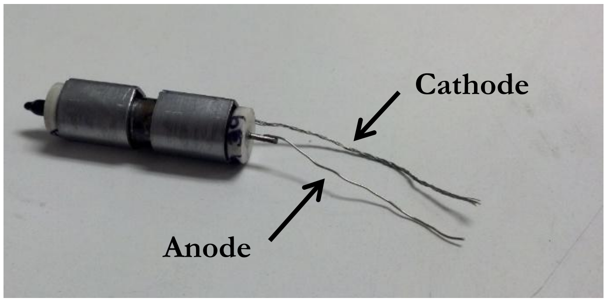

Fig. 1: T2417AC Geiger-Müller tube with energy wraps

Under normal operating conditions at room temperature and biased at 575 V (applied at the anode of the device), this tube has a sensitivity of 450 cpm in a radiative field of 1 milliRoentgen per hour (mR/hr) produced by Cesium-137 (^{137}Cs). The sensitivity of a Geiger tube is a linear measurement that relates radiation over time to cpm. That is, in a 1 mR/hr radiated field, the tube produces 450 cpm, and in a 2 mR/hr field, 900 cpm are measured, and so on. This allows for measureable detection at very low radiation levels and is also rated to have distinguishable results at up to and exceeding 6.9

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[1] See Appendix for detailed specifications. Additional information at http://www.canberra.com/products/detectors/detectors-geiger-mueller.asp (listed as T2417A)

[2] See http://www.remm.nlm.gov/civilian.htm for information on dosimeters

million cpm (115200 counts per second (cps), the maximum our current digital system supports). This corresponds to a radiation rate of 15.36 R/hr or 135.2 Gy/hr if directly absorbed.[3] An instantaneous absorption of 5 Gy in air is lethal to the average human [2][3][4]. The knowledge that anywhere near this dosage of radiation could potentially be absorbed in a single area is more than enough to mark an area as hazardous to human health and require use of personal dosimeters to accurately monitor responders' safety [4].[5]

To power our sensor's Geiger-Müller tube with the requisite 575 V, we created a tunable high-voltage kickback generator[6] (fig. 2) powered by the drone's on-board battery via a 5 V output.

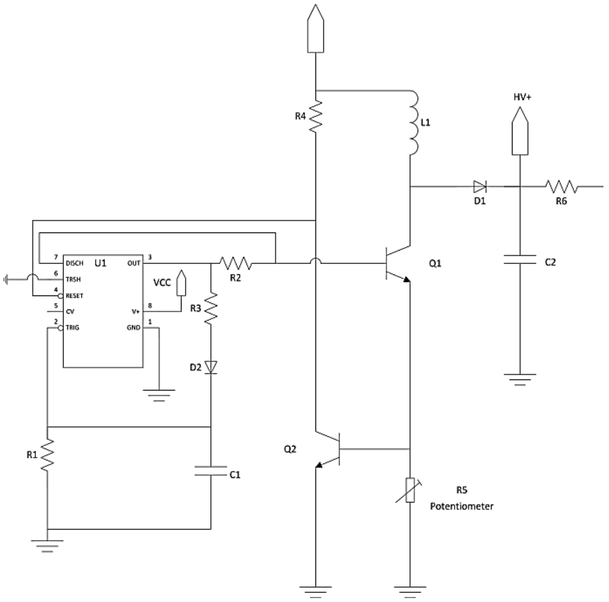

Fig. 2: High-voltage generator circuit[7]

At the core of the circuit is a 555 timer integrated circuit (IC). The timer functions as a pulse generator: when the trigger (TRIG) pin is brought to a low voltage, the output (OUT) generates a logical high (+5 V) square pulse; when the discharge (DIS) pin is brought high, the output returns to low voltage; if the reset (RESET) is triggered by a low voltage, the IC shuts down, producing a low voltage at OUT.

Our design functions by allowing OUT to begin at low voltage, keeping TRIG low. This causes OUT to rise to 5 V. As this happens, current flow through R3 and D2, charges capacitor C1. Once charged, the current flows through R1, creating a high voltage at TRIG to prevent retriggering of the pulse. The pulse at OUT supplies enough voltage through R2 to the base of Q1 to reach the binary junction transistor (BJT) threshold voltage and switch it on. With Q1 on, current gradually begins to flow through L1. When enough current flows through L1, a voltage appears across R5, switching on Q2. The current flow through R4 and across Q2 causes a low voltage at RESET, turning off the IC. With the voltage at OUT now low, Q1 switches off. With a means of current flow to ground for the current through L1 removed, the current through the inductor should drop to zero. However, since inductors impede changes in current, the electromagnetic field stored in L1 manages to force its way across the semiconductor capacitance between the collector and emitter of Q1. When all current (and therefore charge) from L1 is stored in this capacitance, there is enough voltage[8] across Q1 to allow D1 to operate in forward biased mode. Current flows from Q1, through the diode, and into C2. Since the pulses from the IC are only microseconds long (switching time for Q1 and thus current through L1), immense current is stored in Q1.[9] The capacitance of C2 is orders of magnitude less than the capacitance of Q1, so the voltage at HV+ becomes several hundred volts. This voltage is used to power the Geiger-Müller tube across R6. Once the timer IC has been reset, C1 discharges through R1 until TRIG is again brought low, restarting the cycle.

B. *Geiger Counter*

To operate a Geiger-Müller tube, a high voltage is effected across the tube, with the higher potential at the anode. When not in the presence of radiation, a Geiger tube has high resistance (between 1 MΩ and 10 GΩ) and impedes current flow[10]. When no radiation is detected, the cathode of the Geiger tube is held at ground, so Q3 remains off (fig. 3). When a

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[3] 115.07 mR/hr fully absorbed in air is equal to 1 mGy/hr

[4] Background information obtained from http://www.epa.gov/radiation/

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

[6] Modified design inspired by that of Jeff Keyser (CC BY-SA): http://mightyohm.com/files/geiger/geiger_sch_fixedR5R6.png

[7] See Appendix for bill of materials and larger image

[8] Voltage of a capacitor is $V_C = \frac{Q}{C}$

[9] Current through an inductor is $i = \frac{1}{L}\int V_L\,dt$, where V_L is the voltage and L is inductance

[10] See http://webfiles.ehs.ufl.edu/rssc_stdy_chp_4.pdf for more information on Geiger-Müller tube theory

radiative particle or ray strikes the surface of the tube, a small amount of gas molecules becomes ionized, creating a positive ion and a negative free electron. The electrons flow towards the anode in the center of the tube, ionizing more molecules as they collide at high energy. The resulting electron avalanche ionizes all gas around the anode within a few microseconds, causing current to flow out of the tube. After this pulse of current, the positive ions now near the cathode counteract the high electric field caused by the potential difference between electrodes, allowing the electrons to be reclaimed by the positive ions. A Geiger counter measures the current flow from the electron avalanche and presents the information in "counts." To transition from current flow during a radiative event detection, a Geiger counter must display or convey the current as a count. A simple method is to measure a voltage across an external resistor. Our method uses a single BJT to drop the device's output voltage to ground whenever a radiative event is detected. The flow of electrons causes a voltage to appear across R7 and R8, turning Q3 on. The current flowing through the transistor pulls the output low from 5 V. The output represents a constant binary 1 (5 V) until radiation is detected, showing a momentary binary 0 (0 V). At these values, the output is in binary format, readable with a high logic level of 5 V.

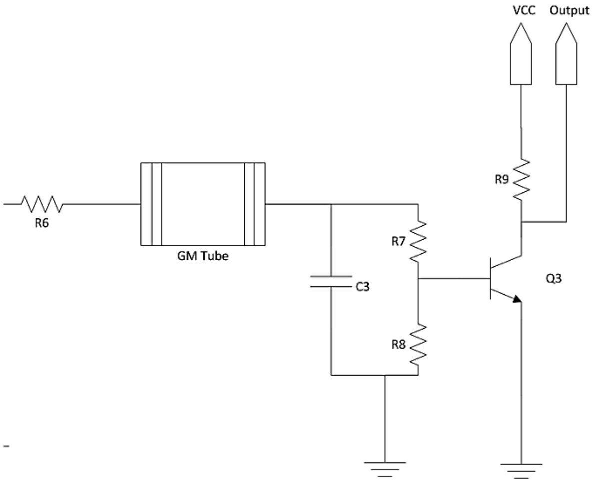

Fig. 3: Output stage of radiation detection circuit

All versions of our sensor were tested against a small sample of Americium-241 (^{241}Am) found in a commercial home smoke detector. ^{241}Am is an extremely lowly radioactive isotope that produces little to no risk of harm for humans.[11] The isotope decays by low-energy alpha emission (stopped by clothing or several cm in air) and low amounts beta emission, which we measured with our sensor.

C. *UAV Quadcopter*

To carry the payload of sensors, a commercially available drone system was selected. The DraganFlyer Guardian[12] from DraganFly Innovations Inc. (fig. 4) was selected for its battery life, payload limit, size, and software customization.

Fig. 4: DraganFlyer Guardian

The UAV has a quadcopter configuration: four boom arms extend from the body and hold a single brushless DC motor with attached rotor blade. Legs below the motors keep the body and underhanging payload off the ground. The drone measures 71 cm in diameter with a height of 25 cm. A maximum payload size of 420 g allows for several sensors to be added to the payload area. This particular model includes a GoPro Hero 3 video camera with dual-axis gyro-stabilized mount (fig. 5) for receiving a live video feed. The stabilization is realized using two brushless DC motors and drone processor-based feedback control to correct for changes in drone roll and pitch. The camera and mount weigh 300 g when secured to the drone, leaving 120 g for our sensor package. A maximum flight time of 30 minutes gives a practical time window for site surveillance. A fail-safe activates at low battery to automatically safely land the drone.

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[11] See http://www.bt.cdc.gov/radiation/isotopes/americium.asp for safety information

[12] See Appendix for detailed specifications. Additional information at http://www.draganfly.com/uav-helicopter/draganflyer-guardian/index.php

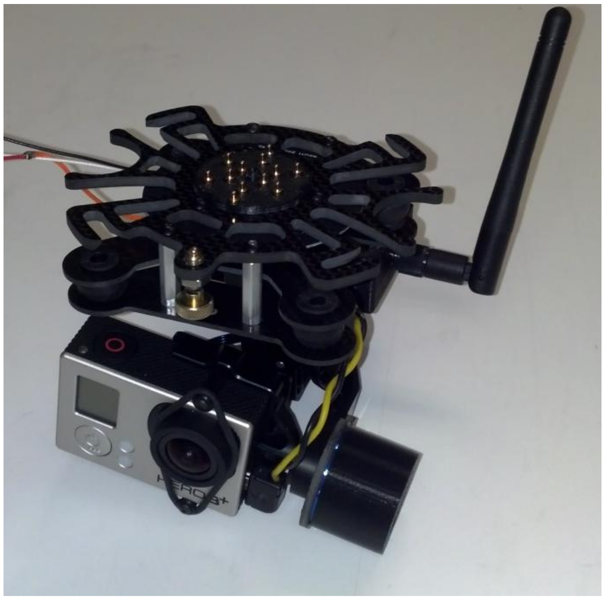
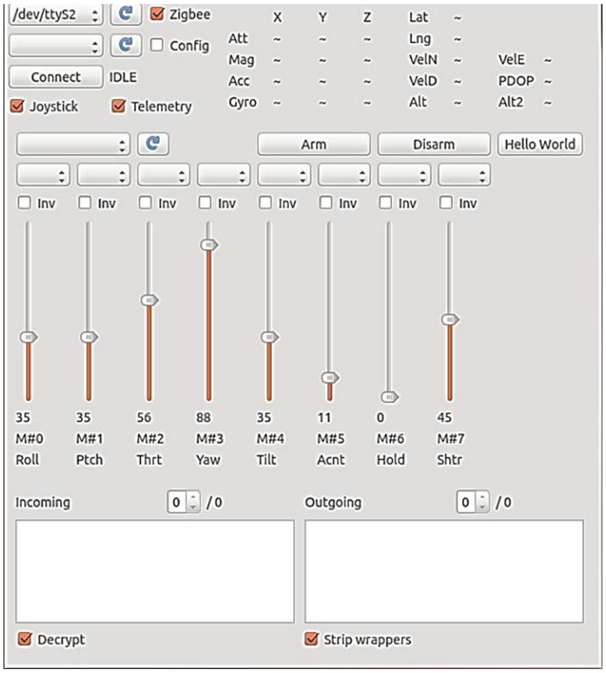


Fig. 5: DraganFlyer GoPro mount

The UAV is controlled by a handheld wireless controller. Two joysticks control thrust, lateral movement, and yaw. Trim switches allow the user to change the sensitivity of both sticks. The center of the controller features a TFT touchscreen to connect to the UAV and configure control and video options. Important drone information is visible on this screen: roll, pitch, yaw, altitude, and battery life.

Included with our DraganFlyer system is a barebones version of DraganView software, a program that visually depicts aircraft telemetry and flight data. The unmodified main window (fig. 6) features four areas: connections (upper-right), telemetry (upper-left), flight controls (center), and data I/O (bottom). The connections area lists all computer COM ports that can support the DraganFly XBee-based transceiver. Once the correct port has been determined and selected, DraganView connects to the virtual COM port that the transceiver makes available (this is to allow direct connection to the XBee through the UART protocol). Then, a list of available drones within range is populated and can be connected. The telemetry area displays a live feed of the connected drone's roll, pitch, yaw, attitude, altitude, throttle amount, and air speed. The flight control area allows the user to override any other controller and directly input values numerically or via sliders for the drone's movement. The data I/O section shows the raw and/or decrypted data stream going to the drone and coming back in.



/dev/ttyS2
☑ Zigbee
☐ Config
IDLE
☑ Joystick
☑ Telemetry

35	35	56	88	35	11	0	45
M#0	M#1	M#2	M#3	M#4	M#5	M#6	M#7
Roll	Ptch	Thrt	Yaw	Tilt	Acnt	Hold	Shtr

Incoming 0 /0
Outgoing 0 /0
☑ Decrypt
☑ Strip wrappers

Fig. 6: Unmodified DraganView software

Source code was obtained to allow customized application programming interfaces (APIs) to be integrated into the software. DraganView is compiled from C++ using Qt 4.8.5.[13] A new data structure was added to extract our data from DraganFly's encrypted wireless data stream and display this data within the DraganView window in cps. This runs alongside the regular DraganView software, allowing the user to easily see incoming and outgoing drone data.

D. *Transmission Methods*

Without modification, the drone sends back telemetry (pitch, roll, yaw, height), and flight data (time, distance) through an encrypted wireless channel. DraganFly uses a proprietary[14] message format to send data to and from the drone. The format allows for multiple types of data to be sent and includes encryption and error correction. All data to and from the drone is packaged and de/encrypted using its on-board processor. An XBee-PRO SE transmits data wirelessly at distances up to one mile through the IEEE 802.15.4

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[13] Information and documentation at http://qt-project.org/doc/qt-4.8/

[14] This, and all information labeled "proprietary" protected under NDA

protocol.[15] A USB XBee transceiver connects via USB to a computer through a VCP. The computer receives and decrypts the data using DraganView software. Data is sent and received by the transceiver. Data can be requested or sent from the transceiver in the handheld controller or connected computer.

Raw video data is sent asynchronously through a separate video transmitter. Video can be captured and streamed at up to 1080p and 60 fps. A standalone 5.8 GHz video receiver collects video data and can be ported to an analog video device or via an analog-to-USB converter.

The main board of the Guardian connects to the video camera payload to control stabilization and camera functions. An additional four pins are exposed to the end user for additional serial programming support and possible additions to sensors. Our radiation sensor was hard-wired to one of these pins to utilize the drone's 5 V logic level to interface with our counting circuit.

III. Experimental Results

Our final radiation sensor used the high-voltage kickback generator seen in fig. 6. The values specified in the Appendix were capable of producing 180-960 V.[16]

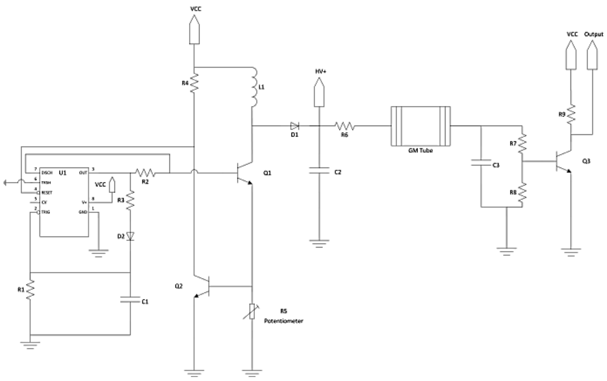

Fig. 6: Final design of kickback generator

Initial versions of this circuit used a smaller inductor (10 mH) and slower transistors (2N3904 in place of 2N4401 and FJN3303F in place of BUL7420). These were capable of producing 70-400 V, just short of the voltage needed to drive the T2417AC tube. Increasing the inductance gave a slight boost to the voltage by increasing the amount of energy the inductor could store. This produced an increase in voltage by 75 V. After testing the circuit, it was found that the inductor was charging and discharging more slowly than desired to produce higher voltages. By changing the transistors to high-power, faster-switching devices, the on/off times were significantly decreased. By allowing Q1 to shut off faster, the inductor could discharge more quickly, effecting a larger voltage across Q1 (and then C2). By giving Q2 a faster on time, the 555 timer was able to reset more quickly, decreasing the time between pulses to turn on and off Q1. These changes were found to have the most effect on the circuit, dramatically improving the range of voltages available for use. With a maximum voltage of 960 V, this circuit could be used for any number of Geiger tubes requiring substantially lower or higher operating voltages.

Once a 575 V power supply was achieved, the full Geiger counter was tested. Before the more sensitive T2417AC tube was used, the circuit was tested with an SBM-20 tube[17] produced during the Soviet era. This tube was chosen for testing due to its purported reliability and sensitivity compared to its low cost. Once it was determined that this tube functioned with the high-voltage supply and detection circuit, the T2417AC tube was tested. This tube was also capable of detecting the small amounts of beta radiation the ^{241}Am sample produced. Fig. 7 shows the output of the sensor for both the SBM-20 and T2417AC. The finished sensor weighed 24.0 g.

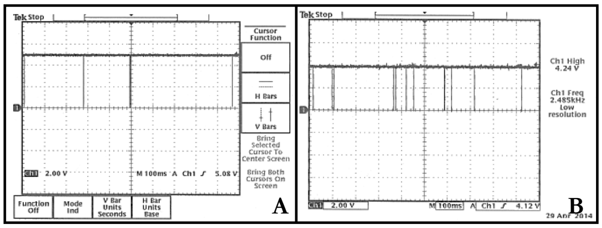

Fig. 7: Radiation sensor output for (a) SBM-20 tube and (b) T2417AC tube

The version of DraganView compiled to communicate with the drone needed to be compiled with an older version of Qt software (4.8.5 vs the newest version 5.2). To fully compile the code, we used a computer running Ubuntu 13.04. Once compiled, a custom radiation data widget was added

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

[16] See Appendix for bill of materials

[17] Information at http://www.gstube.com/data/2398/

(fig. 8) and transceiver connectivity was successfully established.

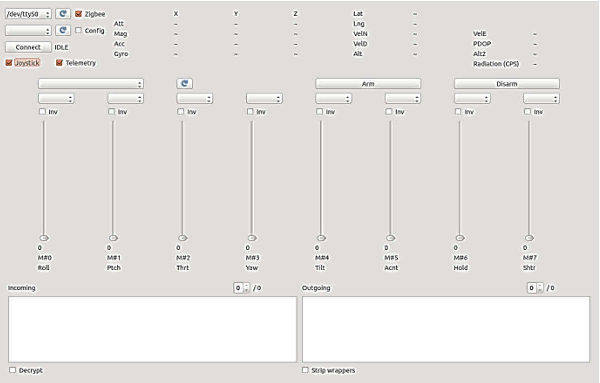

☑ Zigbee
☐ Config
☑ Joystick
☑ Telemetry
☐ Decrypt
☐ Strip wrappers
/dev/ttyS0
IDLE

Fig. 8: Modified DraganView software window

To connect our sensor to the wired serial input of the drone, we were required to modify the drone's firmware. To read in sensor data, the firmware was changed to use an additional read command and stream in raw binary data from a serial pin. This firmware was custom designed and programmed by DraganFly's software engineer.

When running, the drone polled the serial pin consistently to read in sensor data by counting on falling edges (5 V to 0 V transition) and send back this count once per second. Since the sensor output was kept within 0-5 V, no additional modifications or packaging were needed before reading in the counts as bits. Computer-side, this data was read in using DraganFly's message format and the radiation payload was identified. This payload contains a packet number to identify the time at which the signal was sent. Each packet of radiation data is checked to ensure duplicate packets are not reported. Each new non-duplicate data packet is displayed in the DraganView window beneath the drone telemetry data and updated once per second

IV. Conclusion and Future Work

Our system adds additional sensor functionality to a commercial UAV system. Drone-based systems for first response teams currently only offer optical solutions for threat detection and site surveillance. We have created a fully modular sensor package that currently supports radiation detection and can be expanded to include other digital forms of sensors. The data from our sensor is sent back wirelessly using an encrypted data channel with a range of up to one mile. With a flight time of up to 30 minutes with our sensor mounted, the UAV system can be used to remotely investigate a potentially hazardous disaster site. By adding radiation detection, unseen radiological hazards can be detected and avoided by personnel. The capability to find radioactive areas remotely has the potential to greatly reduce the time necessary for a response team to enter and secure a disaster site, as well as protecting responders from the risks that these areas pose to human life.

Moving forward, this work can be augmented in several ways: sensor additions and miniaturization, video processing, and software improvements. The current sensor setup allows for detection and wireless transmission of radiation data in the drone's vicinity. Now that the drone's serial pin is exposed, multiple sensors could be used to collect more information, such as chemical or atmospheric data. By using a simple multiplexer (mux) circuit and either a hardware timer or a signal from the drone main board, many sensors could be polled by the drone using only one serial pin. The sensors could be switched on and off by the mux, alternating each second, or instead time-domain muxed to send all data simultaneously (this would require separating out the data using software after transmission). Once these new modular sensors are set up, new windows in DraganView can be created to display their data. To allow for further sensors, our radiation sensor and all future ones could be made smaller and lighter by creating custom PCBs and using surface mount components instead of the larger through-hole components used in our design. This would cut down on weight and physical space, but create issues regarding high-voltage isolation and the board's parasitic capacitances.

Building on Davis, Pittaluga, and Panetta's work in 2013, future revisions of our sensor package could include Human Visual System-based video processing to detect faces of known survivors in a disaster site. The drone currently only sends back an analog video signal, but many commercially available devices exist to convert this to a computer-friendly digital format via USB. Accessing the COM port of the video device and displaying it within DraganView's window would be a simple task. Applying the algorithms present in their work can be done using the C++ MATLAB library to provide real-time video processing.

Finally, the current software version is only compatible with Linux-based computers. To improve the overall usability of our custom DraganView platform, the code can be edited to function cross-platform and compile using Qt 5.2 (currently the latest stable version). Further revisions could include auto-detection of connected transceivers, real-time GPS (with additional GPS hardware from DraganFly) and radiation data map overlays, and the ability to import site maps for point-to-point navigation or mapping.

Acknowledgment

I would like to give special thanks to my research partner, Nicholas Davis, for all of the hard work he put into this system with me, as well as sharing his knowledge of software and communications; to Greg Wood for his instrumental role in creating our firmware and getting our drone to function; and to our research sponsor, Dr. Karen Panetta, for her immense support and continued help with this system. Thanks to Canberra Industries for helping us locate the correct Geiger tube for our project specifications.

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.

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

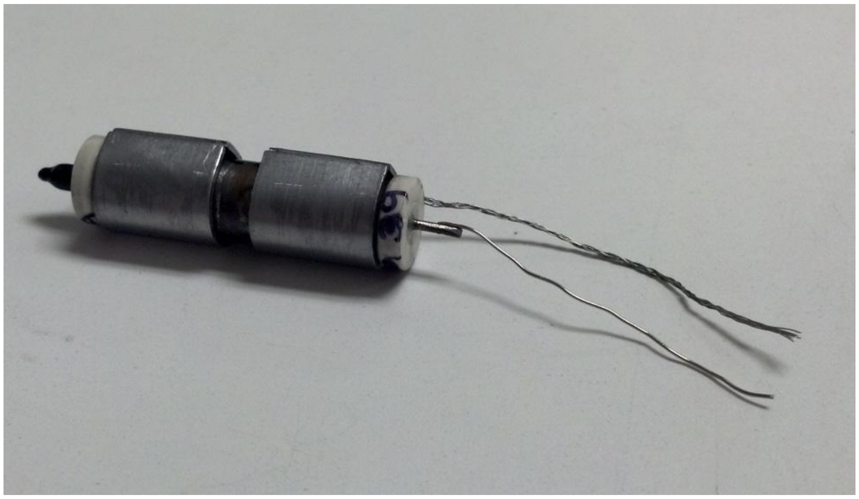
DraganView Software

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

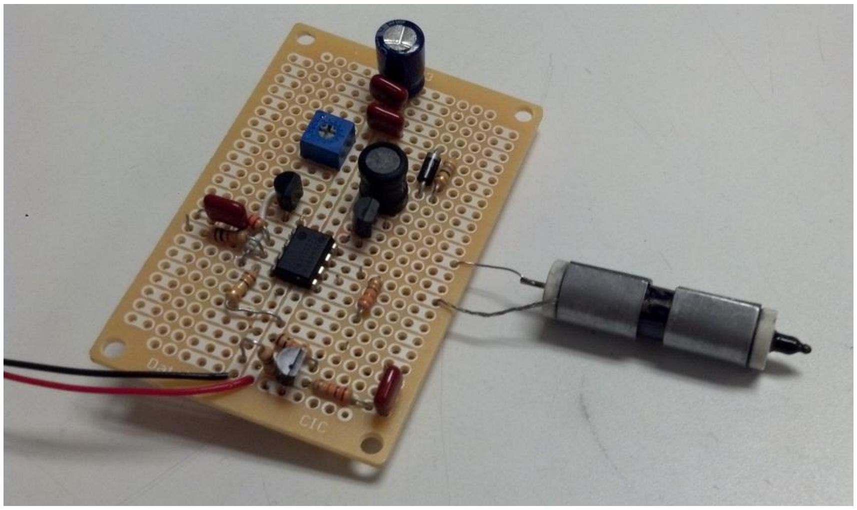
Canberra Industries T2417AC Geiger-Müller Tube:



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

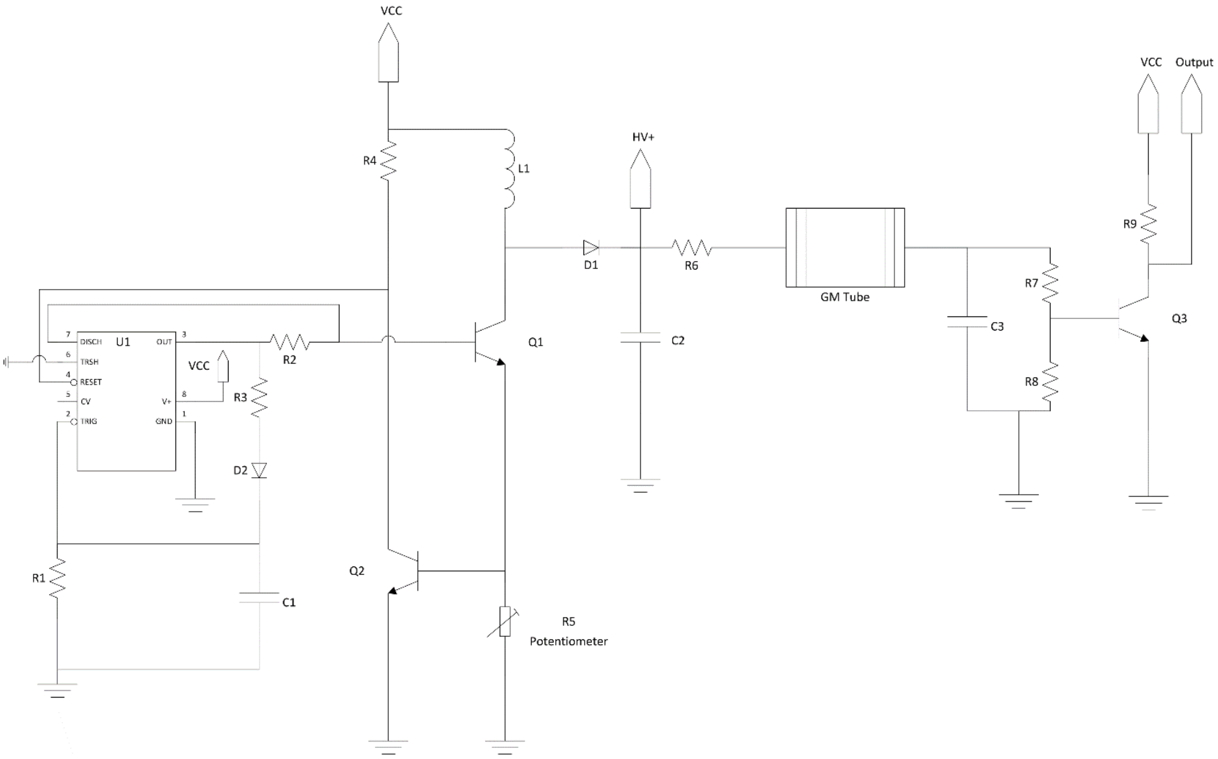
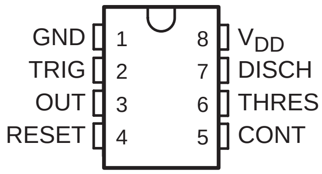


Fig. 1: High-voltage kickback generator and Geiger counter schematic

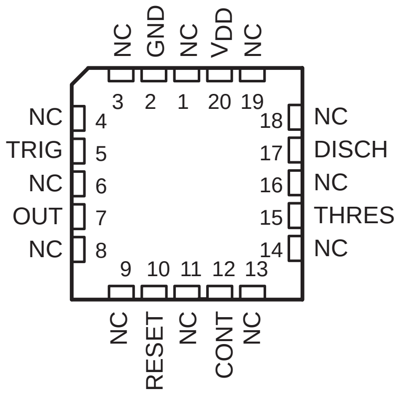
Part 3: Product Datasheets

- **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

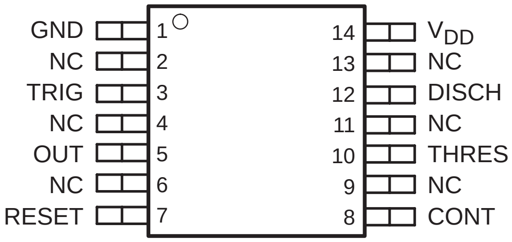
D, DB, JG, OR P PACKAGE
(TOP VIEW)



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.

LinCMOS is a trademark of Texas Instruments.

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.

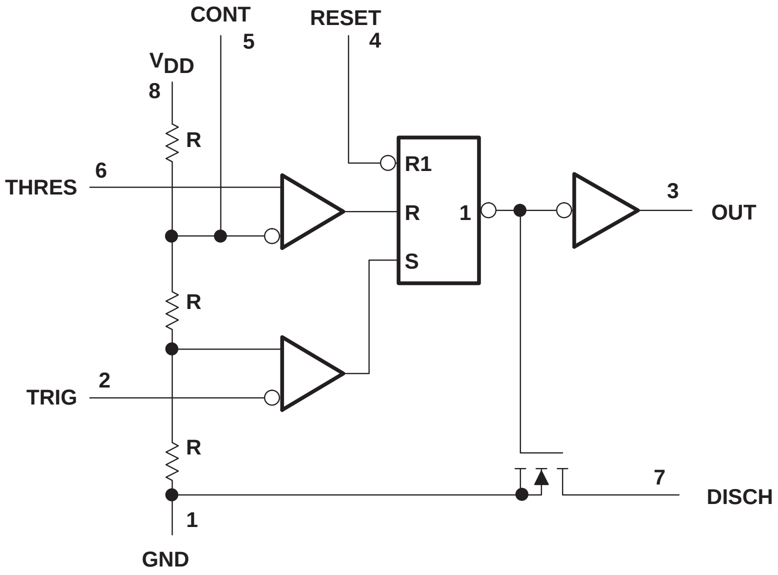
[‡] This package is available taped and reeled. Add the R suffix to device type (e.g., TLC555CDR).

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.

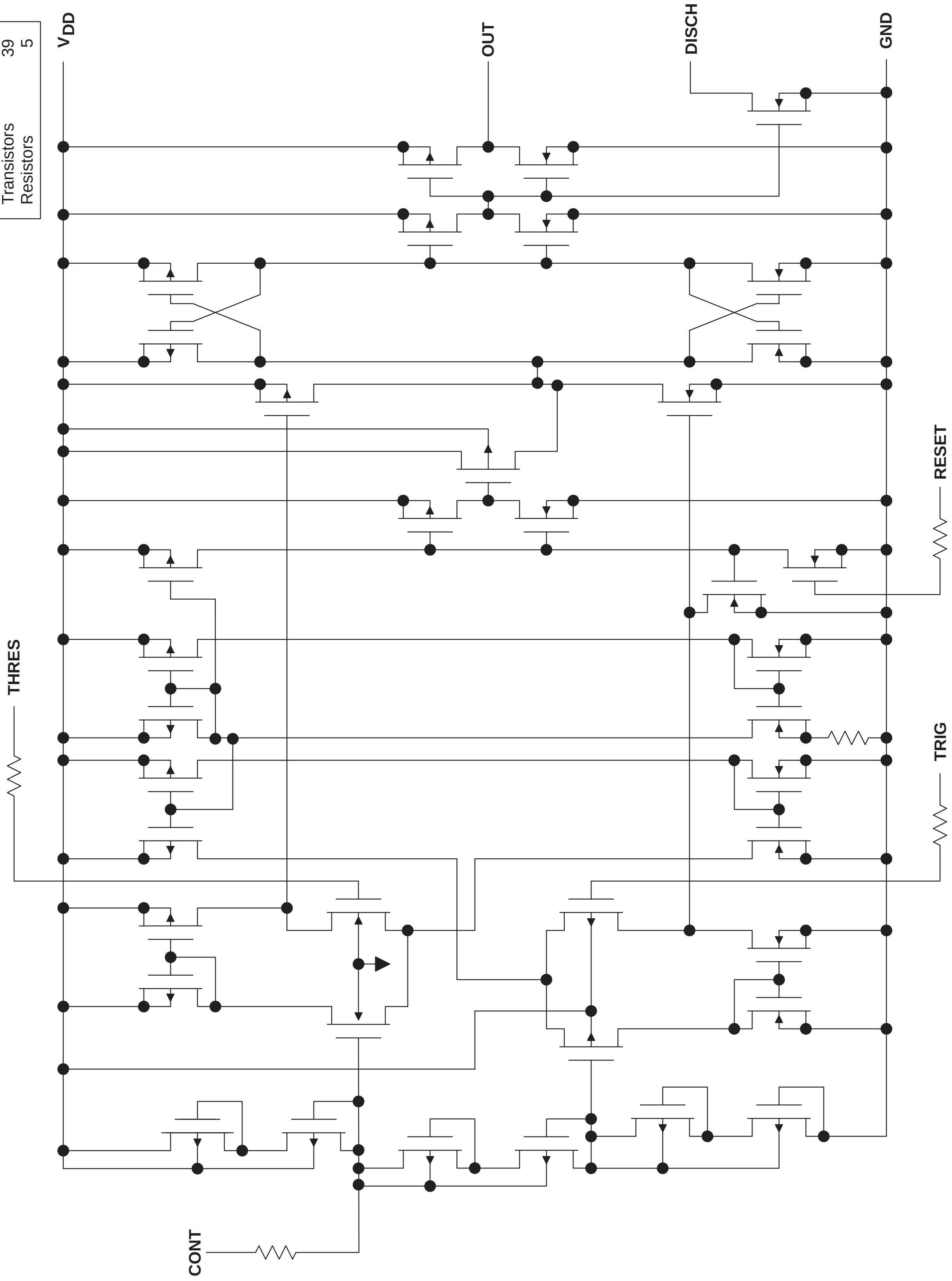
functional block diagram



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

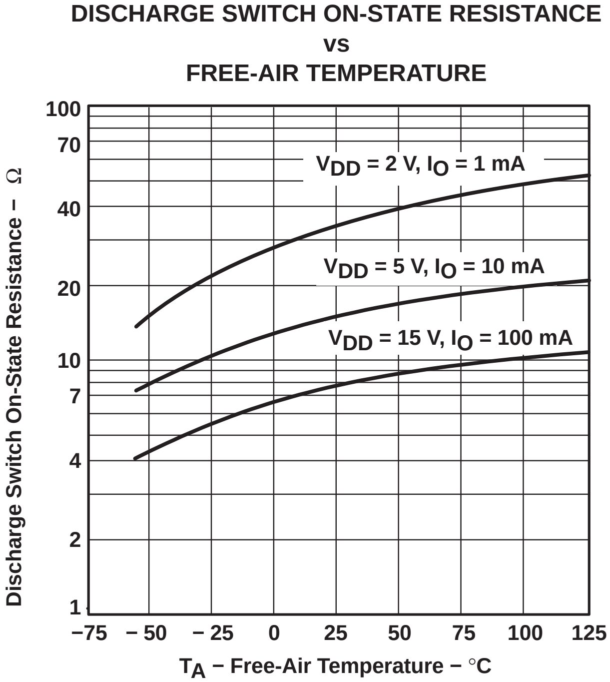
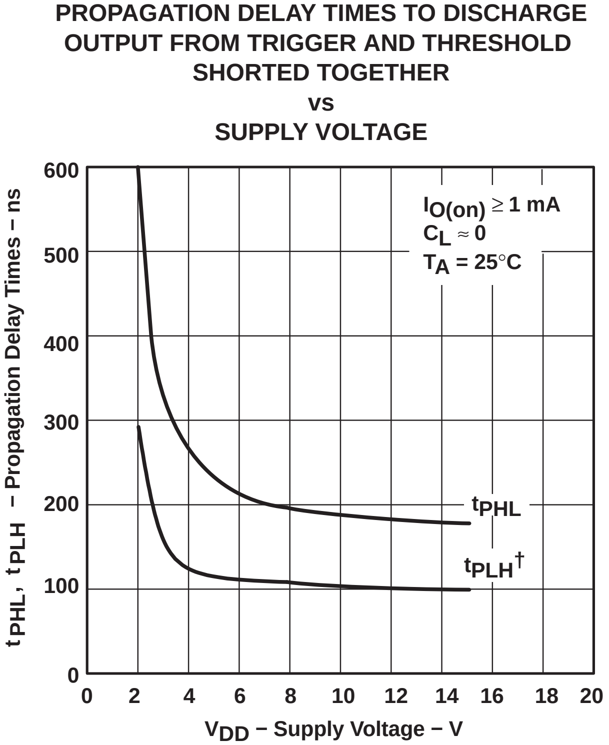


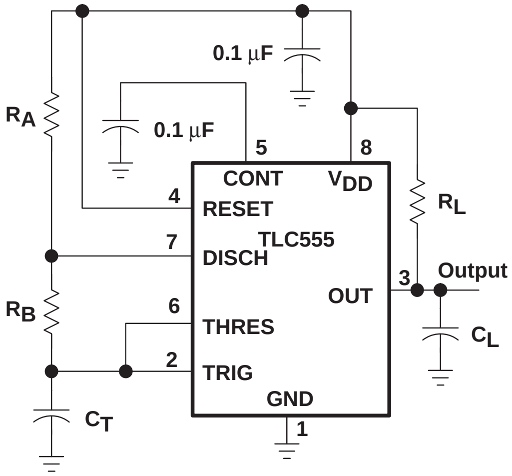
Figure 1



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

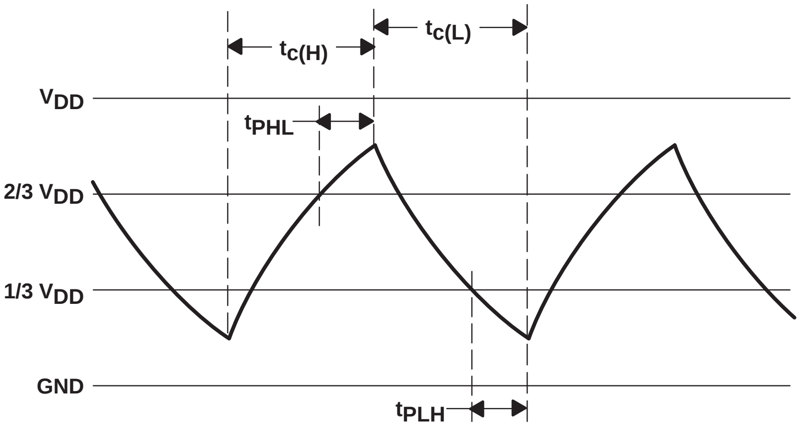
Figure 2

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.

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OTHER QUALIFIED VERSIONS OF TLC555, TLC555M :

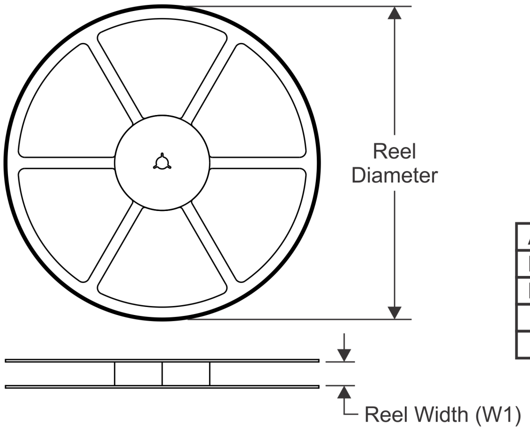
- Catalog: TLC555
- Automotive: TLC555-Q1, TLC555-Q1
- Military: TLC555M

NOTE: Qualified Version Definitions:

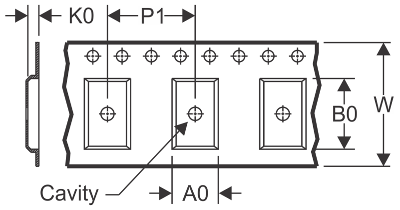
- Catalog - TI's standard catalog product
- Automotive - Q100 devices qualified for high-reliability automotive applications targeting zero defects
- Military - QML certified for Military and Defense Applications

TAPE AND REEL INFORMATION

REEL DIMENSIONS

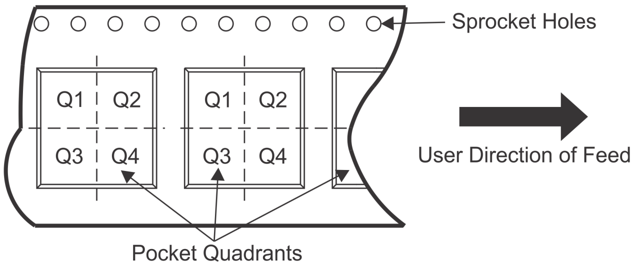


TAPE DIMENSIONS



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

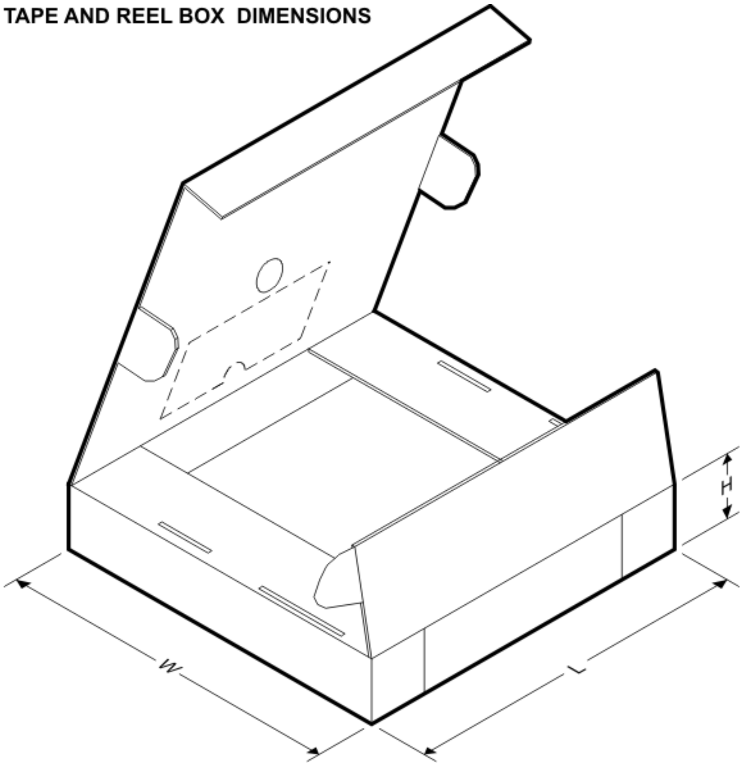
QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE



*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

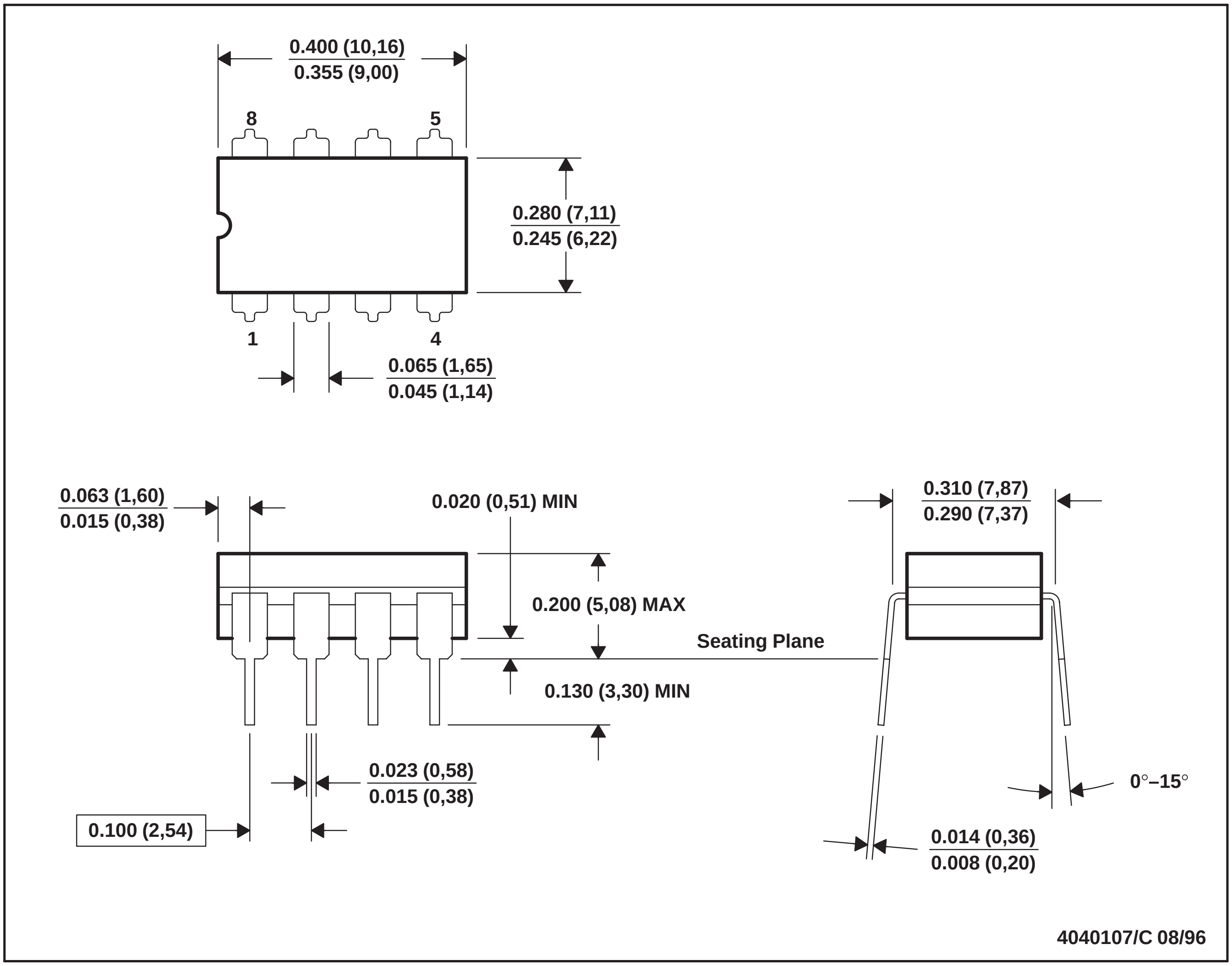
TAPE AND REEL BOX DIMENSIONS



*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

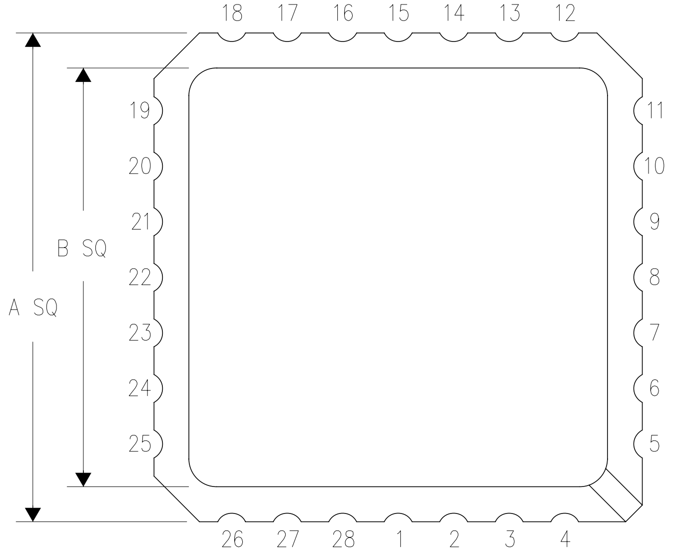
JG (R-GDIP-T8) CERAMIC DUAL-IN-LINE



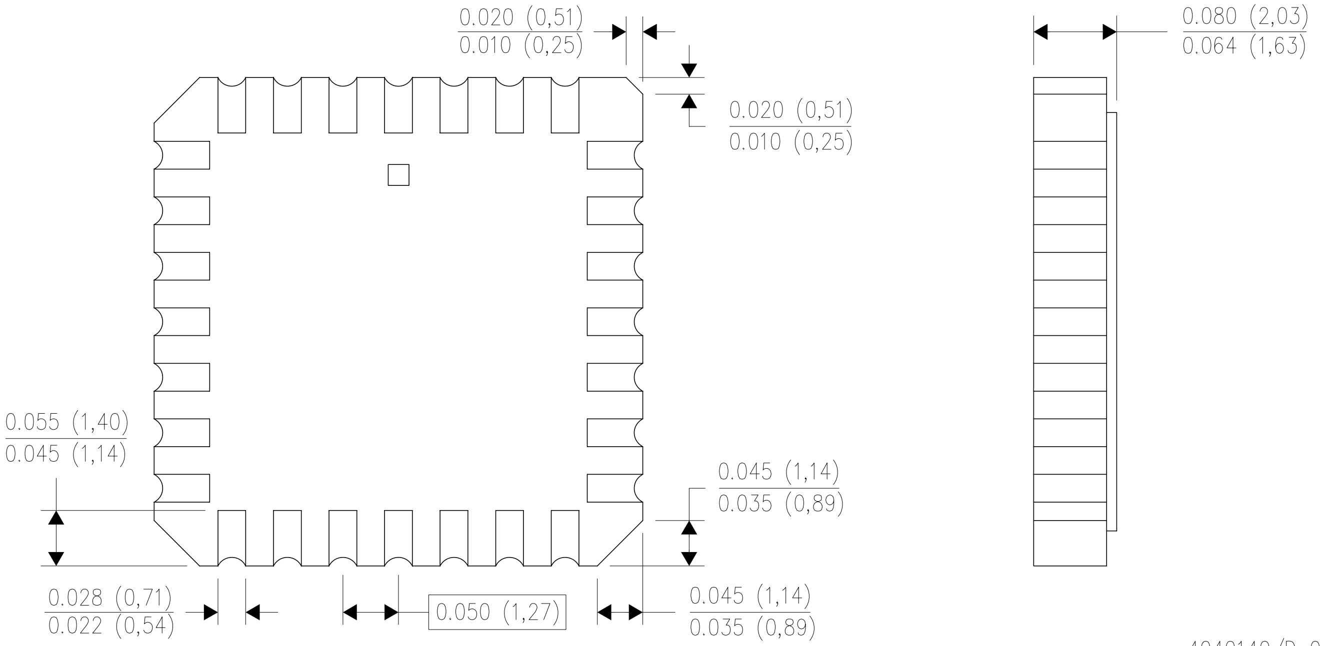
NOTES:
- A. All linear dimensions are in inches (millimeters).
- B. This drawing is subject to change without notice.
- C. This package can be hermetically sealed with a ceramic lid using glass frit.
- D. Index point is provided on cap for terminal identification.
- E. Falls within MIL STD 1835 GDIP1-T8

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

28 TERMINAL SHOWN



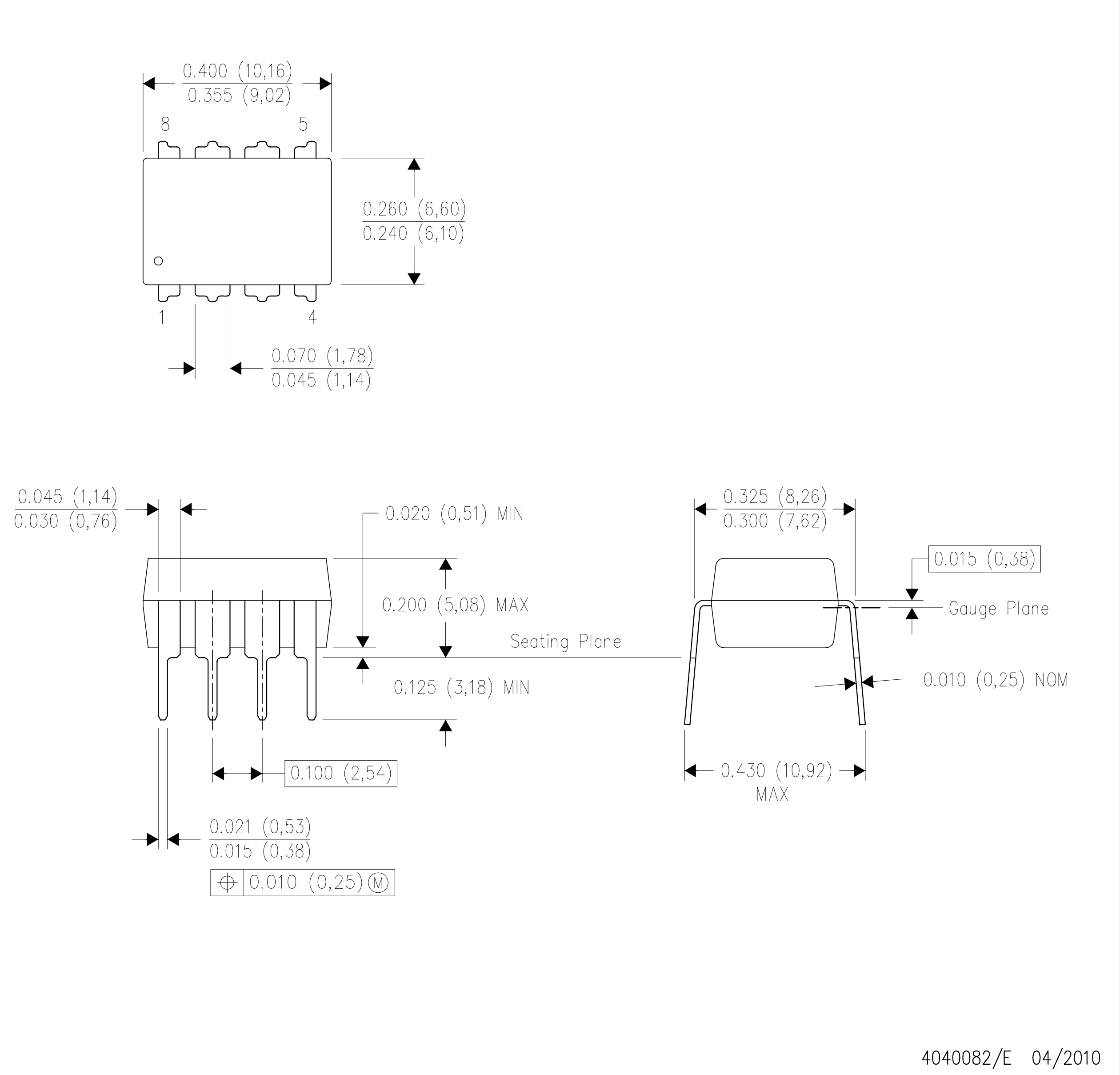
NO. OF TERMINALS **	A		B	
	MIN	MAX	MIN	MAX
20	0.342 (8,69)	0.358 (9,09)	0.307 (7,80)	0.358 (9,09)
28	0.442 (11,23)	0.458 (11,63)	0.406 (10,31)	0.458 (11,63)
44	0.640 (16,26)	0.660 (16,76)	0.495 (12,58)	0.560 (14,22)
52	0.740 (18,78)	0.761 (19,32)	0.495 (12,58)	0.560 (14,22)
68	0.938 (23,83)	0.962 (24,43)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

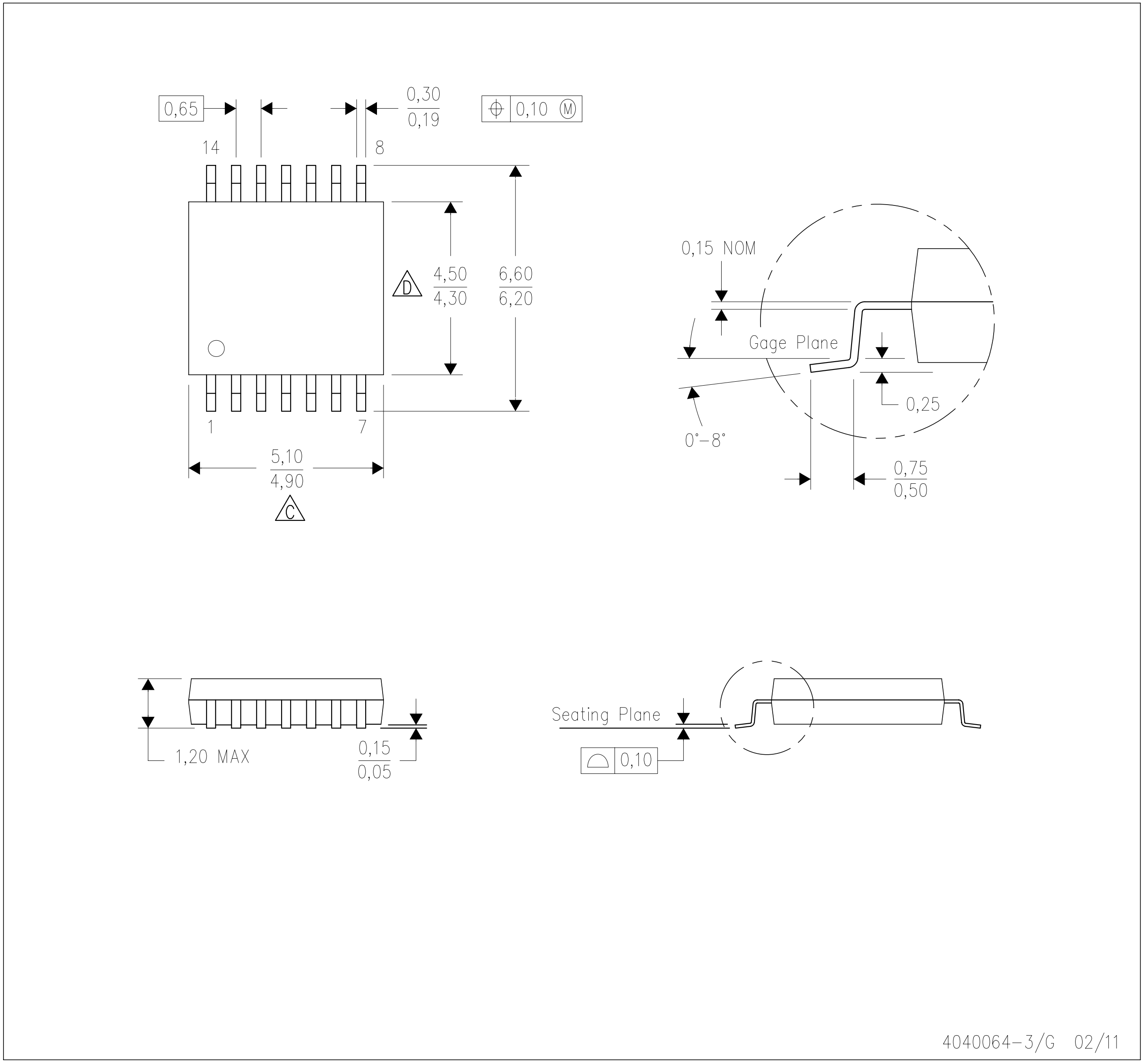
NOTES:
A. All linear dimensions are in inches (millimeters).
B. This drawing is subject to change without notice.
C. This package can be hermetically sealed with a metal lid.
D. Falls within JEDEC MS-004

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



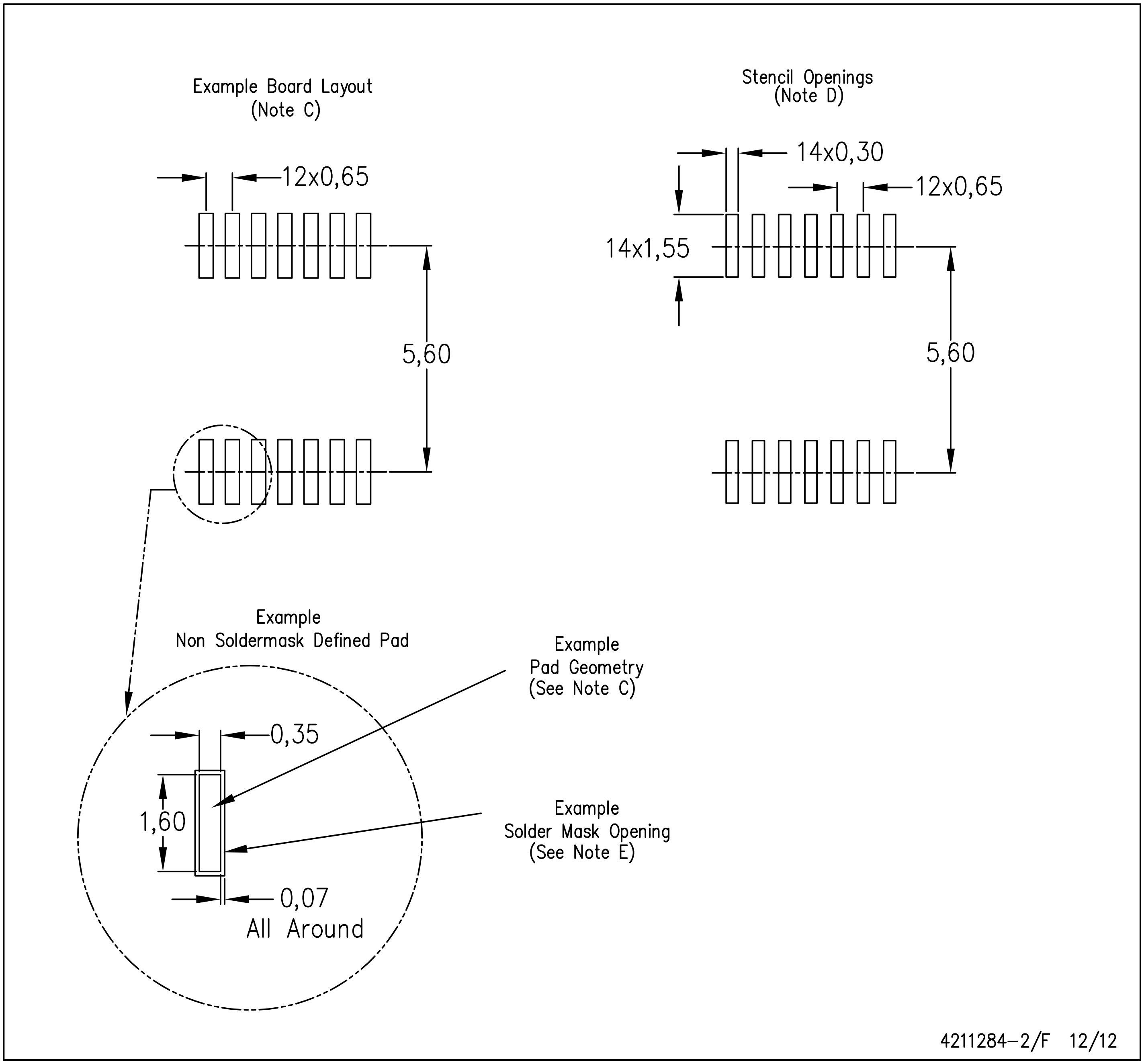
NOTES:
A. All linear dimensions are in inches (millimeters).
B. This drawing is subject to change without notice.
C. Falls within JEDEC MS-001 variation BA.

PW (R–PDSO–G14) PLASTIC SMALL OUTLINE



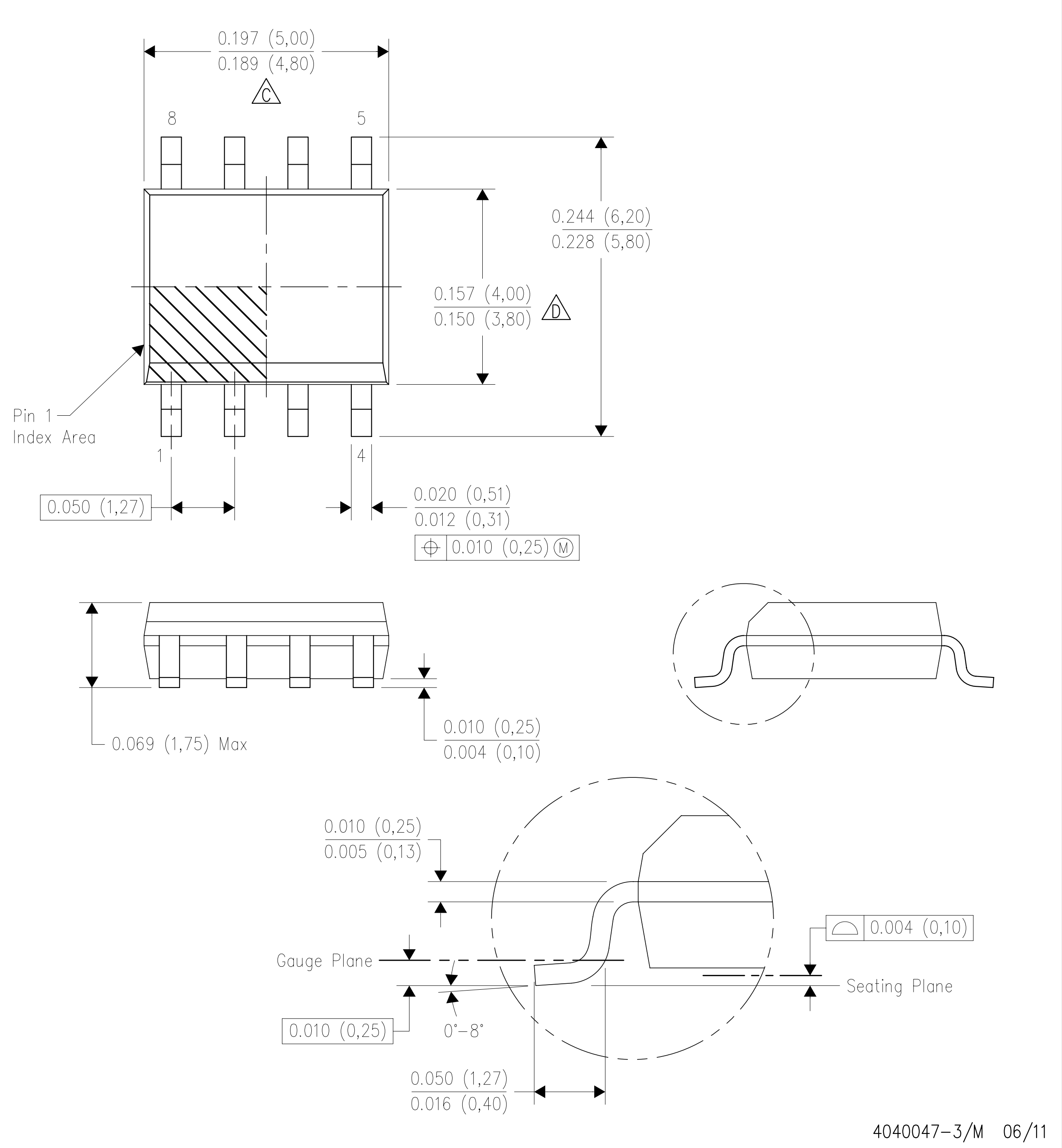
NOTES:
A. All linear dimensions are in millimeters. Dimensioning and tolerancing per ASME Y14.5M–1994.
B. This drawing is subject to change without notice.
C. Body length does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0,15 each side.
D.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



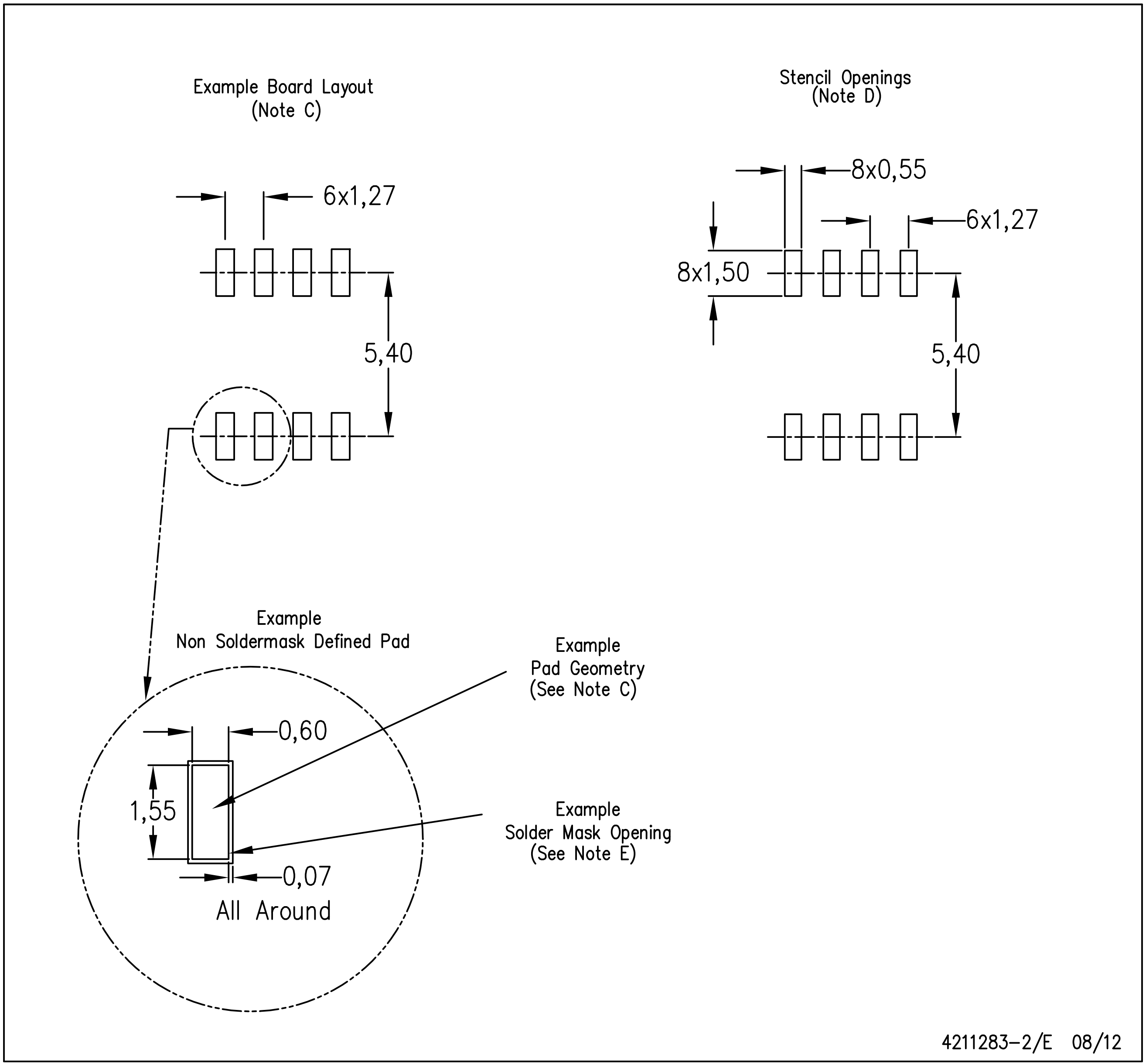
NOTES:
- A. All linear dimensions are in millimeters.
- B. This drawing is subject to change without notice.
- C. Publication IPC–7351 is recommended for alternate designs.
- D. Laser cutting apertures with trapezoidal walls and also rounding corners will offer better paste release. Customers should 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

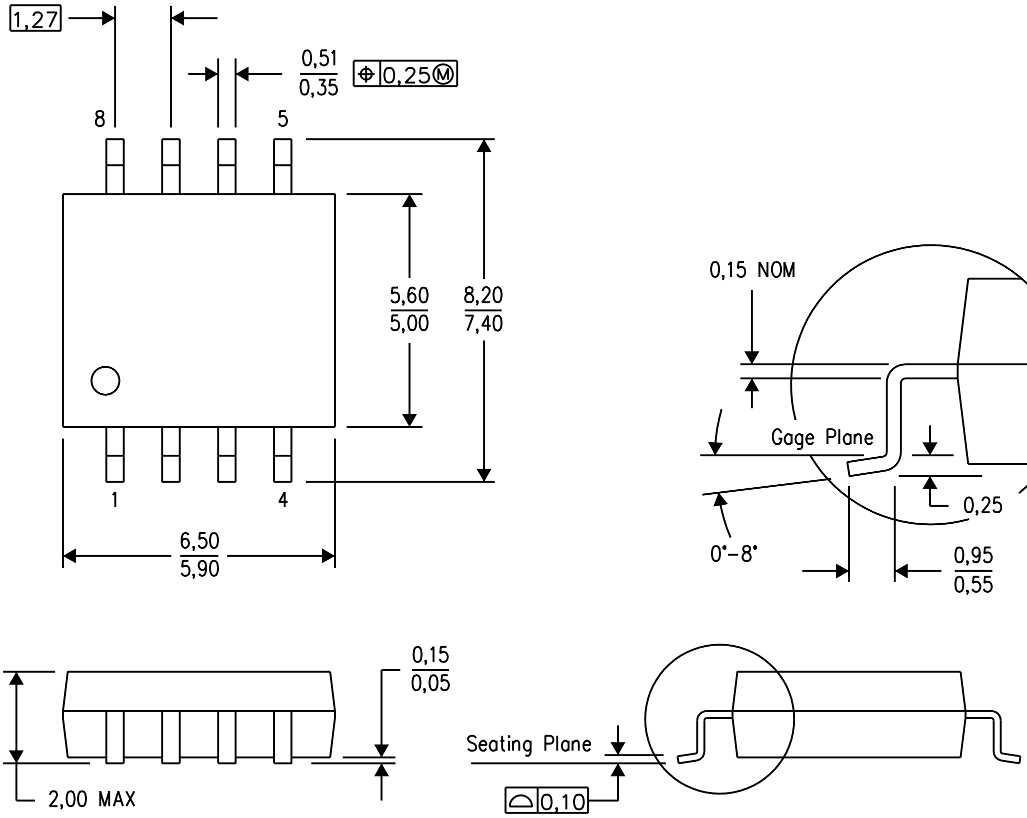


NOTES:
- A. All linear dimensions are in inches (millimeters).
- B. This drawing is subject to change without notice.
- C. Body length does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.006 (0,15) each side.
- D. Body width does not include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



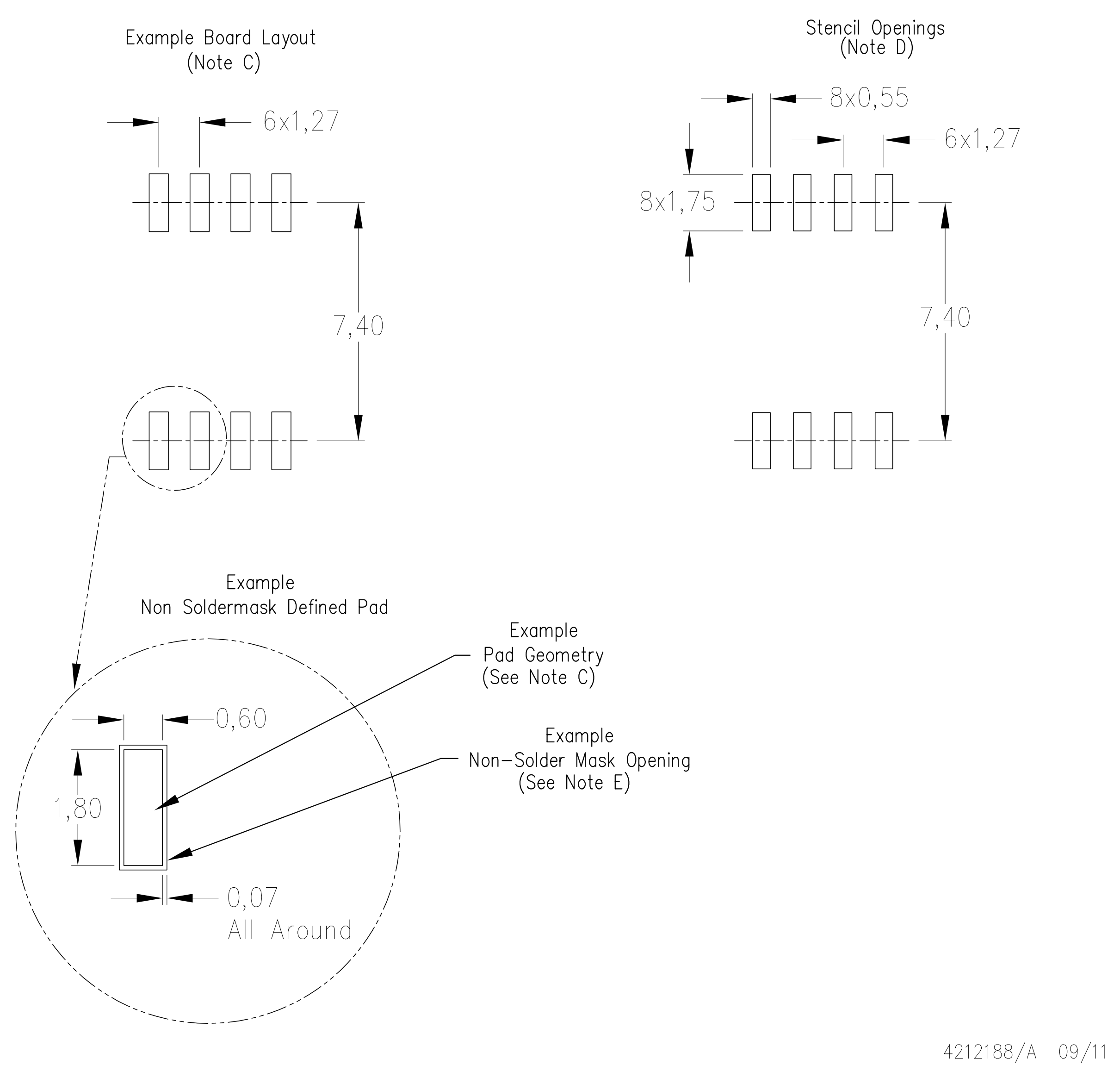
NOTES:
- A. All linear dimensions are in millimeters.
- B. This drawing is subject to change without notice.
- C. Publication IPC-7351 is recommended for alternate designs.
- D. Laser cutting apertures with trapezoidal walls and also rounding corners will offer better paste release. Customers should 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.



4040063/C 03/03

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.

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