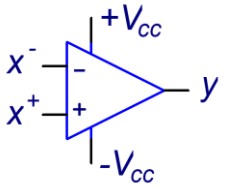
Branje lastnosti operacijskega ojačevalnika (OP) iz podatkov proizvajalca.

Operacijski ojačevalnik (OP) ima dve vhodni sponki (invertirani in ne-invertirani vhodni priključek) ter eno izhodno sponko po sliki ena. Za delovanje potrebuje vir energije – napajanje, ki ga priključimo med dodatni dve sponki ojačevalnika. Napajalni napetosti sta običajno dve, pozitivna in negativna, a ju v poenostavljenih elektronskih shemah ne rišemo, ampak privzamemo njuno prisotnost, slika 1.

Za idealni OP velja, da močno ojači razliko med signaloma, ki ju priključimo med ne-invertirano (x^+) in invertirano (x^-) vhodno sponko. Izhodni signal y je zato podan z:

$$y = G(x^+ - x^-)$$

Ojačenje zaznamuje faktor $G \to \infty$ (»Gain«). Idealnemu OP ne pripisujemo drugih lastnosti in marsikdaj se da vezje z OP narediti tako, da ni potrebno upoštevati njegovih pravih (realnih) lastnosti. Ker to ne drži vedno, se je potrebno zavedati omejitev realnega OP, kar bomo pogledali v nadaljevanju.

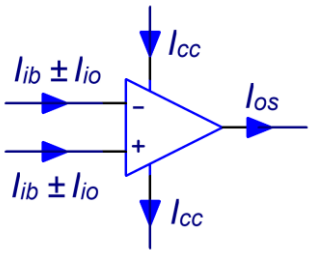


Slika 1: Operacijski ojačevalnik in priključeni signali

Operacijski ojačevalnik ima veliko ojačenje G, a ne neskončno veliko. Za večino OP se G giblje okoli vrednosti 10^5. Vezja, kjer OP uporabljamo, imajo običajno bistveno manjše ojačenje, zato za taka vezja privzamemo ojačenje idealnega OP, to je neskončno.

Omenili smo, da vsak OP potrebuje napajalno napetost. Ta mora biti prilagojena uporabljenemu OP in pričakovanih signalih v vezju; moderni OP so delani za napajalne različne napajalne napetosti. Nekateri prenesejo tudi nekaj deset voltov, spet drugi prenesejo vsega nekaj voltov. Parameter je običajno zaznamovan z V_{cc}.

V vsak elektronski element teče tok takrat, ko je na njegov vhodni priključek pritisnjena napetost, tudi OP ni izjema. Na obe vhodni sponki OP je pritisnjen električni signal, zato v vsako od obeh sponk teče tok, ki ga imenujemo »bias« tok (I_{ib}, »input bias«). Ta je lahko zelo majhen v primerjavi s tokovi, ki tečejo skozi elemente ob vhodnih sponkah OP, zato lahko takrat tok I_{ib} zanemarimo. Mnogokrat pa temu ni tako in upoštevati moramo, da je tok I_{ib} za različne OP lahko od femto ampera (10^{-15} A) do stotin mikro ampera, točne velikosti podaja proizvajalec OP. Za realni OP se tokova I_{ib} v vhodni sponki morda malo razlikujeta, to razliko opisuje veličina imenovana »ofsetni« vhodni tok (I_{io}, »input offset«).



Slika 2: Operacijski ojačevalnik in tokovi

Vhodni sponki OP sta pravzaprav bazna priključka diferenčnega para tranzistorjev. Če sta tranzistorja v diferenčnem paru popolnoma enaka, sta tudi padca napetosti med bazama in emitorjema teh dveh tranzistorjev popolnoma enaka. Za OP s takima tranzistorjema velja formula za izhodni signal y, podana v začetku zapisa. Žal je nemogoče izdelati par popolnoma enakih tranzistorjev. Če tranzistorja nista enaka, sta padca napetosti med njunima bazama in emitorjema malenkostno različna in to razliko je treba upoštevati v formuli za ojačeni izhodni signal. Neenakost tranzistorjev zaznamuje tako

imenovana »ofsetna« napetost V_{io} (»input offset«), ki za različne OP znaša od mikro voltov do desetin mili voltov. Formula za izhodni signal y, ki upošteva ofsetno napetost V_{io}, je:

$$y = G(x^+ - x^- - V_{io})$$

Tako ofsetna napetost V_{io} kot vhodni tok I_{ib} OP sta odvisna od temperature okolice. Tovarne zato podajajo njune povprečne vrednosti pri sobni temperaturi in najslabšo možno vrednost pri drugih temperaturah ali pa temperaturni koeficient spreminjanja.

Izhodni signal y OP ne more biti po formuli v prvem delu tega zapisa poljubno velik, pač pa je omejen z velikostjo napajalne napetosti OP. Pri modernih OP lahko y seže skoraj do obeh napajalnih napetosti. Na primer: če je napajalna napetost $\pm 5\ V$, lahko pričakujemo y med +4,95 in -4,95 V; za takšne OP pravimo, da imajo »rail-to-rail« izhodno sponko (»RRO«). Večina OP ne zmore tako širokega območja izhodnih signalov, ampak se y le bolj ali manj približa napajalnim napetostim. Takrat govorimo o napetosti nasičenja oziroma o skrajni meji izhodne napetosti U_{opp} (»output peak-to-peak«). Napetost nasičenja je lahko na primer 1 V, potem pri napajalni napetosti $V_{cc} = \pm 12\ V$ izhodni signal seže do največ $\pm 11\ V$.

Izhodni tok OP je navadno namenoma omejen s sklopi elektronike v notranjosti OP. Omejitev toka prepreči poškodbe OP zaradi prevelikega izhodnega toka (in s tem povzročenega pregrevanja OP), ki bi ga povzročilo breme z majhno upornostjo. Za tipični OP je izhodni tok omejen na okoli 20 mA.

Formula, ki smo jo podali v začetku za izhodni signal OP velja le v primeru, da noben od signalov na vhodnih sponkah (x^+ in x^-) ni preveč blizu napajalnih napetosti OP. Še več: če signali na vhodnih sponkah OP presežejo napajalne napetosti OP, ga lahko poškodujejo. Dopustno območje vhodnih signalov je zato največ enako napajalni napetosti $\pm V_{CC}$. Če smejo vhodni signali za dani OP seči do obeh napajalnih napetosti in OP še vedno deluje pravilno, govorimo o RRI (»Rail-to-rail input«) OP. Večina OP-jev pa deluje po prej navedeni formuli le, če sta oba vhodna signala nekaj voltov nad $-V_{CC}$ in hkrati nekaj voltov pod $+V_{CC}$. Za primer: OP deluje pravilno le, če so pri napajalni napetosti $\pm 5\ V$ vhodni signali med najmanj -3 V in največ +3 V. To lastnost opisuje »input common mode range« (V_{icm}), ki bi za navedeni primer znašal $\pm 3\ V$. Obstajajo izjemni OP, za katere vhodni signali lahko za nekaj sto mili voltov presegajo eno ali celo obe napajalni napetosti.

Za svoje delovanje OP porablja električni tok, tipično nekaj mili amperov. Poraba električnega toka je posledica v OP vgrajenih elementov, označuje pa jo I_{cc} (»quiscent current«). Na splošno velja, da so tisti OP, ki porabijo manj toka, počasnejši. Poraba toka se za različne OP giblje od delca mikro ampera do stotin mili ampera. Za naprave, ki izrabljajo baterije za napajanje, iščemo OP s čim manjšo porabo.

Pomembna lastnost OP je njegova hitrost; noben OP ne zmore ojačevanja signalov s frekvenco stotin GHz. Hitrost OP popisujeta vsaj dva parametra, to sta »gain-bandwidth product« (GBW) in »slew-rate« (SR, hitrost vzpona).

- Na vhodno sponko OP lahko priključimo majhen harmonski signal; če sta amplituda in frekvenca tega signala majhni, bo izhodni signal y prav tako harmonske oblike in G-krat večji. Ko vhodnemu signalu povečujemo frekvenco, se izhodni signal y zmanjšuje in pri dovolj veliki frekvenci postane po velikosti enak vhodnemu. Pravimo, da ima takrat vhodni signal frekvenco GBW; GBW podaja produkt frekvence vhodnega signala in ojačenja OP. Enakovredno bi lahko parameter GBW izračunali tudi z množenjem frekvence vhodnega signala in dejanskega razmerja amplitud (ojačenja) izhodnega ter vhodnega signala, le izhodni signal bi moral pri tem biti po obliki enak vhodnemu. Tipične vrednosti GBW so za različne OP med nekaj deset kHz

(za OP z majhno lastno porabo električnega toka) in več GHz (ti porabijo 10 mili amperov ali več).

- Na vhodno sponko lahko priključimo tudi primerno majhen izmeničen pravokoten signal; ravni deli vhodnega signala povzročijo prav tako ravne dele izhodnega signala, le njihova vrednost je za faktor G večja. Takoj po spremembi (ob zamenjavi polaritete) vhodnega signala izhodni signal y zaradi lastnosti OP ne more poskočiti na novo vrednost, pač pa se ji bolj ali manj enakomerno približuje. Izhodni signal y je zato bolj ali manj trapezne oblike. Največjo hitrost spreminjanja izhodnega signala poimenujemo »slew rate« SR, tipične vrednosti SR pa med mili volti na mikro sekundo in tisočimi voltov na mikrosekundo. Kot prej omenjeno hitrejši OP tipično porabijo več električnega toka, saj le tako lahko hitreje polnijo in praznijo kapacitivnosti med elektronskimi elementi v svoji notranjosti.

Lastnosti tipičnega OP

Poglejmo lastnosti tipičnega operacijskega ojačevalnika, za zgled naj bo TL081, standardni široko potrošni operacijski ojačevalnik s ceno približno 0,5 €. Brskanje po internetu oziroma iskanje ključne besede »TL081 pdf« vrne datoteko z opisom tega elementa, ki je pripeta temu dokumentu. Različne firme izdelujejo precej podobne OP, ki jih vse najdemo pod imenom TL081, zato je za točnejše podatke o integriranem vezju potrebno poznati oznako vezja in proizvajalca ter tako najti pravo datoteko z opisom. Poskusimo z datoteko za izdelek firme ST, ki je pripeta temu zapisu.

Na prvi strani levo zgoraj so naštete lastnosti tega OP, ki so se zdele proizvajalcu še posebej vabljive. Med te sodi podatek o tem, da lahko vhodna napetost v ta OP seže do pozitivne napajalne napetosti, da je vhodni tok in razglašenost para vhodnih tranzistorjev majhna, da je izhodni tok omejen in tako naprej. Podrobnosti si bomo raje ogledali v tabelah in diagramih. Na desni polovici iste strani je navadno skica ohišja, v katerem je mogoče dobiti ta OP. V tem zapisu je na isti strani še razpored priključkov na nožicah integriranega vezja; vhodna priključka OP sta dostopna na nožicah 2 (x^-) in 3 (x^+), izhodni priključek y pa na nožici 6. Napajalni napetosti priključimo med množici 7 in 4 tako, da je na množici 7 pozitivna napajalna napetost ($+V_{cc}$), na množici 4 pa negativna ($-V_{cc}$). Preostale množice čipa lahko ostanejo nepriključene. Opis vezja navaja izjemo, ki velja le za ta OP: s pomočjo zunanjega vezja (potenciometra), ki ga priključimo med nožici 1 in 5 po shemi na sliki 2 lahko kompenziramo neenakost vhodnih tranzistorjev ter tako izničimo ofsetno napetost V_{io}.

Kadar je mogoče dobiti izbrani OP v več različnih ohišjih z različnim razporedom nožic najdemo v datoteki tloris za vsak razpored posebej. Velikost ohišja je navadno kotirana ob koncu opisa elementa, tam je narisan tudi predlog za tloris tiskanega vezja, kamor se tak element prispajka. V imenu integriranega vezja dodatne črke za oznako TL081C označujejo vrsto ohišja.

Osnovnemu opisu OP sledi navedba največjih napetosti, tokov in moči, ki jih vezje še prenese brez poškodb. V dani datoteki so te navedbe v tabeli 1 (»Absolute maximum ratings«). Prva vrstica podaja največjo dopustno napajalno napetost na nožicah 7 in 4, to je ±18 V; več poškoduje OP. Druga vrstica podaja največjo vhodno napetost, ki znaša ±15 V; med vhodna priključka x^+ in x^- torej lahko priključimo +30 V ali -30 V, večja napetost lahko poškoduje OP. V opombah je navedeno, da ta omejitev velja le za napajalno napetost ±18 V; pri manjših napajalnih napetostih je dopustna vhodna napetost manjša in enaka napajalni napetosti.

Četrta vrstica tabele podaja največjo moč, ki jo je OP sposoben brez poškodbe pretvoriti v toploto, naslednja vrstica pa zagotavlja, da lahko izhodno sponko OP brez škode povežemo na ozemljitev (0 V), saj bo notranje vezje za omejitev izhodnega toka zaščitilo OP.

Sledi nekaj temperaturnih podatkov. OP lahko hranimo pri temperaturi od -65 do 150 °C, kar je zapisano v šesti vrstici tabele. Sedma vrstica tabele podaja termično upornost proti okolici (R_{thja}, »thermal resistance junction-to-ambient«) za dve različni ohišji, v katerih je ta OP mogoče dobiti pri firmi ST. Za OP, ki jih bomo uporabljali v šoli in so izdelani v tako imenovanem DIP8 ohišju velja, da se temperatura silicijeve ploščice v notranjosti ohišja poveča za 8,5 °C za vsak vat električne moči, ki se v OP pretvarja v toploto in mora prej ali slej preiti v okolico. V osmi vrstici je navedena termično upornost med ploščico silicija z OP in plastičnim ohišjem (R_{thjc}, »thermal resistance junction-to-case«). Ta podatek bi bil pomemben, če bi plastično ohišje prisilno hladili, a za naše potrebe ni relevanten.

Zadnje tri vrstice tabele podajajo še največje napetosti, ki jih brez škode lahko za hip pritisnemo na vhode operacijskega ojačevalnika. Do takšnih hipnih preobremenitev prihaja ob razelektritvah, morda takrat, ko se dotaknemo nožice integriranega vezja pa je bilo naše telo nabito z električnim nabojem. To se lahko pri nas najpogosteje dogaja pozimi ob suhem ozračju v zaprtih prostorih in centralnem gretju. Da bi preprečili poškodbe OP zaradi razelektritev, so lahko integrirana vezja med transportom vtaknjena v prevodno penasto snov ali zaščitena z aluminijevo folijo. Pri rokovanju s takšnimi čipi pa je najpomembneje to, da naboj iz našega telesa pred dotikom čipa odvedemo na varno mesto. Če na primer čip podajamo iz roke v roko med dvema osebama je smiselno, da se ti osebi najprej dotakneta z prostima rokama in šele potem prva oseba drugi preda integrirano vezje.

Tabela 2 (»Operating conditions«) podaja tipične pogoje, pri katerih bo OP pravilno deloval. V prvi vrstici je navedena potrebna napajalna napetost, ki je vsaj 6 V in največ 36 V. OP je navadno izdelan v več verzijah, ki se lahko za malenkost drugače vedejo ali pa prenesejo večje tolerance delovnih pogojev. Vezja, ki so nemenjena običajni rabi, najdemo pod imenom »komercialna« verzija (»commercial version«). Vezja, ki morajo prenesti širši razpon delovnih pogojev, najdemo pod imenom »industrijska« ali »vojaška« verzija (»industrial version« ali »military version«). V tej tabeli je opaziti razlike med verzijami istega OP, ki poleg oznake TL081 nosijo še dodatno oznako »I« ali »C«. Za našo rabo je dovolj dobra običajna izvedba, torej komercialna verzija (»C«), ki je pogostejša in cenejša.

OP v komercialni izvedbi pravilno deluje pri različnih temperaturah okolice od 0 °C do 70 °C. okoliške temperature prek navedenih meja ga morda še ne poškodujejo, a se lastnosti OP zaradi temperature vsaj začasno spremenijo.

Tabela 3 (»Electrical characteristics«) podaja natančnejše električne karakteristike vezja pri napajalni napetosti ±15 V in sobni temperaturi (25 °C), kar je navedeno v glavi tabele; izjeme oziroma drugačni pogoji so podane v opombah. Oglejmo si lastnosti najbolj splošno uporabljanega OP TL081C, ki so zapisane v desnem stolpcu te tabele.

Ofsetna napetost V_{io} za TL081C je navedena v prvi vrstici te tabele na desni in znaša za tipični primerek tega OP 3 mV; pri nekaterih primerkih tega OP je ofsetna napetost V_{io} največ 10 mV. Če se temperatura okolice spreminja od minimalne (0 °C) do maksimalne (70 °C), se ofsetna napetost V_{io} lahko poveča do največ 13 mV, kar je podano v spodnji polovici tretjega okenca. Ofsetna napetost V_{io} je odvisna od temperature okolice in se za tipični primerek TL081C poveča za 10 μV za vsako stopinjo povečanja temperature okolice, kar je navedeno v drugi vrstici tabele.

Vhodni tok I_{ib} OP je naveden v četrti vrstici tabele 3 in za tipični predstavnik tega OP znaša do 5 pA pri sobni temperaturi; pri nekaterih predstavnikih lahko znaša do 400 pA. Izjemoma lahko vhodni tok naraste zaradi spreminjanja okoliške temperature v normalnem območju delovanja (0 °C do 70 °C), vendar ostaja manjši od 20 nA.

Vhodna tokova I_{ib} v vhodna priključka OP se lahko razlikujeta za vhodni ofsetni tok I_{io}; za dani OP pri sobni temperaturi je razlika tipično 5 pA, kar je navedeno v tretji vrstici tabele. Pri nekaterih primerkih

lahko razlika znaša do 100 pA. Pri drugih temperaturah v območju delovanja OP se lahko poveča tudi vhodni ofsetni tok, vendar ne preseže 10 nA.

Tipično ojačenje G za TL081C je podano v peti vrstici tabele in nosi oznako A_{vd}. Pri sobni temperaturi znaša ojačenje povprečnega primerka 200000. Pri nekaterih primerkih je ojačenje lahko manjše, vendar ne manj kot 25000. Ojačanje je odvisno od temperature, a ne pade pod vrednost 15000.

Spreminjanje napajalne napetosti malenkostno vpliva na izhodno napetost OP, kar podaja šesta vrstica tabele. Pri sobni temperaturi je pričakovati, da bo sprememba napajalne napetosti za 1 V spremenila izhodni signal OP za 50 μV. Če ta vpliv prevedemo v logaritemsko skalo, pridemo preko 20-kratnega logaritma razmerja navedenih vrednosti do številke -86 dB. Pri nekaterih OP je vpliv spremembe napajalne napetosti lahko večji, a ne večji od -70 dB. Prevedeno v prejšnje številke torej sprememba napajalne napetosti za 1 V spremeni izhodno napetost OP za največ 0,3 mV.

Operacijski ojačevalnik potrebuje za delovanje električno energijo. Pridobi jo tako, da iz napajalnih linij jemlje tok I_{cc} (»supply current, no load« ali »quiscent current«), ki pri sobni temperaturi znaša 1,4 mA. Pri nekaterih OP je lahko tok I_{cc} do 2,5 mA in je lahko odvisen od temperature okolice, vendar nikoli ne preseže 2,5 mA.

V prvem delu tega zapisa je bilo navedeno, da smemo na vhoda OP priključiti signala v območju ±15 V. V osmi vrstici tabele je to območje natančneje določeno. Imenujemo ga »common mode range«, podaja ga parameter V_{icm}. Na vhodni sponki tipičnega OP, ki ga napajamo s ±15 V, smemo priključiti signala v območju med -12 V in +15 V in vse bo delovalo po pričakovanjih. Najdejo se tudi primerki tega OP, kjer je uporabno območje vhodnih signalov manjše in znaša vsega ±11 V pri enaki napajalni napetosti.

Izhodni signal y OP izračunamo po formuli v prvem delu tega zapisa. Za realni OP formula ni popolnoma točna. Vhodna signala sta na primer lahko enaka in zato bi moral biti izhodni signal enak nič. V resnici na izhodno napetost malenkostno vpliva tudi to, kje v območju »common mode« sta vhodna signala. Če imata oba vrednost -1 V, bo morda zaradi tega izhodni signal izmaknjen na -50 μV. Podobno bo morda imel izhodni signal vrednost +50 μV takrat, ko sta oba vhodna signala enaka in imata vrednost +1 V. Le če sta oba vhodna signala enaka in imata vrednost 0 V, ima izhodni signal vrednost nič. Govorimo o sposobnosti izločanja skupne vrednosti vhodnih signalov (»common mode rejection ratio«), ki za zgoraj navedene številke, prevedene v enote dB, znaša -86 dB; to je tudi zapisano v deveti vrstici tabele tri za tipičnega predstavnika teh OP. V najslabšem primeru je vpliv skupne napetosti večji in znaša -70 dB, torej enak odmik obeh vhodnih signalov od nič za 1 V povzroči 0,3 mV na izhodu OP. Vpliv je odvisen tudi od temperature, a ni nikoli večji od -70 dB.

Izhodni tok operacijskega ojačevalnika je zaradi varnosti OP elektronsko omejen. Pri sobni temperaturi je največji izhodni tok za tipični TL081C 40 mA, a je najmanj 10 mA in največ 60 mA za ekstremne primerke tega OP. Omejitev je odvisna od temperature okolice, a za tudi pri skrajnih temperaturah v območju delovanja OP ostaja med 10 mA in 60 mA.

Izhodni signal y ne more doseči napajalnih napetosti $\pm V_{cc}$. V enajsti vrstici tabele tri je navedeno območje za izhodni signal OP pri sobni temperaturi (»output voltage swing«, V_{opp}), napajalni napetosti ±15 V in bremenu, ki ga predstavlja upornik $R = 2\ k\Omega$. Tipičen OP TL081C lahko požene izhodno napetost do ±12 V, a nekateri primerki zmorejo samo ±10 V. Če je upornost bremena večja, na primer 10 kΩ, je območje izhodnih napetosti večje in znaša tipično ±13,5 V, pri nekaterih šibkejših primerkih tega OP pa le ±12 V. V spodnjem delu tega okenca so enakovredni podatki za celotno območje temperatur od 0 °C do 70 °C za najslabše primerke tega OP.

Izhodni signal y OP torej bolj ali manj sledi formuli za izhodno napetost, ki je bila podana v začetku tega zapisa, a žal za sledenje potrebuje čas. Zaradi notranjih kapacitivnosti v OP in končnih vrednosti tokov, ki so na razpolago za njihovo polnjenje in praznjenje, se izhodna napetost OP spreminja s končno hitrostjo, popisano s parametrom SR (»slew rate«). Za tipičen predstavnik TL081C, ki je obremenjen z upornikom $R = 2\ k\Omega$ in kondenzatorjem $C = 100\ pF$ ter ima ojačenje 1, znaša SR 16 V/μs, kar preberemo v dvanajsti vrstici tabele. Pri najpočasnejših primerkih tega OP in enakem bremenu znaša SR vsaj 8 V/μs. Podatki veljajo za velike spremembe izhodnega signala, ki znaša 10 V. Po izkušnjah je mogoče trditi, da utegne biti SR večji za manjšo upornost in kapacitivnost bremena. Za majhne spremembe vhodne napetosti, ki znašajo 0,2 V, in enakem bremenu se izhodni signal ustali na novi vrednosti v vsega 100 ns, kar je navedeno v trinajsti vrstici tabele.

Izhodni signal OP zaradi trenutne spremembe vhodne napetosti zaniha okoli končne vrednosti. Pri sobni temperaturi, bremenski upornosti 2 kΩ in kapacitivnosti 100 pF bo v vezavi napetostnega sledilnika izhodni signal za največ 10 % presegel končno vrednost preden se bo na njej ustalil, kar je navedeno v štirinajsti vrstici tabele.

Na vhod OP lahko priključimo tudi majhen izmenični signal sinusne oblike. Če je OP obremenjen z upornikom $R = 2\ k\Omega$ in kondenzatorjem $C = 100\ pF$, bo ta OP ojačeval signal do frekvence 4 MHz, nekateri šibkejši primerki pa bodo zmogli le 2,5 MHz, nad tema frekvencama bo izhodni signal manjši od vhodnega. Ta parameter je podan kot GBP (»gain bandwidth product«) v petnajsti vrstici tabele.

Vhodna upornost OP lahko definiramo kot kvocient spremembe vhodne napetosti in ustrezne spremembe vhodnega toka. Za dani OP je tipična vhodna upornost enaka 10^{12} Ω, kar je navedeno v šestnajsti vrstici tabele tri.

Na vhod ojačevalnika, ki ima vgrajen ta OP in ima ojačenje 20 decibelov (ojačenje znaša 10), lahko pritisnemo sinusni signal s frekvenco 1 kHz in amplitudo 100 mV ter opazujemo izhodni signal; velikost izhodnega signala bo 2 V_{pp} (od vrha do vrha). Naj bo OP pri tem spet obremenjen z upornikom $R = 2\ k\Omega$ in kondenzatorjem $C = 100\ pF$. Pričakujemo, da bo na izhodu ojačevalnika prisoten le omenjeni signal s frekvenco 1 kHz, a zaradi nepopolnosti OP temu ni tako. Pojavijo se še komponente s frekvencami, ki so mnogokratniki 1 kHz (pravimo jim harmonski mnogokratniki, izhodni signal pa je zaradi tega popačena verzija vhodnega). Po navedbi v vrstici sedemnajst tabele lahko pričakujemo 0.01 % teh komponent. Ker tu govorimo o THD (»total harmonic distorsion«) pomeni, da primerjamo efektivno vrednost osnovne komponente (pri 1 kHz) z efektivno vrednostjo vseh ostalih komponent (pri 2 kHz, 3 kHz, 4 kHz, …), ki se pojavijo na izhodu ojačevalne stopnje. Efektivna vrednost osnovne komponente izhodnega signala torej znaša 0.707 V_{rms}, efektivna vrednost vseh harmonskih komponent skupaj pa največ 70,7 μV_{rms}.

Na izhodu OP vedno poleg signala, ki ga ojačujemo, na merimo še naključne spremembe napetosti, ki jih imenujemo šum. Ta šum ovrednotimo s frekvenčnim analizatorjem, ki pove, kako močno je ta šum zastopan pri različnih frekvencah. Šum je nadloga, porojena v OP in onemogoča točno določanje izhodnega signala OP in s tem obdelavo majhnih vhodnih signalov. Za testiranje kakovosti stopnje z OP vhodno sponko v vezje ozemljimo in analiziramo šumni signal na izhodu. Dobljeni frekvenčni spekter šuma delimo z ojačenjem analizirane stopnje in dobimo spekter ekvivalentnega vhodnega šuma. Ta za dani OP pod pogoji, navedenimi v osemnajsti vrstici tabele, znaša $15\ nV/\sqrt{Hz}$. O šumih bomo še govorili, zato na tem mestu ne bomo komentirali na videz čudne enote. Za najboljše OP znaša spektralna gostota šuma okoli $1\ nV/\sqrt{Hz}$, za slabe (v pogledu spektralne gostote šuma) pa več kot $100\ nV/\sqrt{Hz}$.

Zadnja vrstica te tabele podaja fazno varnost, to je fazni kot med izhodnim signalom y in vhodnim signalom pri frekvenci, kjer ojačenje OP pade na vrednost ena. Podatek se nanaša na stabilnost vezja z OP, ki jo določamo s pomočjo Bodejevih diagramov, tudi o tem bomo še govorili. Za TL081C znaša fazna varnost 45° kar zagotavlja, da OP oziroma stopnja, v kateri je takšen OP uporabljen, ne bo sama od sebe nihala niti takrat, ko bo ojačenje vezja s tem OP enako ena (za napetostni sledilnik).

Za lažjo interpretacijo podatkov iz navedenih tabel navadno v opisu OP sledi niz diagramov. Za dani primer sta v »Figure 3« in »Figure 4« podani skici največje možne amplitude izhodnega signala sinusne oblike za različne frekvence in napajalne napetosti pri 25 °C ter dve različni upornosti bremena. Diagrama se navezujeta na podatka za SR in V_{opp}. Naslednja dva diagrama podajata vpliv temperature na največjo možno amplitudo izhodnega signala z navezavo na ista parametra, diagrama v »Figure 7« in »Figure 8« pa podajata vpliv upornosti bremena in vpliv napajalne napetosti na največjo možno amplitudo izhodnega signala.

Diagram na sliki 9 podaja vpliv temperature na vhodni tok v OP (I_{ib}). Tok za ta OP (TL081) s povečevanjem temperature hitreje-kot-eksponentno narašča! Takšno hitro naraščanje je značilno za tiste OP, ki izrabljajo FET tranzistorje na vhodih. Deseti diagram podaja odvisnost ojačenja G od temperature.

Od ostalih diagramov velja omeniti še diagram na sliki 16, ki podaja časovno spreminjanje izhodnega signala pri skokoviti spremembi vhodnega signala. Diagram se nanaša na hitrost vzpona (SR) za ta OP. Iz diagrama lahko odčitamo SR kot spremembo izhodnega signala v času in znaša $^{12\ V}/_{0.9\ \mu s}$ za naraščanje izhodnega signala in $^{12\ V}/_{1.1\ \mu s}$ za padanje.

Nekatere firme podajajo še bolj podrobne specifikacije svojih izdelkov. Za zgled je temu zapisu pripeta še sorodna datoteka druge firme (TI) za OP z enako generično oznakoTL081.

TL081

General purpose JFET single operational amplifiers

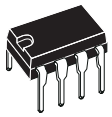
Features

- Wide common-mode (up to V_{CC}^+) and differential voltage range
- Low input bias and offset current
- Output short-circuit protection
- High input impedance JFET input stage
- Internal frequency compensation
- Latch-up free operation
- High slew rate: 16 V/µs (typ)

Description

The TL081, TL081A and TL081B are high-speed JFET input single operational amplifiers incorporating well matched, high-voltage JFET and bipolar transistors in a monolithic integrated circuit.

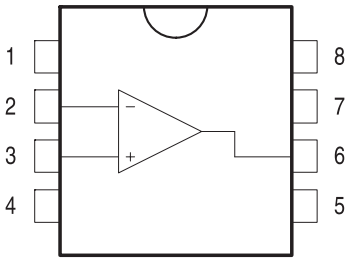
The devices feature high slew rates, low input bias and offset currents, and low offset voltage temperature coefficient.



N
DIP8
(Plastic package)

D
SO-8
(Plastic micropackage)

Pin connections
(top view)



1 - Offset null 1
2 - Inverting input
3 - Non-inverting input
4 - V_{CC}^-
5 - Offset null 2
6 - Output
7 - V_{CC}^+
8 - N.C.

1 Schematic diagram

Figure 1. Schematic diagram

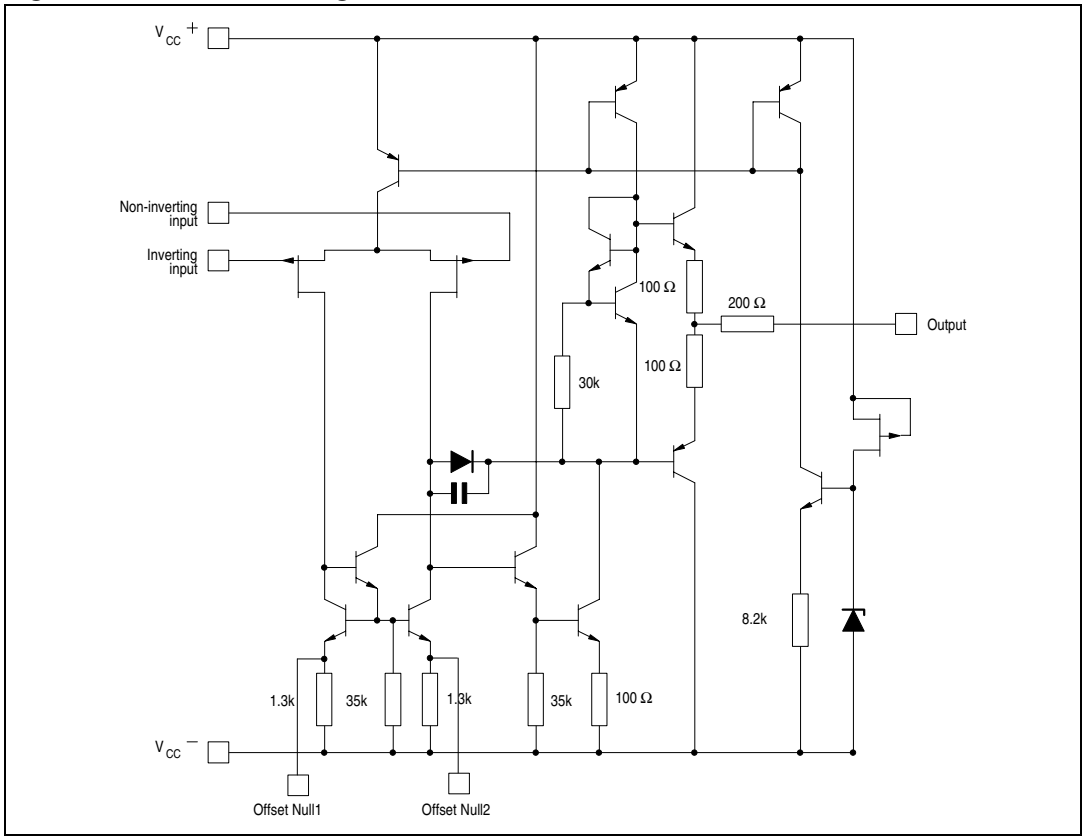
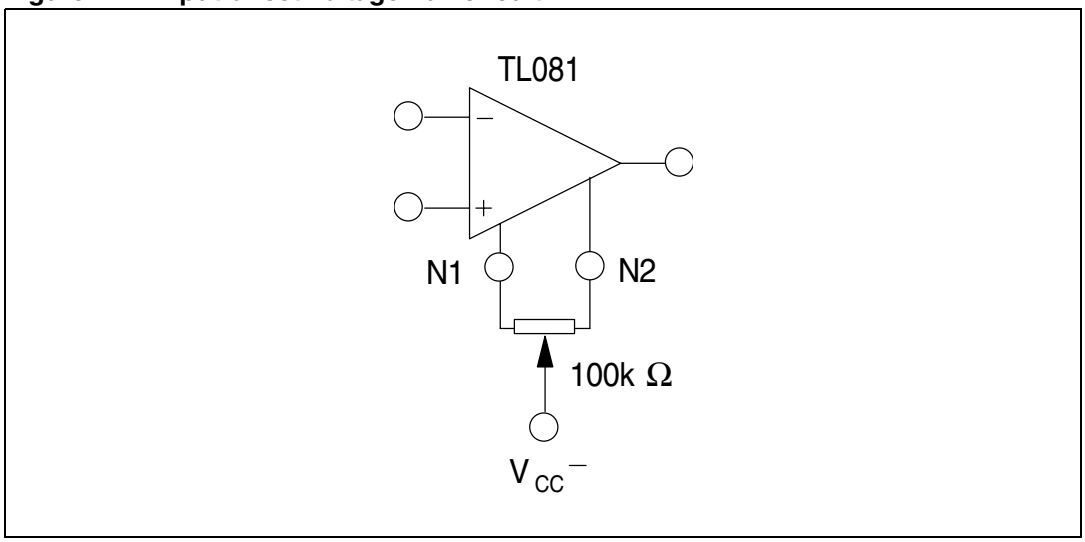


Figure 2. Input offset voltage null circuit



2 Absolute maximum ratings

Table 1. Absolute maximum ratings

Symbol	Parameter	TL081I, AI, BI	TL081C, AC, BC	Unit
V_{CC}	Supply voltage (1)	±18		V
V_{in}	Input voltage (2)	±15		V
V_{id}	Differential input voltage (3)	±30		V
P_{tot}	Power dissipation	680		mW
	Output short-circuit duration (4)	Infinite		
T_{stg}	Storage temperature range	-65 to +150		°C
R_{thja}	Thermal resistance junction to ambient(5) (6) SO-8 DIP8	 125 85		°C/W
R_{thjc}	Thermal resistance junction to case(5) (6) SO-8 DIP8	 40 41		°C/W
ESD	HBM: human body model(7)	500		V
	MM: machine model(8)	200		V
	CDM: charged device model(9)	1.5		kV

1. All voltage values, except differential voltage, are with respect to the zero reference level (ground) of the supply voltages where the zero reference level is the midpoint between V_{CC}^{+} and V_{CC}^{-}.
2. The magnitude of the input voltage must never exceed the magnitude of the supply voltage or 15 volts, whichever is less.
3. Differential voltages are the non-inverting input terminal with respect to the inverting input terminal.
4. The output may be shorted to ground or to either supply. Temperature and/or supply voltages must be limited to ensure that the dissipation rating is not exceeded.
5. Short-circuits can cause excessive heating and destructive dissipation.
6. Rth are typical values.
7. Human body model: 100 pF discharged through a 1.5kΩ resistor between two pins of the device, done for all couples of pin combinations with other pins floating.
8. Machine model: a 200 pF cap is charged to the specified voltage, then discharged directly between two pins of the device with no external series resistor (internal resistor < 5 Ω), done for all couples of pin combinations with other pins floating.
9. Charged device model: all pins plus package are charged together to the specified voltage and then discharged directly to the ground.

Table 2. Operating conditions

Symbol	Parameter	TL081I, AI, BI	TL081C, AC, BC	Unit
V_{CC}	Supply voltage range	6 to 36		V
T_{oper}	Operating free-air temperature range	-40 to +105	0 to +70	°C

3 Electrical characteristics

Table 3. V_{CC} = ±15V, T_{amb} = +25°C (unless otherwise specified)

Symbol	Parameter	TL081I, AC, AI, BC, BI			TL081C			Unit
		Min.	Typ.	Max.	Min.	Typ.	Max.	
V_{io}	Input offset voltage (R_s = 50Ω) T_{amb} = +25°C TL081 TL081A TL081B $T_{min} \le T_{amb} \le T_{max}$ TL081 TL081A TL081B		 3 3 1	 10 6 3 13 7 5		3	10 13	mV
DV_{io}	Input offset voltage drift		10			10		µV/°C
I_{io}	Input offset current (1) T_{amb} = +25°C $T_{min} \le T_{amb} \le T_{max}$		5	100 4		5	100 10	pA nA
I_{ib}	Input bias current (1) T_{amb} = +25°C $T_{min} \le T_{amb} \le T_{max}$		20	200 20		20	400 20	nA
A_{vd}	Large signal voltage gain (R_L = 2kΩ, V_o = ±10V) T_{amb} = +25°C $T_{min} \le T_{amb} \le T_{max}$	50 25	200		25 15	200		V/mV
SVR	Supply voltage rejection ratio (R_S = 50Ω) T_{amb} = +25°C $T_{min} \le T_{amb} \le T_{max}$	80 80	86		70 70	86		dB
I_{CC}	Supply current, no load T_{amb} = +25°C $T_{min} \le T_{amb} \le T_{max}$		1.4	2.5 2.5		1.4	2.5 2.5	mA
V_{icm}	Input common mode voltage range	±11	+15 -12		±11	+15 -12		V
CMR	Common mode rejection ratio (R_S = 50Ω) T_{amb} = +25°C $T_{min} \le T_{amb} \le T_{max}$	80 80	86		70 70	86		dB
I_{os}	Output short-circuit current T_{amb} = +25°C $T_{min} \le T_{amb} \le T_{max}$	10 10	40	60 60	10 10	40	60 60	mA
$\pm V_{opp}$	Output voltage swing T_{amb} = +25°C R_L = 2kΩ R_L = 10kΩ $T_{min} \le T_{amb} \le T_{max}$ R_L = 2kΩ R_L = 10kΩ	10 12 10 12	12 13.5		10 12 10 12	12 13.5		V
SR	Slew rate (T_{amb} = +25°C) V_{in} = 10V, R_L = 2kΩ, C_L = 100pF, unity gain	8	16		8	16		V/µs

Table 3. V_{CC} = ±15V, T_{amb} = +25°C (unless otherwise specified) (continued)

Symbol	Parameter	TL081I, AC, AI, BC, BI			TL081C			Unit
		Min.	Typ.	Max.	Min.	Typ.	Max.	
t_r	Rise time (T_{amb} = +25°C) V_{in} = 20mV, R_L = 2kΩ, C_L = 100pF, unity gain		0.1			0.1		µs
K_{ov}	Overshoot (T_{amb} = +25°C) V_{in} = 20mV, R_L = 2kΩ, C_L = 100pF, unity gain		10			10		%
GBP	Gain bandwidth product (T_{amb} = +25°C) V_{in} = 10mV, R_L = 2kΩ, C_L = 100pF, F= 100kHz	2.5	4		2.5	4		MHz
R_i	Input resistance		10^{12}			10^{12}		Ω
THD	Total harmonic distortion (T_{amb} = +25°C), F= 1kHz, R_L = 2kΩ,C_L = 100pF, A_v = 20dB, V_o = $2V_{pp}$		0.01			0.01		%
e_n	Equivalent input noise voltage R_S = 100Ω, F= 1kHz		15			15		$\frac{nV}{\sqrt{Hz}}$
∅m	Phase margin		45			45		degrees

1. The input bias currents are junction leakage currents which approximately double for every 10°C increase in the junction temperature.

Figure 3. Maximum peak-to-peak output voltage versus frequency

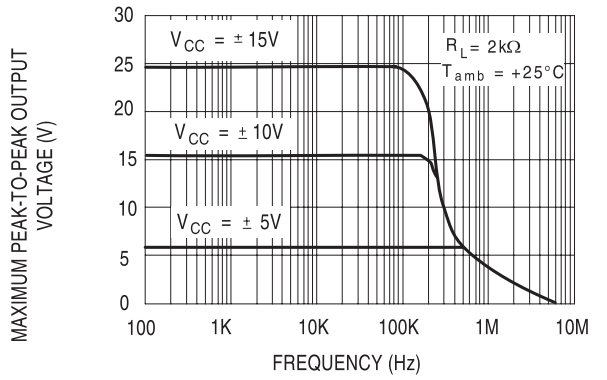


Figure 4. Maximum peak-to-peak output voltage versus frequency

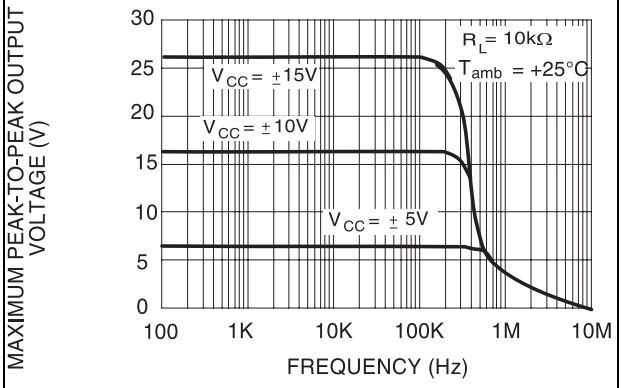


Figure 5. Maximum peak-to-peak output voltage versus frequency

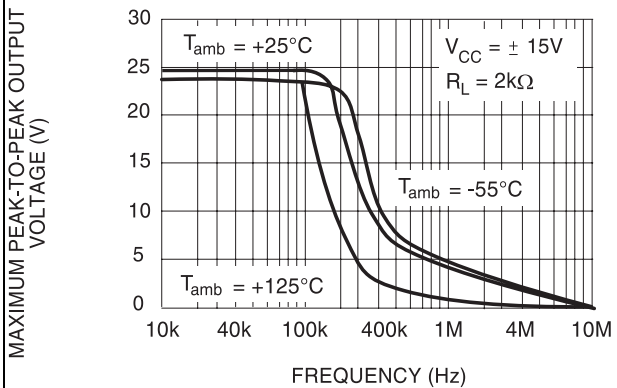


Figure 6. Maximum peak-to-peak output voltage versus free air temperature

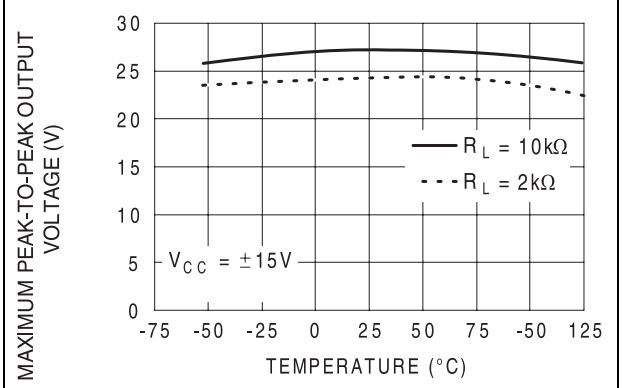


Figure 7. Maximum peak-to-peak output voltage versus load resistance

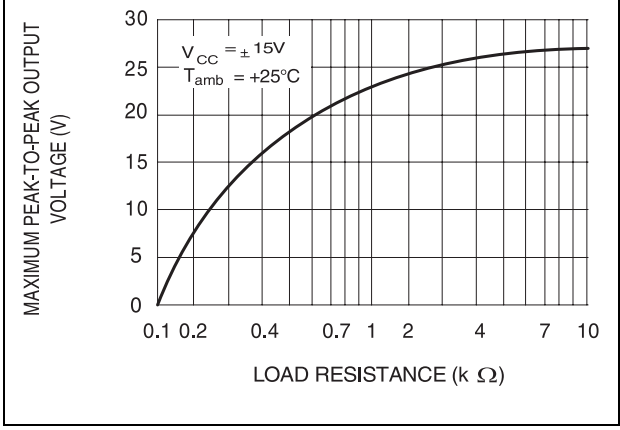


Figure 8. Maximum peak-to-peak output voltage versus supply voltage

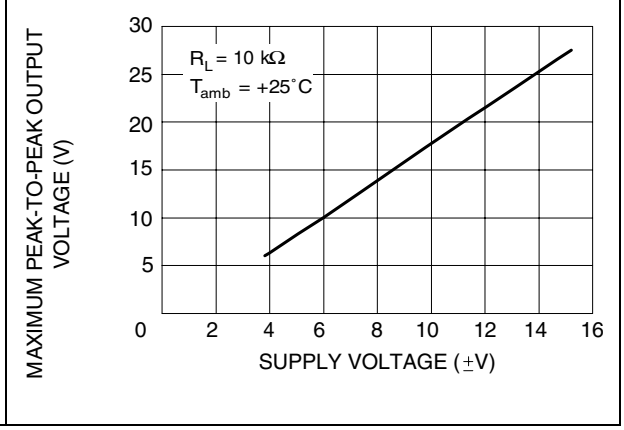


Figure 9. Input bias current versus free air temperature

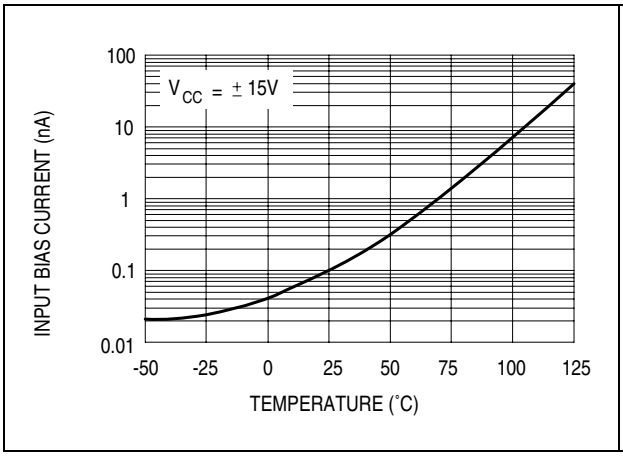


Figure 10. Large signal differential voltage amplification versus free air temp

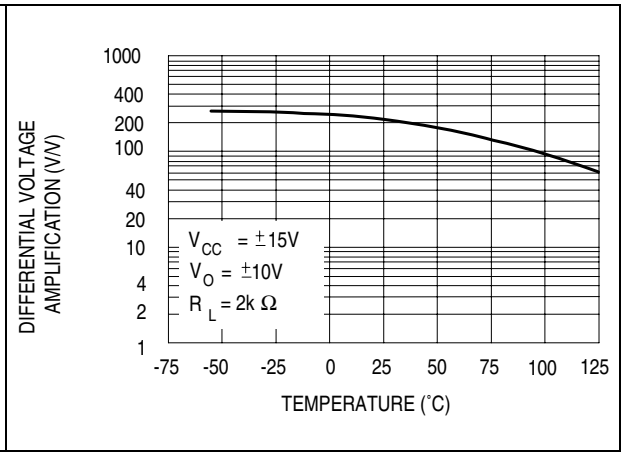


Figure 11. Large signal differential voltage amplification and phase shift versus frequency

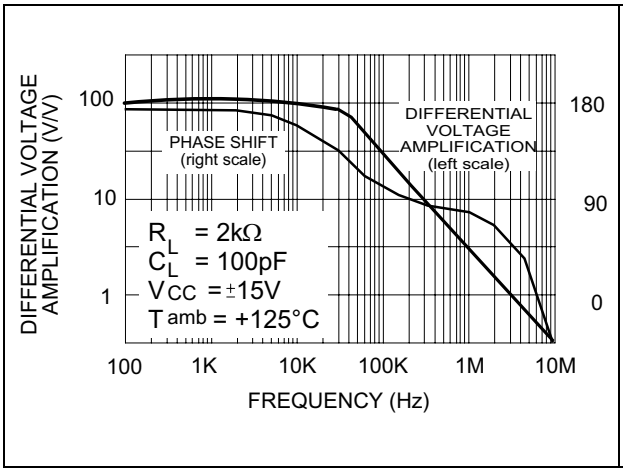


Figure 12. Total power dissipation versus free air temperature

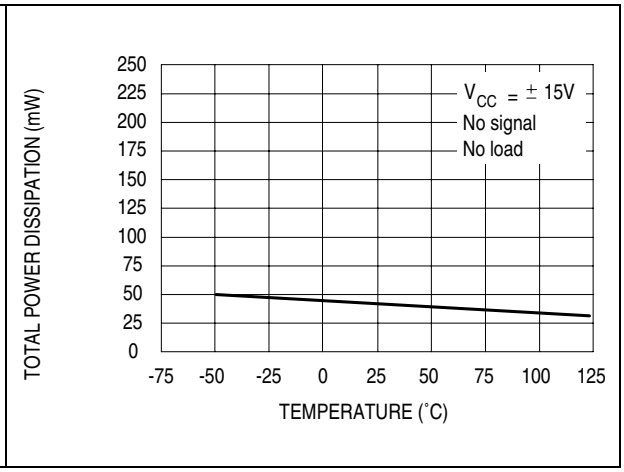


Figure 13. Supply current per amplifier versus free air temperature

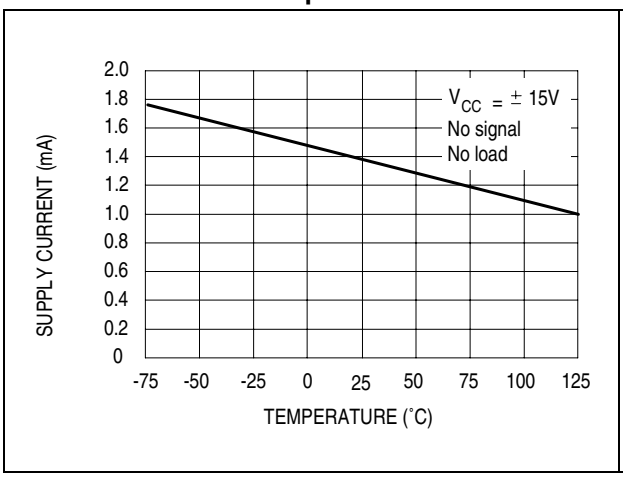


Figure 14. Supply current per amplifier versus supply voltage

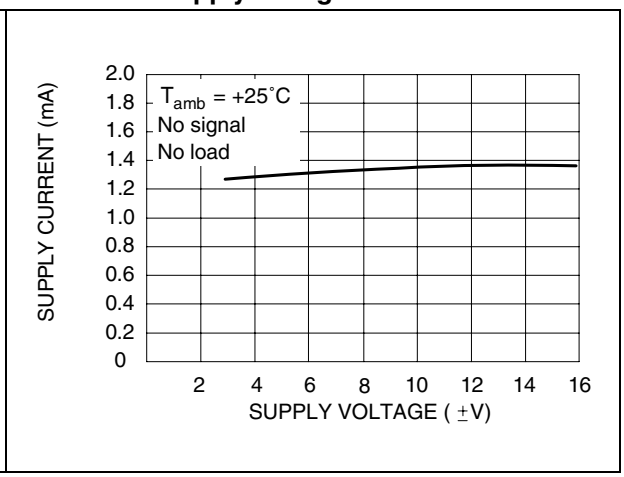


Figure 15. Common mode rejection ratio versus free air temperature

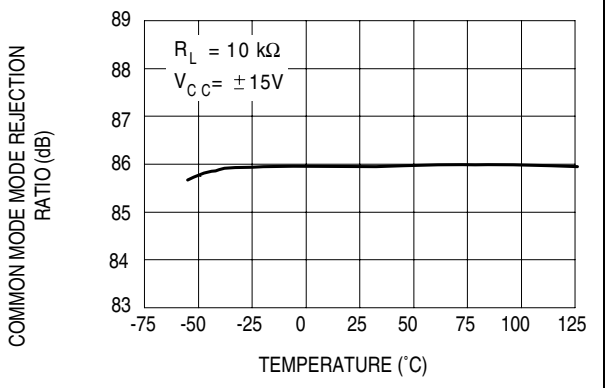


Figure 16. Equivalent input noise voltage versus frequency

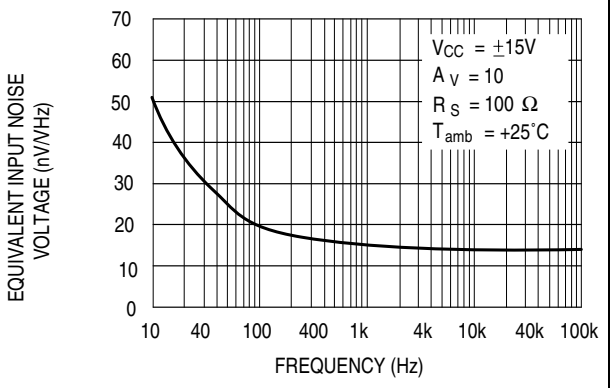


Figure 17. Output voltage versus elapsed time

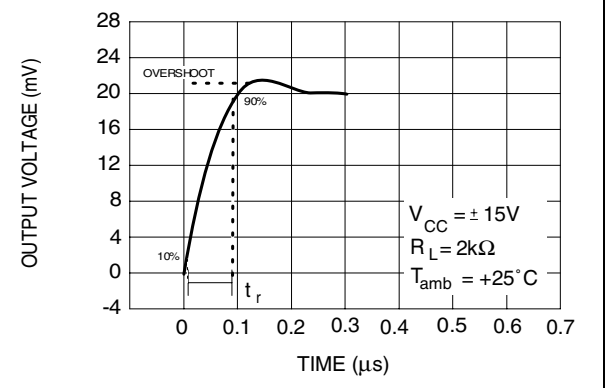


Figure 18. Total harmonic distortion versus frequency

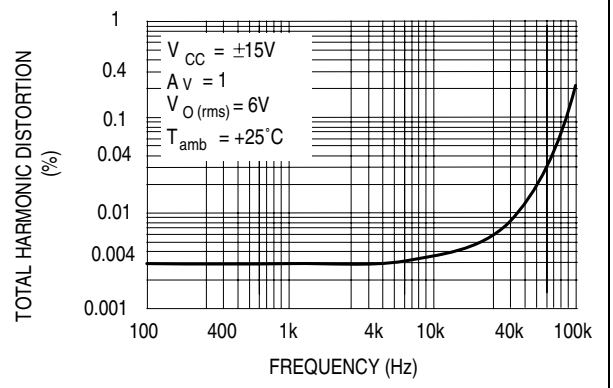
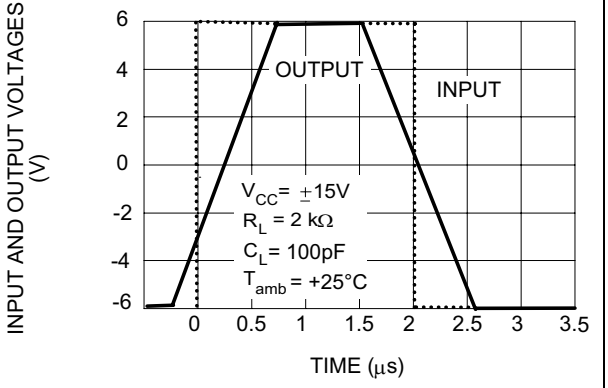


Figure 19. Voltage follower large signal pulse response



4 Parameter measurement information

Figure 20. Voltage follower

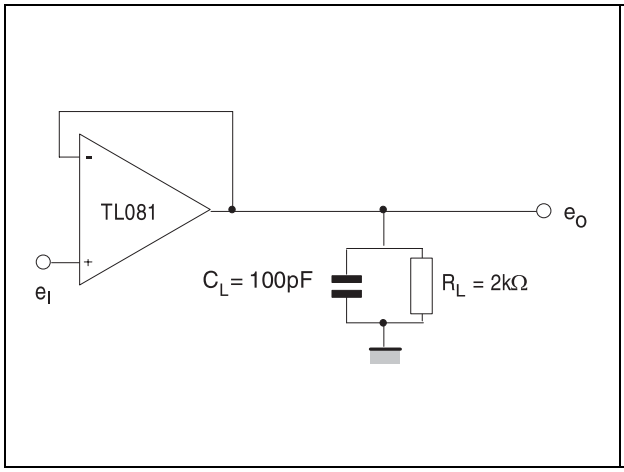
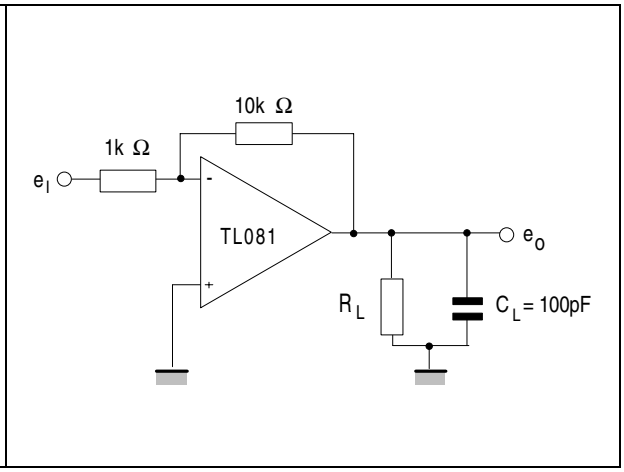


Figure 21. Gain-of-10 inverting amplifier



5 Typical applications

Figure 22. 0.5 Hz square wave oscillator

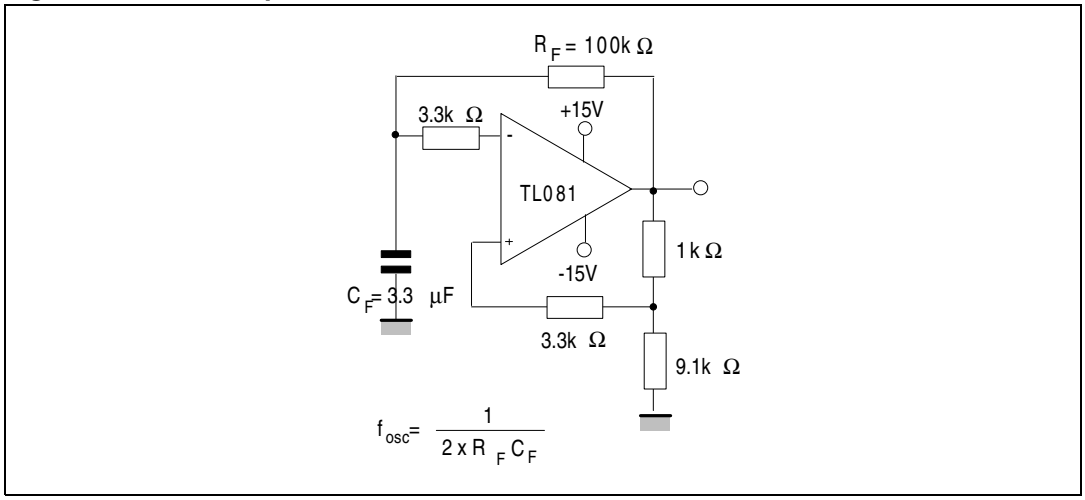
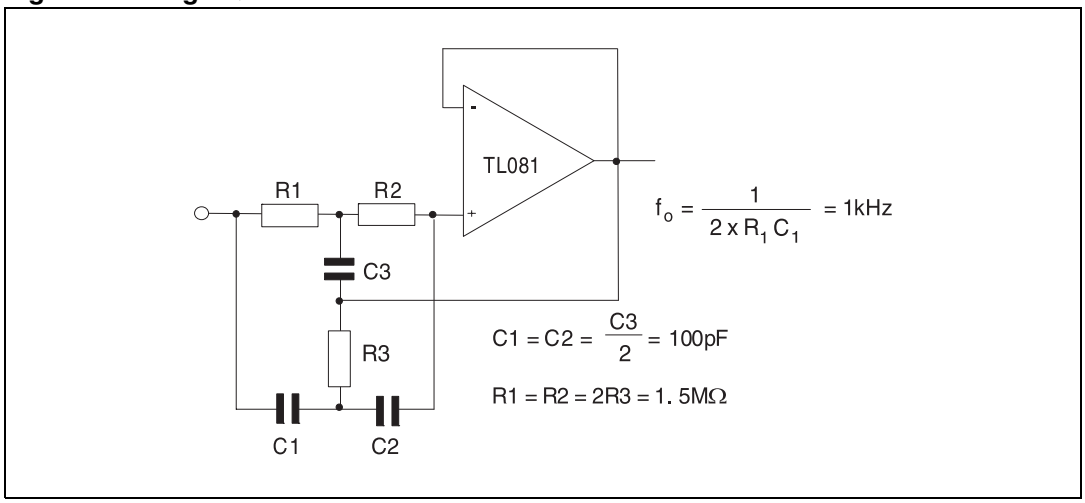


Figure 23. High Q notch filter



6 Package information

In order to meet environmental requirements, ST offers these devices in ECOPACK® packages. These packages have a lead-free second level interconnect. The category of second level interconnect is marked on the package and on the inner box label, in compliance with JEDEC Standard JESD97. The maximum ratings related to soldering conditions are also marked on the inner box label. ECOPACK is an ST trademark. ECOPACK specifications are available at: www.st.com.

6.1 DIP 8 package information

Figure 24. DIP8 package mechanical drawing

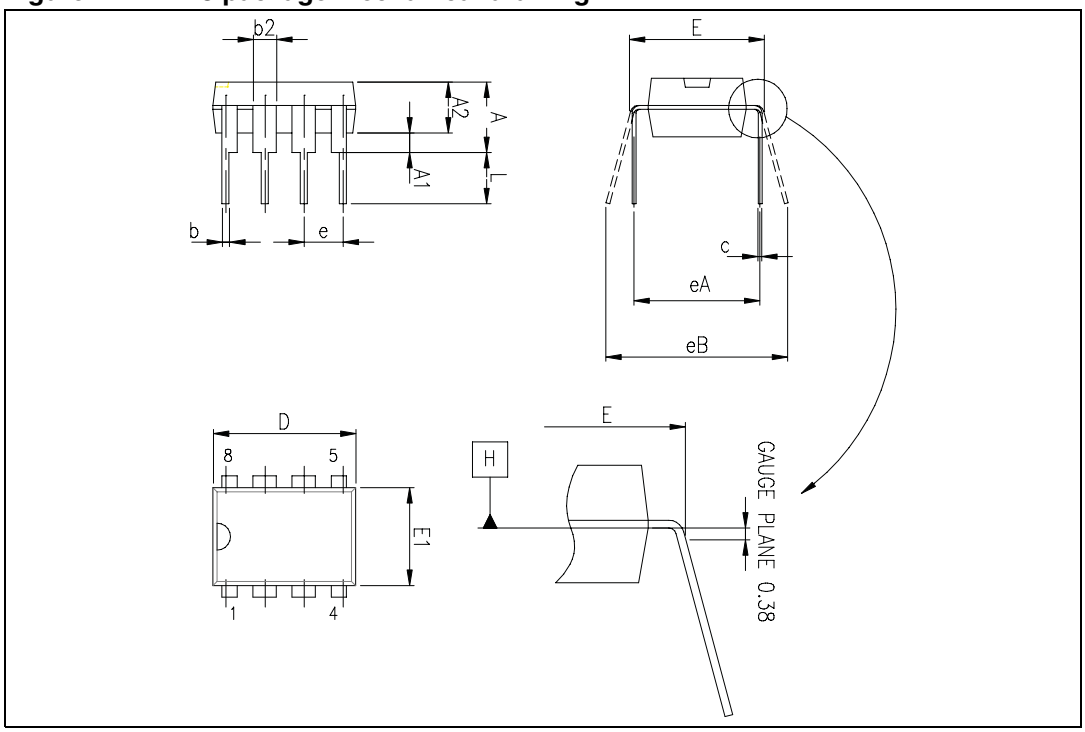


Table 4. DIP8 package mechanical data

Ref.	Dimensions					
	Millimeters			Inches		
	Min.	Typ.	Max.	Min.	Typ.	Max.
A			5.33			0.210
A1	0.38			0.015		
A2	2.92	3.30	4.95	0.115	0.130	0.195
b	0.36	0.46	0.56	0.014	0.018	0.022
b2	1.14	1.52	1.78	0.045	0.060	0.070
c	0.20	0.25	0.36	0.008	0.010	0.014
D	9.02	9.27	10.16	0.355	0.365	0.400
E	7.62	7.87	8.26	0.300	0.310	0.325
E1	6.10	6.35	7.11	0.240	0.250	0.280
e		2.54			0.100	
eA		7.62			0.300	
eB			10.92			0.430
L	2.92	3.30	3.81	0.115	0.130	0.150

6.2 SO-8 package information

Figure 25. SO-8 package mechanical drawing

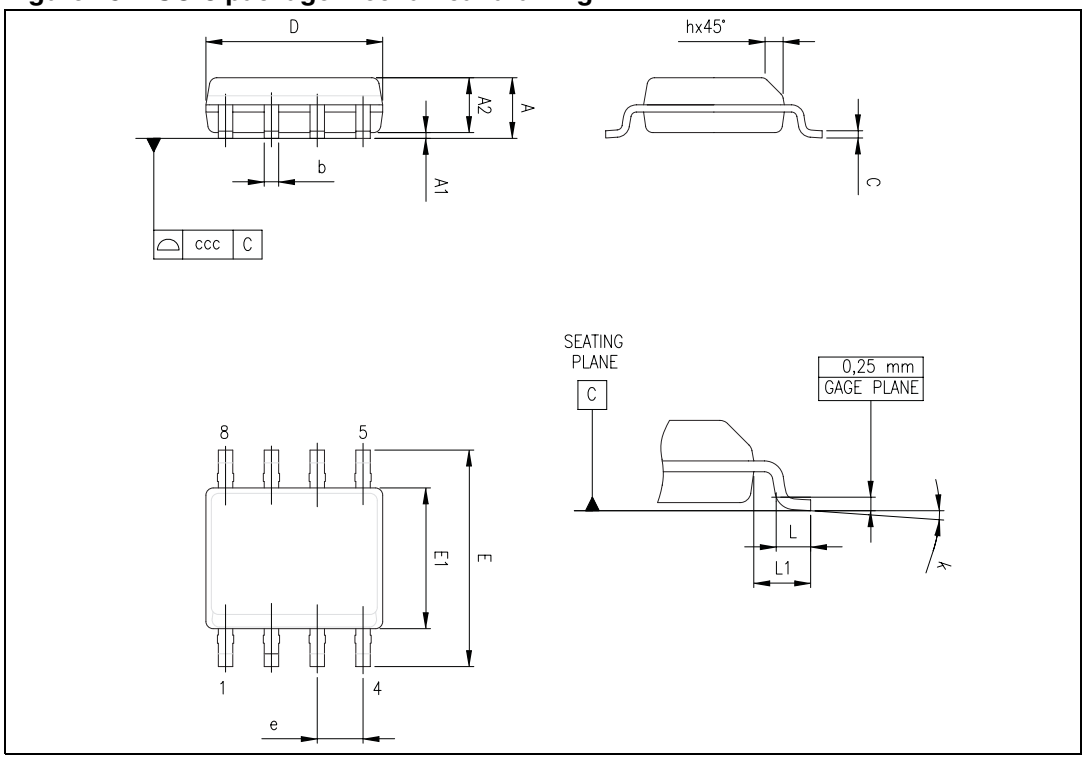


Table 5. SO-8 package mechanical data

Ref.	Dimensions					
	Millimeters			Inches		
	Min.	Typ.	Max.	Min.	Typ.	Max.
A			1.75			0.069
A1	0.10		0.25	0.004		0.010
A2	1.25			0.049		
b	0.28		0.48	0.011		0.019
c	0.17		0.23	0.007		0.010
D	4.80	4.90	5.00	0.189	0.193	0.197
E	5.80	6.00	6.20	0.228	0.236	0.244
E1	3.80	3.90	4.00	0.150	0.154	0.157
e		1.27			0.050	
h	0.25		0.50	0.010		0.020
L	0.40		1.27	0.016		0.050
k	1°		8°	1°		8°
ccc			0.10			0.004

7 Ordering information

Table 6. Order codes

Order code	Temperature range	Package	Packing	Marking
TL081IN TL081AIN TL081BIN	-40°C, +105°C	DIP8	Tube	TL081IN TL081AIN TL081BIN
TL081ID/IDT TL081AID/AIDT TL081BID/BIDT		SO-8	Tube or tape & reel	081I 081AI 081BI
TL081IYD/DT(1) TL081AIYD/DT(1) TL081BIYD/DT(1)		SO-8 (Automotive grade)	Tube or tape & reel	081IY 081AIY 081BIY
TL081CN TL081ACN TL081BCN	0°C, +70°C	DIP8	Tube	TL081CN TL081ACN TL081BCN
TL081CD/CDT TL081ACD/ACDT TL081BCD/BCDT		SO-8	Tube or tape & reel	081C 081AC 081BC

1. Qualification and characterization according to AEC Q100 and Q003 or equivalent, advanced screening according to AEC Q001 & Q 002 or equivalent are on-going.

8 Revision history

Table 7. Document revision history

Date	Revision	Changes
30-Apr-2001	1	Initial release.
27-Jul-2007	2	Added values for R_{thja} and R_{thjc} in *Table 1: Absolute maximum ratings*. Added *Table 2: Operating conditions*. Added automotive grade part numbers in *Table 6: Order codes*. Format update.
27-Jun-2008	3	Removed information concerning military temperature range (TL081Mx, TL081AMx, TL081BMx). Added missing order codes for automotive grade products and updated footnote in *Table 6: Order codes*.

TL081, TL081A, TL081B, TL081H
TL082, TL082A, TL082B, TL082H
TL084, TL084A, TL084B, TL084H
SLOS081M – FEBRUARY 1977 – REVISED DECEMBER 2021

TL08xx FET-Input Operational Amplifiers

1 Features

- High slew rate: 20 V/µs (TL08xH, typ)
- Low offset voltage: 1 mV (TL08xH, typ)
- Low offset voltage drift: 2 µV/°C
- Low power consumption: 940 µA/ch (TL08xH, typ)
- Wide common-mode and differential voltage ranges
  - Common-mode input voltage range includes V_{CC+}
- Low input bias and offset currents
- Low noise: V_n = 18 nV/√Hz (typ) at f = 1 kHz
- Output short-circuit protection
- Low total harmonic distortion: 0.003% (typ)
- Wide supply voltage: ±2.25 V to ±20 V, 4.5 V to 40 V

2 Applications

- Solar energy: string and central inverter
- Motor drives: AC and servo drive control and power stage modules
- Single phase online UPS
- Three phase UPS
- Pro audio mixers
- Battery test equipment

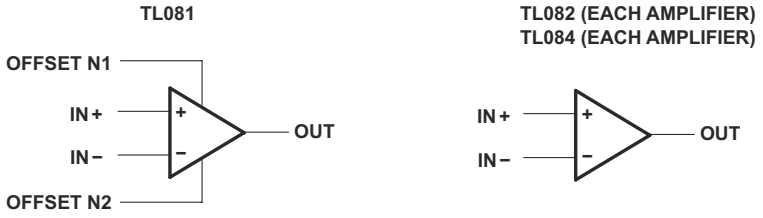
3 Description

The TL08xH (TL081H, TL082H, and TL084H) family of devices are the next-generation versions of the industry-standard TL08x (TL081, TL082, and TL084) devices. These devices provide outstanding value for cost-sensitive applications, with features including low offset (1 mV, typical), high slew rate (20 V/µs), and common-mode input to the positive supply. High ESD (1.5 kV, HBM), integrated EMI and RF filters, and operation across the full –40°C to 125°C enable the TL08xH devices to be used in the most rugged and demanding applications.

Device Information

PART NUMBER(1)	PACKAGE	BODY SIZE (NOM)
TL081x	PDIP (8)	9.59 mm × 6.35 mm
	SC70 (5)	2.00 mm × 1.25 mm
	SO (8)	6.20 mm × 5.30 mm
	SOIC (8)	4.90 mm × 3.90 mm
	SOT-23 (5)	1.60 mm × 1.20 mm
TL082x	PDIP (8)	9.59 mm × 6.35 mm
	SO (8)	6.20 mm × 5.30 mm
	SOIC (8)	4.90 mm × 3.90 mm
	SOT-23 (8)	2.90 mm × 1.60 mm
	TSSOP (8)	4.40 mm × 3.00 mm
TL082M	CDIP (8)	9.59 mm × 6.67 mm
	LCCC (20)	8.89 mm × 8.89 mm
TL084x	PDIP (14)	19.30 mm × 6.35 mm
	SO (14)	10.30 mm × 5.30 mm
	SOIC (14)	8.65 mm × 3.91 mm
	SOT-23 (14)	4.20 mm × 2.00 mm
	TSSOP (14)	5.00 mm × 4.40 mm
TL084M	CDIP (14)	19.56 mm × 6.92 mm
	LCCC (20)	8.89 mm × 8.89 mm

(1) For all available packages, see the orderable addendum at the end of the data sheet.



Logic Symbols

Table of Contents

4 Revision History

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

Changes from Revision L (July 2021) to Revision M (December 2021) — **Page**

- Corrected DCK pinout diagram and table in *Pin Configurations and Functions* section....4

Changes from Revision K (June 2021) to Revision L (July 2021) — **Page**

- Deleted preview note from TL081H SOIC (8), SOT-23 (5), and SC70 (5) packages throughout the data sheet....1

Changes from Revision J (November 2020) to Revision K (June 2021) — **Page**

- Deleted VSSOP (8) package references throughout data sheet....1
- Deleted preview note from TL082H SOIC (8), SOT-23 (8), and TSSOP (8) packages throughout the data sheet....1
- Added DBV, DCK, and D packages to TL081H in *Pin Configuration and Functions* section....4
- Added ESD information for TL082H....10
- Added D, DCK, and DBV package thermal information in Thermal Information for Single Channel: TL081H section....11
- Added D, DDF, and PW package thermal information in Thermal Information for Dual Channel: TL082H section....11
- Added I_B and I_{OS} specification for single channel DCK and DBV package....13
- Added I_Q spec for TL081H and TL082H....13
- Removed *Related Links* section from *Device and Documentation Support* section....36

Changes from Revision I (May 2015) to Revision J (November 2020) **Page**

- Updated the numbering format for tables, figures, and cross-references throughout the document....1
- Added TL08xH devices throughout the data sheet....1
- Added features for TL08xH to the *Features* section....1
- Added link to applications in the *Applications* section....1
- Added TL08xH in the *Description* section....1
- Added TL08xH in the *Device Information* table....1
- Updated pinout diagrams and pinout tables in *Pin Configurations and Functions* section....4
- Added TSSOP, VSSOP and DDF packages to TL082x in *Pin Configuration and Functions* section....4
- Added DYY package to TL084x in *Pin Configuration and Functions* section....4
- Added *Typical Characteristics:TL08xH* section in *Specifications* section....18
- Removed Table of Graphs in *Typical Characteristics: All Other Devices* section....25
- Removed references to obsolete documentation....35

Changes from Revision H (January 2014) to Revision I (May 2015) **Page**

- Added *Applications* section, *Device Information* table, Pin Functions table, Thermal Information table, *Feature Description* section, *Device Functional Modes* section, *Application and Implementation* section, *Power Supply Recommendations* section, ESD information, *Layout* section, *Device and Documentation Support* section, and *Mechanical, Packaging, and Orderable Information* section....1
- Added *Applications*....1
- Moved *Typical Characteristics* into *Specifications* section....25

Changes from Revision G (September 2004) to Revision H (January 2014) **Page**

- Deleted *Ordering Information* table....1

5 Pin Configuration and Functions

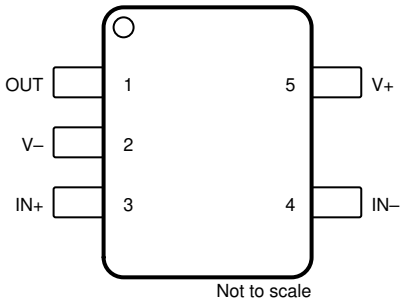


Figure 5-1. TL081H DBV Package
5-Pin SOT-23
(Top View)

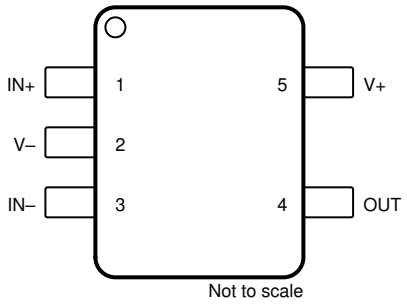
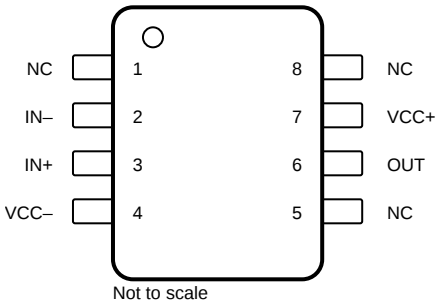


Figure 5-2. TL081H DCK Package
5-Pin SC70
(Top View)

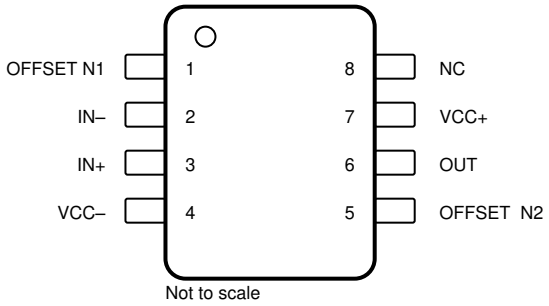


NC- no internal connection

Figure 5-3. TL081H D Package
8-Pin SOIC
(Top View)

Table 5-1. Pin Functions: TL081H

PIN				I/O	DESCRIPTION
NAME	DBV	DCK	D		
IN–	4	3	2	I	Inverting input
IN+	3	1	3	I	Noninverting input
NC	—	—	8	—	Do not connect
NC	—	—	1	—	Do not connect
NC	—	—	5	—	Do not connect
OUT	1	4	6	O	Output
VCC–	2	2	4	—	Power supply
VCC+	5	5	7	—	Power supply



NC- no internal connection

Figure 5-4. TL081x D, P, and PS Package
8-Pin SOIC, PDIP, and SO
(Top View)

Table 5-2. Pin Functions: TL081x

PIN		I/O	DESCRIPTION
NAME	NO.		
IN–	2	I	Inverting input
IN+	3	I	Noninverting input
NC	8	—	Do not connect
OFFSET N1	1	—	Input offset adjustment
OFFSET N2	5	—	Input offset adjustment
OUT	6	O	Output
VCC–	4	—	Power supply
VCC+	7	—	Power supply

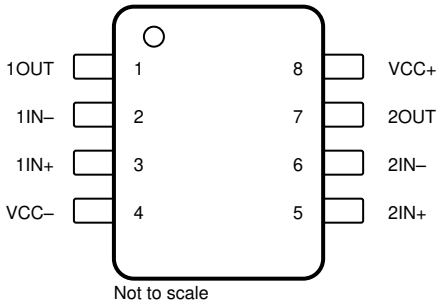
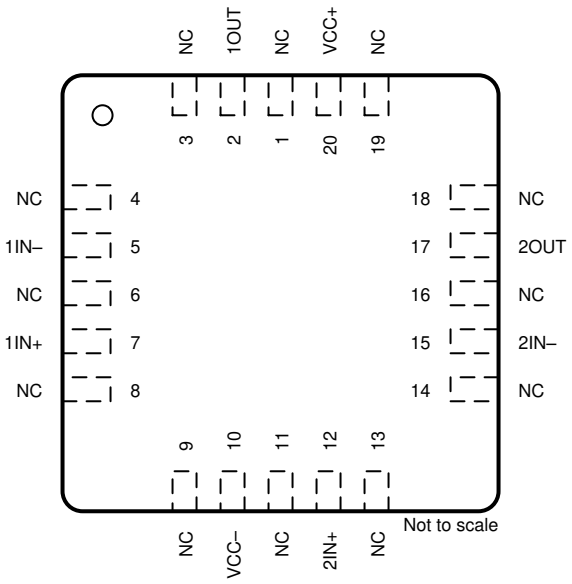


Figure 5-5. TL082x D, DDF, DGK, JG, P, PS, and PW Package 8-Pin SOIC, SOT-23 (8), VSSOP, CDIP, PDIP, SO, and TSSOP (Top View)

Table 5-3. Pin Functions: TL082x

PIN		I/O	DESCRIPTION
NAME	NO.		
1IN–	2	I	Inverting input
1IN+	3	I	Noninverting input
1OUT	1	O	Output
2IN–	6	I	Inverting input
2IN+	5	I	Noninverting input
2OUT	7	O	Output
VCC–	4	—	Power supply
VCC+	8	—	Power supply



NC- no internal connection

Figure 5-6. TL082 FK Package
20-Pin LCCC
(Top View)

Table 5-4. Pin Functions: TL082x

PIN		I/O	DESCRIPTION
NAME	NO.		
1IN–	5	I	Inverting input
1IN+	7	I	Noninverting input
1OUT	2	O	Output
2IN–	15	I	Inverting input
2IN+	12	I	Noninverting input
2OUT	17	O	Output
NC	1, 3, 4, 6, 8, 9, 11, 13, 14, 16, 18, 19	—	Do not connect
VCC–	10	—	Power supply
VCC+	20	—	Power supply

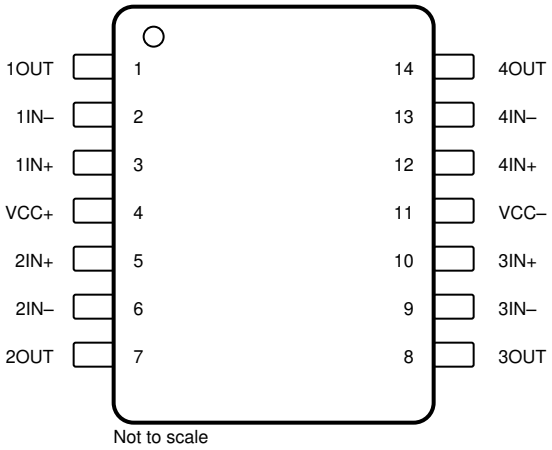
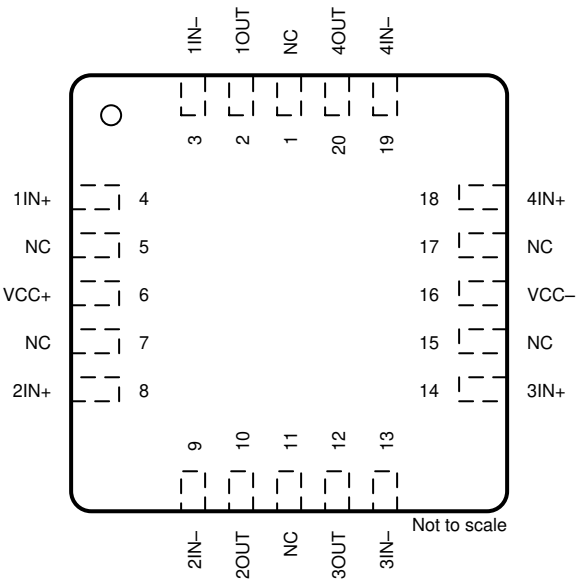


Figure 5-7. TL084x D, N, NS, PW, J, and DYY Package 14-Pin SOIC, PDIP, SO, TSSOP, CDIP, and SOT-23 (14) (Top View)

Table 5-5. Pin Functions: TL084x

PIN		I/O	DESCRIPTION
NAME	NO.		
1IN–	2	I	Inverting input
1IN+	3	I	Noninverting input
1OUT	1	O	Output
2IN–	6	I	Inverting input
2IN+	5	I	Noninverting input
2OUT	7	O	Output
3IN–	9	I	Inverting input
3IN+	10	I	Noninverting input
3OUT	8	O	Output
4IN–	13	I	Inverting input
4IN+	12	I	Noninverting input
4OUT	14	O	Output
V_{CC-}	11	—	Power supply
V_{CC+}	4	—	Power supply



NC- no internal connection

Figure 5-8. TL084 FK Package
20-Pin LCCC
(Top View)

Table 5-6. Pin Functions: TL084x

PIN		I/O	DESCRIPTION
NAME	NO.		
1IN–	3	I	Inverting input
1IN+	4	I	Noninverting input
1OUT	2	O	Output
2IN–	9	I	Inverting input
2IN+	8	I	Noninverting input
2OUT	10	O	Output
3IN–	13	I	Inverting input
3IN+	14	I	Noninverting input
3OUT	12	O	Output
4IN–	19	I	Inverting input
4IN+	18	I	Noninverting input
4OUT	20	O	Output
NC	1, 5, 7, 11, 15, 17	—	Do not connect
VCC–	16	—	Power supply
VCC+	6	—	Power supply

6 Specifications

6.1 Absolute Maximum Ratings: TL08xH

over operating ambient temperature range (unless otherwise noted) (1)

		MIN	MAX	UNIT
Supply voltage, $V_S = (V_{CC+}) - (V_{CC-})$		0	42	V
Signal input pins	Common-mode voltage (3)	$(V_{CC-}) - 0.5$	$(V_{CC+}) + 0.5$	V
	Differential voltage (3)		$V_S + 0.2$	V
	Current (3)	–10	10	mA
Output short-circuit (2)		Continuous		
Operating ambient temperature, T_A		–55	150	°C
Junction temperature, T_J			150	°C
Storage temperature, T_{stg}		–65	150	°C

(1) Stresses beyond those listed under *Absolute Maximum Ratings* may cause permanent damage to the device. These are stress ratings only, which do not imply functional operation of the device at these or any other conditions beyond those indicated under *Recommended Operating Conditions*. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.
(2) Short-circuit to ground, one amplifier per package.
(3) Input pins are diode-clamped to the power-supply rails. Input signals that may swing more than 0.5 V beyond the supply rails must be current limited to 10 mA or less.

6.2 Absolute Maximum Ratings: All Other Devices

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

		MIN	MAX	UNIT
V_{CC+} - V_{CC-}	Supply voltage(2)	-18	18	V
V_{ID}	Differential input voltage(3)	-30	+30	V
V_I	Input voltage(2) (4)	-15	+15	V
	Duration of output short circuit(5)	Unlimited		
	Continuous total power dissipation	See *Section 6.15*		
T_{stg}	Storage temperature	–65	150	°C

(1) 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.
(2) All voltage values, except differential voltages, are with respect to the midpoint between V_{CC+} and V_{CC-}.
(3) Differential voltages are at IN+, with respect to IN−.
(4) The magnitude of the input voltage must never exceed the magnitude of the supply voltage or 15 V, whichever is less.
(5) The output may be shorted to ground or to either supply. Temperature and/or supply voltages must be limited to ensure that the dissipation rating is not exceeded.

6.3 ESD Ratings: TL08xH

			VALUE	UNIT
TL084H				
$V_{(ESD)}$	Electrostatic discharge	Human-body model (HBM), per ANSI/ESDA/JEDEC JS-001(1)	±1500	V
		Charged-device model (CDM), per JEDEC specification JESD22-C101 (2)	±1000	
TL082H and TL081H				
$V_{(ESD)}$	Electrostatic discharge	Human-body model (HBM), per ANSI/ESDA/JEDEC JS-001(1)	±2000	V
		Charged-device model (CDM), per JEDEC specification JESD22-C101 (2)	±1000	

(1) JEDEC document JEP155 states that 500-V HBM allows safe manufacturing with a standard ESD control process.
(2) JEDEC document JEP157 states that 250-V CDM allows safe manufacturing with a standard ESD control process.

6.4 ESD Ratings: All Other Devices

			VALUE	UNIT
$V_{(ESD)}$	Electrostatic discharge	Human-body model (HBM), per ANSI/ESDA/JEDEC JS-001[1]	±1000	V
		Charged-device model (CDM), per JEDEC specification JESD22-C101[2]	±1500	

(1) JEDEC document JEP155 states that 500-V HBM allows safe manufacturing with a standard ESD control process.
(2) JEDEC document JEP157 states that 250-V CDM allows safe manufacturing with a standard ESD control process.

6.5 Recommended Operating Conditions: TL08xH

over operating ambient temperature range (unless otherwise noted)

		MIN	MAX	UNIT
V_S	Supply voltage, $(V_{CC+}) – (V_{CC–})$	4.5	40	V
V_I	Input voltage range	$(V_{CC–}) + 2$	$(V_{CC+}) + 0.1$	V
T_A	Specified temperature	–40	125	°C

6.6 Recommended Operating Conditions: All Other Devices

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

			MIN	MAX	UNIT
V_{CC+}	Supply voltage		5	15	V
$V_{CC–}$	Supply voltage		–5	–15	V
V_{CM}	Common-mode voltage		$V_{CC–} + 4$	$V_{CC+} – 4$	V
T_A	Ambient temperature	TL08xM	–55	125	°C
		TL08xQ	–40	125	
		TL08xI	–40	85	
		TL08xC	0	70	

6.7 Thermal Information for Single Channel: TL081H

THERMAL METRIC [1]		TL081H			UNIT
		D (SOIC)	DCK (SC70)	DBV (SOT-23)	
		8 PINS	5 PINS	5 PINS	
$R_{\theta JA}$	Junction-to-ambient thermal resistance	158.8	217.5	212.2	°C/W
$R_{\theta JC(top)}$	Junction-to-case (top) thermal resistance	98.6	113.1	111.1	°C/W
$R_{\theta JB}$	Junction-to-board thermal resistance	102.3	63.8	79.4	°C/W
ψ_{JT}	Junction-to-top characterization parameter	45.8	34.8	51.8	°C/W
ψ_{JB}	Junction-to-board characterization parameter	101.5	63.5	79.0	°C/W
$R_{\theta JC(bot)}$	Junction-to-case (bottom) thermal resistance	N/A	N/A	N/A	°C/W

(1) For more information about traditional and new thermal metrics, see the *Semiconductor and IC Package Thermal Metrics* application report, SPRA953.

6.8 Thermal Information for Dual Channel: TL082H

THERMAL METRIC [1]		TL082H			UNIT
		D (SOIC)	DDF (SOT-23)	PW (TSSOP)	
		8 PINS	8 PINS	8 PINS	
$R_{\theta JA}$	Junction-to-ambient thermal resistance	147.8	181.5	200.3	°C/W
$R_{\theta JC(top)}$	Junction-to-case (top) thermal resistance	88.2	112.5	89.4	°C/W
$R_{\theta JB}$	Junction-to-board thermal resistance	91.4	98.2	131.0	°C/W
ψ_{JT}	Junction-to-top characterization parameter	36.8	17.2	22.0	°C/W
ψ_{JB}	Junction-to-board characterization parameter	90.6	97.6	129.3	°C/W

6.8 Thermal Information for Dual Channel: TL082H (continued)

THERMAL METRIC (1)		TL082H			UNIT
		D (SOIC)	DDF (SOT-23)	PW (TSSOP)	
		8 PINS	8 PINS	8 PINS	
$R_{\theta JC(bot)}$	Junction-to-case (bottom) thermal resistance	N/A	N/A	N/A	°C/W

(1) For more information about traditional and new thermal metrics, see the *Semiconductor and IC Package Thermal Metrics* application report, SPRA953.

6.9 Thermal Information for Quad Channel: TL084H

THERMAL METRIC (1)		TL084H			UNIT
		D (SOIC)	DYY (2) (SOT-23)	PW (TSSOP)	
		14 PINS	14 PINS	14 PINS	
$R_{\theta JA}$	Junction-to-ambient thermal resistance	114.2	TBD	134.4	°C/W
$R_{\theta JC(top)}$	Junction-to-case (top) thermal resistance	70.3	TBD	62.6	°C/W
$R_{\theta JB}$	Junction-to-board thermal resistance	70.2	TBD	77.6	°C/W
ψ_{JT}	Junction-to-top characterization parameter	28.8	TBD	13.0	°C/W
ψ_{JB}	Junction-to-board characterization parameter	69.8	TBD	77.0	°C/W
$R_{\theta JC(bot)}$	Junction-to-case (bottom) thermal resistance	N/A	TBD	N/A	°C/W

(1) For more information about traditional and new thermal metrics, see the *Semiconductor and IC Package Thermal Metrics* application report, SPRA953.
(2) This package option is preview for TL084H.

6.10 Thermal Information: All Other Devices

THERMAL METRIC(1)		TL08xxx											UNIT
		D (SOIC)		FK (LCCC)	J (CDIP)		N (PDIP)		NS (SO)		PW (TSSOP)		
		8 PIN	14 PIN	20 PIN	8 PIN	14 PIN	8 PIN	14 PIN	8 PIN	14 PIN	8 PIN	14 PIN	
$R_{\theta JA}$	Junction-to-ambient thermal resistance	97	86				85	80	95	76	150	113	°C/W
$R_{\theta JC(top)}$	Junction-to-case (top) thermal resistance			5.61	15.05	14.5							

(1) For more information about traditional and new thermal metrics, see the *IC Package Thermal Metrics* application report, SPRA953.

6.11 Electrical Characteristics: TL08xH

For $V_S = (V_{CC+}) – (V_{CC–}) = 4.5$ V to 40 V (±2.25 V to ±20 V) at $T_A = 25°C$, $R_L = 10$ kΩ connected to $V_S / 2$, $V_{CM} = V_S / 2$, and $V_{O\ UT} = V_S / 2$, unless otherwise noted.

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
OFFSET VOLTAGE							
V_{OS}	Input offset voltage				±1	±4	mV
			T_A = –40°C to 125°C			±5	
dV_{OS}/dT	Input offset voltage drift		T_A = –40°C to 125°C		±2		µV/°C
PSRR	Input offset voltage versus power supply	V_S = 5 V to 40 V, $V_{CM} = V_S / 2$	T_A = –40°C to 125°C		±1	±10	µV/V
	Channel separation	f = 0 Hz			10		µV/V
INPUT BIAS CURRENT							
I_B	Input bias current				±1	±120	pA
			DCK and DBV packages		±1	±300	pA
			T_A = –40°C to 125°C (1)			±5	nA
I_{OS}	Input offset current				±0.5	±120	pA
			DCK and DBV packages		±0.5	±250	pA
			T_A = –40°C to 125°C (1)			±5	nA
NOISE							
E_N	Input voltage noise	f = 0.1 Hz to 10 Hz			9.2		μV_{PP}
					1.4		μV_{RMS}
e_N	Input voltage noise density	f = 1 kHz			37		$nV/\sqrt{Hz}$
		f = 10 kHz			21		
i_N	Input current noise	f = 1 kHz			80		$fA/\sqrt{Hz}$
INPUT VOLTAGE RANGE							
V_{CM}	Common-mode voltage range			$(V_{CC–}) + 1.5$		(V_{CC+})	V
CMRR	Common-mode rejection ratio	V_S = 40 V, $(V_{CC–}) + 2.5$ V < V_{CM} < $(V_{CC+}) – 1.5$ V		100	105		dB
CMRR	Common-mode rejection ratio		T_A = –40°C to 125°C	95			dB
CMRR	Common-mode rejection ratio	V_S = 40 V, $(V_{CC–}) + 2.5$ V < V_{CM} < (V_{CC+})		90	105		dB
CMRR	Common-mode rejection ratio		T_A = –40°C to 125°C	80			dB
INPUT CAPACITANCE							
Z_{ID}	Differential				100 || 2		MΩ || pF
Z_{ICM}	Common-mode				6 || 1		TΩ || pF
OPEN-LOOP GAIN							
A_{OL}	Open-loop voltage gain	V_S = 40 V, $V_{CM} = V_S / 2$, $(V_{CC–}) + 0.3$ V < V_O < $(V_{CC+}) – 0.3$ V	T_A = –40°C to 125°C	118	125		dB
A_{OL}	Open-loop voltage gain	V_S = 40 V, $V_{CM} = V_S / 2$, R_L = 2 kΩ, $(V_{CC–}) + 1.2$ V < V_O < $(V_{CC+}) – 1.2$ V	T_A = –40°C to 125°C	115	120		dB
FREQUENCY RESPONSE							
GBW	Gain-bandwidth product				5.25		MHz
SR	Slew rate	V_S = 40 V, G = +1, C_L = 20 pF			20		V/µs
t_S	Settling time	To 0.1%, V_S = 40 V, V_{STEP} = 10 V , G = +1, CL = 20 pF			0.63		µs
		To 0.1%, V_S = 40 V, V_{STEP} = 2 V , G = +1, CL = 20 pF			0.56		
		To 0.01%, V_S = 40 V, V_{STEP} = 10 V , G = +1, CL = 20 pF			0.91		
		To 0.01%, V_S = 40 V, V_{STEP} = 2 V , G = +1, CL = 20 pF			0.48		
	Phase margin	G = +1, R_L = 10kΩ, C_L = 20 pF			56		°
	Overload recovery time	V_{IN} × gain > V_S			300		ns

6.11 Electrical Characteristics: TL08xH (continued)

For $V_S = (V_{CC+}) – (V_{CC–}) = 4.5$ V to 40 V (±2.25 V to ±20 V) at $T_A = 25°C$, $R_L = 10$ kΩ connected to $V_S / 2$, $V_{CM} = V_S / 2$, and $V_{O\ UT} = V_S / 2$, unless otherwise noted.

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
THD+N	Total harmonic distortion + noise	$V_S = 40$ V, $V_O = 6\ V_{RMS}$, G = +1, f = 1 kHz			0.00012		%
EMIRR	EMI rejection ratio	f = 1 GHz			53		dB
OUTPUT							
	Voltage output swing from rail	Positive rail headroom	$V_S = 40$ V, $R_L = 10$ kΩ		115	210	mV
			$V_S = 40$ V, $R_L = 2$ kΩ		520	965	
		Negative rail headroom	$V_S = 40$ V, $R_L = 10$ kΩ		105	215	
			$V_S = 40$ V, $R_L = 2$ kΩ		500	1030	
I_{SC}	Short-circuit current				±26		mA
C_{LOAD}	Capacitive load drive				300		pF
Z_O	Open-loop output impedance	f = 1 MHz, $I_O = 0$ A			125		Ω
POWER SUPPLY							
I_Q	Quiescent current per amplifier	$I_O = 0$ A			937.5	1125	μA
		$I_O = 0$ A, (TL081H)			960	1156	
		$I_O = 0$ A	$T_A = –40°C$ to 125°C			1130	
		$I_O = 0$ A, (TL082H)				1143	
		$I_O = 0$ A, (TL081H)				1160	
	Turn-On Time	At $T_A = 25°C$, $V_S = 40$ V, V_S ramp rate > 0.3 V/μs			60		μs

(1) Max I_B and I_{os} data is specified based on characterization results.

6.12 Electrical Characteristics for TL08xC, TL08xxC, and TL08xI

$V_{CC\pm}$ = ±15 V (unless otherwise noted)

PARAMETER		TEST CONDITIONS	T_A (1)	TL081C, TL082C, TL084C			TL081AC, TL082AC, TL084AC			TL081BC, TL082BC, TL084BC			TL081I, TL082I, TL084I			UNIT
				MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
V_{IO}	Input offset voltage	V_O = 0, R_S = 50 Ω	25°C		3	15		3	6		2	3		3	6	mV
			Full range			20			7.5			5			9	
α_{VIO}	Temperature coefficient of input offset voltage	V_O = 0, R_S = 50 Ω	Full range		18			18			18			18		μV/°C
I_{IO}	Input offset current(2)	V_O = 0	25°C		5	200		5	100		5	100		5	100	pA
			Full range			2			2			2			10	nA
I_{IB}	Input bias current(2)	V_O = 0	25°C		30	400		30	200		30	200		30	200	pA
			Full range			10			7			7			20	nA
V_{ICR}	Common-mode input voltage range		25°C	±11	–12 to 15		±11	–12 to 15		±11	–12 to 15		±11	–12 to 15		V
V_{OM}	Maximum peak output voltage swing	R_L = 10 kΩ	25°C	±12	±13.5		±12	±13.5		±12	±13.5		±12	±13.5		V
		R_L ≥ 10 kΩ	Full range	±12			±12			±12			±12			
		R_L ≥ 2 kΩ		±10	±12		±10	±12		±10	±12		±10	±12		
A_{VD}	Large-signal differential voltage amplification	V_O = ±10 V, R_L ≥ 2 kΩ	25°C	25	200		50	200		50	200		50	200		V/mV
			Full range	15			15			25			25			
B_1	Unity-gain bandwidth		25°C		3			3			3			3		MHz
r_i	Input resistance		25°C		10^{12}			10^{12}			10^{12}			10^{12}		Ω
CMRR	Common-mode rejection ratio	V_{IC} = V_{ICR}min, V_O = 0, R_S = 50 Ω	25°C	70	86		75	86		75	86		75	86		dB
k_{SVR}	Supply-voltage rejection ratio ($\Delta V_{CC\pm}$/ΔV_{IO})	V_{CC} = ±15 V to ±9 V, V_O = 0, R_S = 50 Ω	25°C	70	86		80	86		80	86		80	86		dB
I_{CC}	Supply current (each amplifier)	V_O = 0, No load	25°C		1.4	2.8		1.4	2.8		1.4	2.8		1.4	2.8	mA
V_{O1}/V_{O2}	Crosstalk attenuation	A_{VD} = 100	25°C		120			120			120			120		dB

(1) All characteristics are measured under open-loop conditions with zero common-mode voltage, unless otherwise specified. Full range for T_A is 0°C to 70°C for TL08_C, TL08_AC, TL08_BC and –40°C to 85°C for TL08_I.

(2) Input bias currents of an FET-input operational amplifier are normal junction reverse currents, which are temperature sensitive, as shown in Figure 6-52. Pulse techniques must be used that maintain the junction temperature as close to the ambient temperature as possible.

6.13 Electrical Characteristics for TL08xM and TL084x

$V_{CC\pm}$ = ±15 V (unless otherwise noted)

PARAMETER		TEST CONDITIONS(1)	T_A	TL081M, TL082M			TL084Q, TL084M			UNIT
				MIN	TYP	MAX	MIN	TYP	MAX	
V_{IO}	Input offset voltage	V_O = 0, R_S = 50 Ω	25°C		3	6		3	9	mV
			Full range			9			15	
α_{VIO}	Temperature coefficient of input offset voltage	V_O = 0, R_S = 50 Ω	Full range		18			18		µV/°C
I_{IO}	Input offset current(2)	V_O = 0	25°C		5	100		5	100	pA
			125°C			20			20	nA
I_{IB}	Input bias current(2)	V_O = 0	25°C		30	200		30	200	pA
			125°C			50			50	nA
V_{ICR}	Common-mode input voltage range		25°C	±11	–12 to 15		±11	–12 to 15		V
V_{OM}	Maximum peak output voltage swing	R_L = 10 kΩ	25°C	±12	±13.5		±12	±13.5		V
		R_L ≥ 10 kΩ	Full range	±12			±12			
		R_L ≥ 2 kΩ		±10	±12		±10	±12		
A_{VD}	Large-signal differential voltage amplification	V_O = ±10 V, R_L ≥ 2 kΩ	25°C	25	200		25	200		V/mV
			Full range	15			15			
B_1	Unity-gain bandwidth		25°C		3			3		MHz
r_i	Input resistance		25°C		10^{12}			10^{12}		Ω
CMRR	Common-mode rejection ratio	V_{IC} = V_{ICR}min, V_O = 0, R_S = 50 Ω	25°C	80	86		80	86		dB
k_{SVR}	Supply-voltage rejection ratio ($\Delta V_{CC\pm}/\Delta V_{IO}$)	V_{CC} = ±15 V to ±9 V, V_O = 0, R_S = 50 Ω	25°C	80	86		80	86		dB
I_{CC}	Supply current (each amplifier)	V_O = 0, No load	25°C		1.4	2.8		1.4	2.8	mA
V_{O1}/V_{O2}	Crosstalk attenuation	A_{VD} = 100	25°C		120			120		dB

(1) All characteristics are measured under open-loop conditions, with zero common-mode input voltage, unless otherwise specified.
(2) Input bias currents of a FET-input operational amplifier are normal junction reverse currents, which are temperature sensitive, as shown in Figure 6-52. Pulse techniques must be used that maintain the junction temperatures as close to the ambient temperature as possible.

6.14 Switching Characteristics

$V_{CC±}$ = ±15 V, T_A= 25°C (unless otherwise noted)

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
SR	Slew rate at unity gain	V_I = 10 V, R_L = 2 kΩ, C_L = 100 pF, see Figure 7-1		8[1]	13		V/µs
		V_I = 10 V, R_L = 2 kΩ, C_L = 100 pF, T_A = −55°C to 125°C, see Figure 7-1		5[1]			
t_r	Rise-time	V_I = 20 V, R_L = 2 kΩ, C_L = 100 pF, see Figure 7-1			0.05		µs
	overshoot factor				20%		
V_n	Equivalent input noise voltage	R_S = 20 Ω	f = 1 kHz		18		nV/√Hz
			f = 10 Hz to 10 kHz		4		µV
I_n	Equivalent input noise current	R_S = 20 Ω	f = 1 kHz		0.01		pA/√Hz
THD	Total harmonic distortion	$V_I$rms = 6 V, A_{VD} = 1, R_S ≤ 1 kΩ, R_L ≥ 2 kΩ, f = 1 kHz			0.003%		

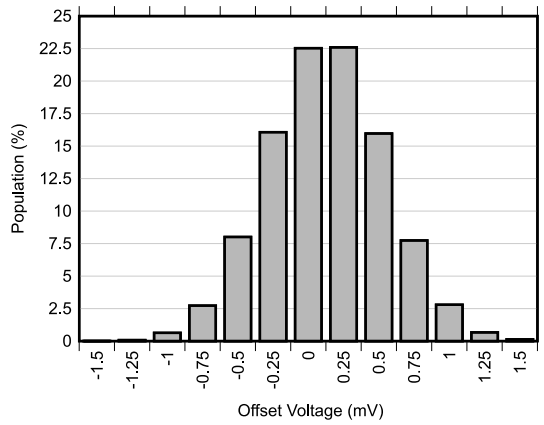
(1) On products compliant to MIL-PRF-38535, this parameter is not production tested.

6.15 Dissipation Rating Table

PACKAGE	T_A ≤ 25°C POWER RATING	DERATING FACTOR	DERATE ABOVE T_A	T_A = 70°C POWER RATING	T_A = 85°C POWER RATING	T_A = 125°C POWER RATING
D (14 pin)	680 mW	7.6 mW/°C	60°C	604 m/W	490 mW	186 mW
FK	680 mW	11.0 mW/°C	88°C	680 m/W	680 mW	273 mW
J	680 mW	11.0 mW/°C	88°C	680 m/W	680 mW	273 mW
JG	680 mW	8.4 mW/°C	69°C	672 m/W	546 mW	210 mW

6.16 Typical Characteristics: TL08xH

at T_A = 25°C, V_S = 40 V (±20 V), V_{CM} = V_S / 2, R_{LOAD} = 10 kΩ connected to V_S / 2, and C_L = 20 pF (unless otherwise noted)



T_A = 25°C

Figure 6-1. Offset Voltage Production Distribution

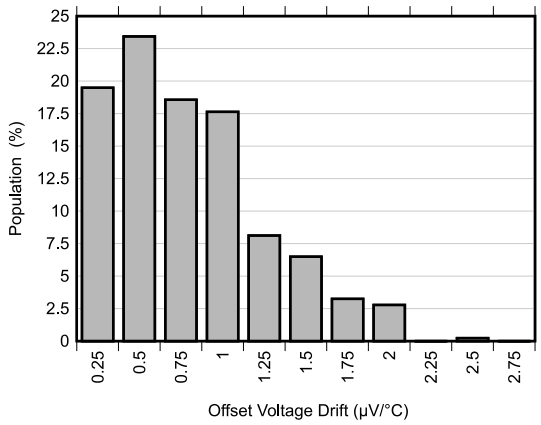
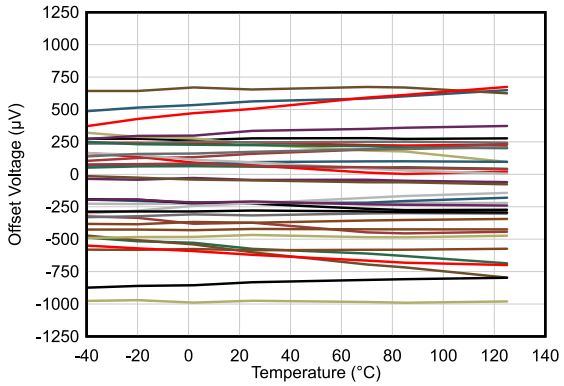
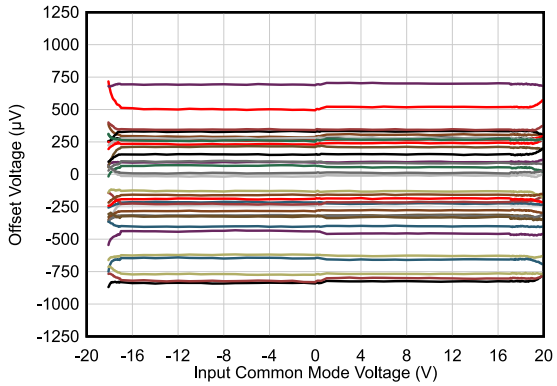


Figure 6-2. Offset Voltage Drift Distribution



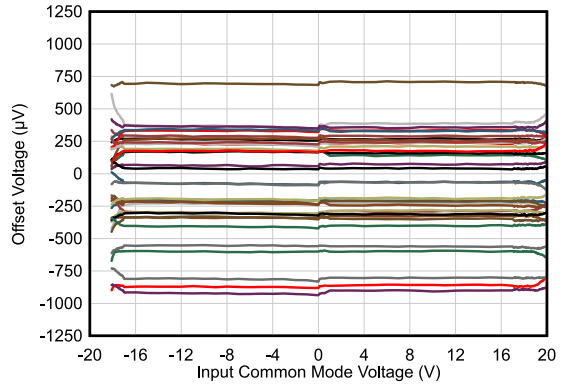
V_{CM} = V_S / 2

Figure 6-3. Offset Voltage vs Temperature



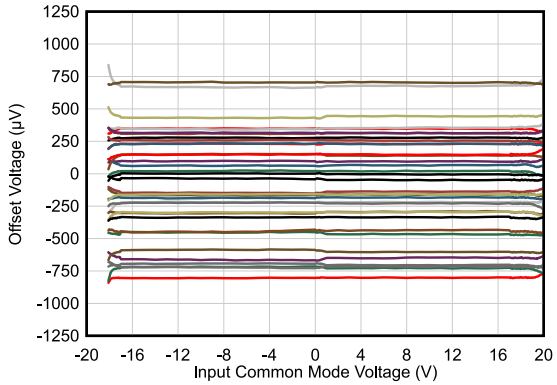
T_A = 25°C

Figure 6-4. Offset Voltage vs Common-Mode Voltage



T_A = 125°C

Figure 6-5. Offset Voltage vs Common-Mode Voltage



T_A = –40°C

Figure 6-6. Offset Voltage vs Common-Mode Voltage

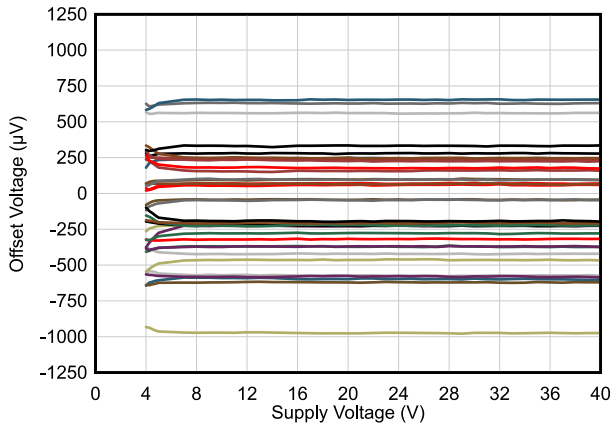


Figure 6-7. Offset Voltage vs Power Supply

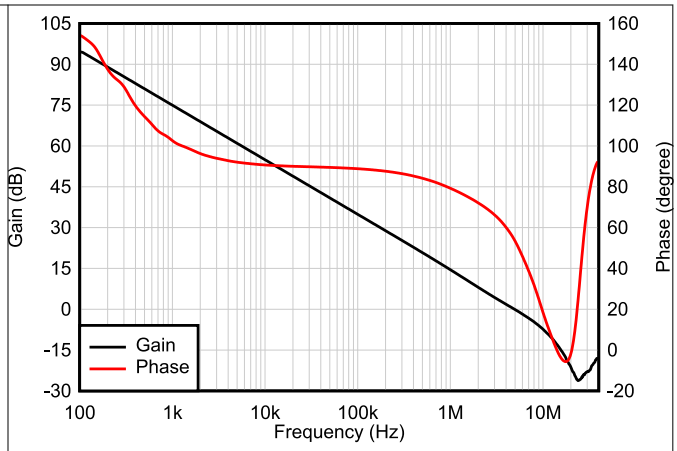


Figure 6-8. Open-Loop Gain and Phase vs Frequency

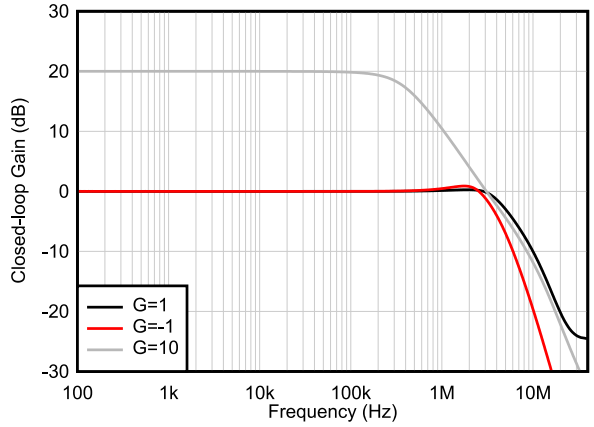


Figure 6-9. Closed-Loop Gain vs Frequency

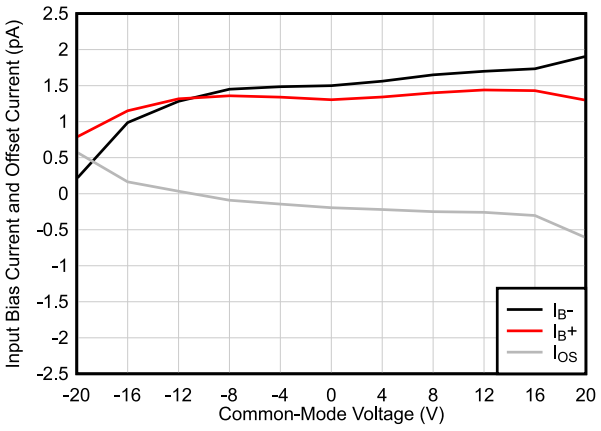


Figure 6-10. Input Bias Current vs Common-Mode Voltage

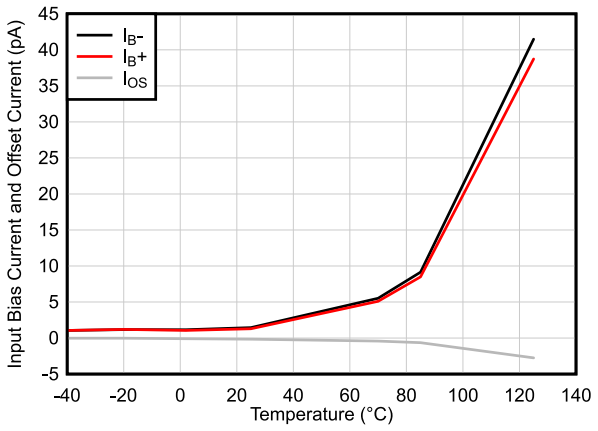


Figure 6-11. Input Bias Current vs Temperature

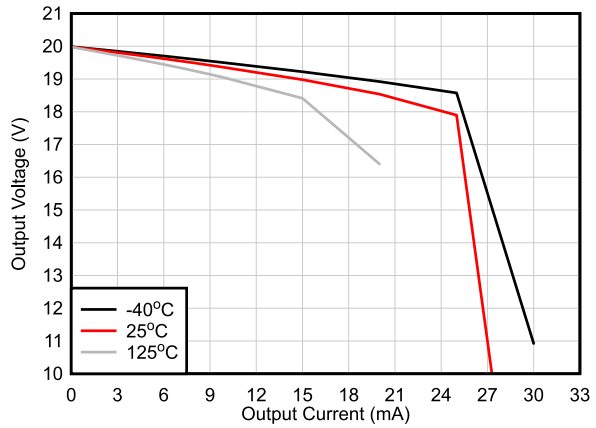


Figure 6-12. Output Voltage Swing vs Output Current (Sourcing)

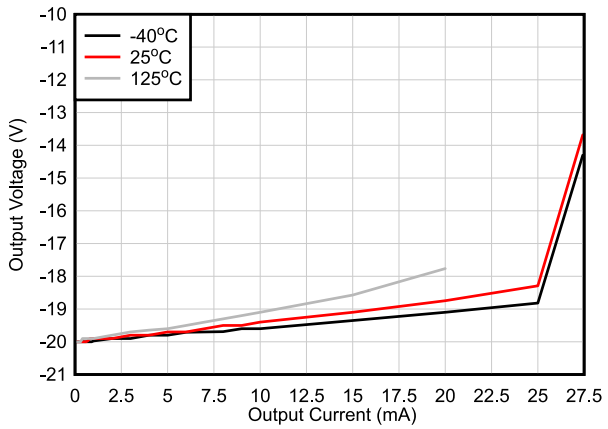


Figure 6-13. Output Voltage Swing vs Output Current (Sinking)

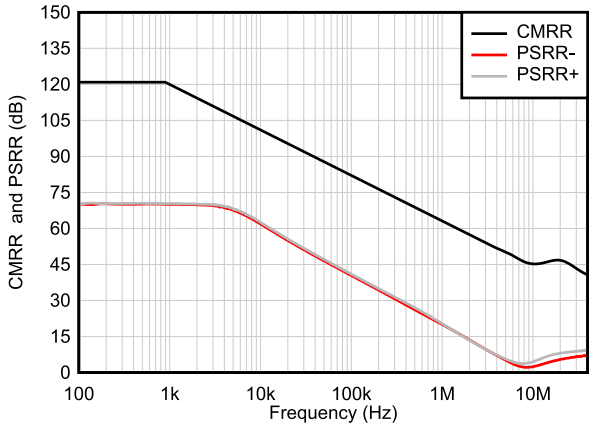
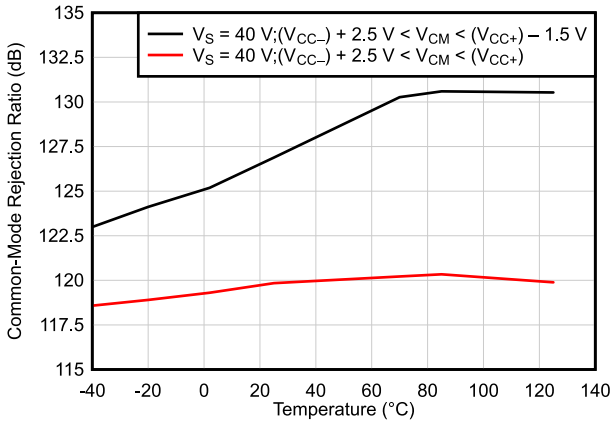
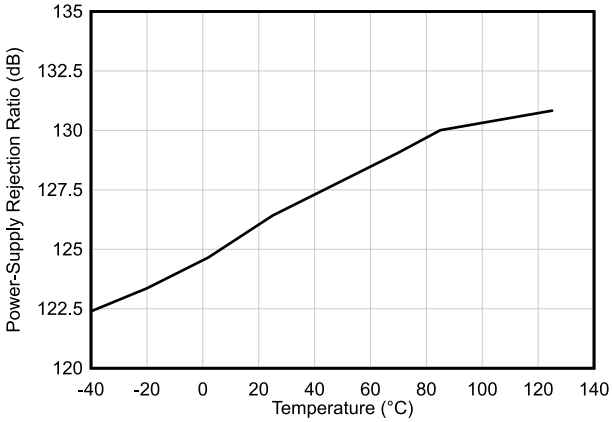


Figure 6-14. CMRR and PSRR vs Frequency



f = 0 Hz

Figure 6-15. CMRR vs Temperature (dB)



f = 0 Hz

Figure 6-16. PSRR vs Temperature (dB)

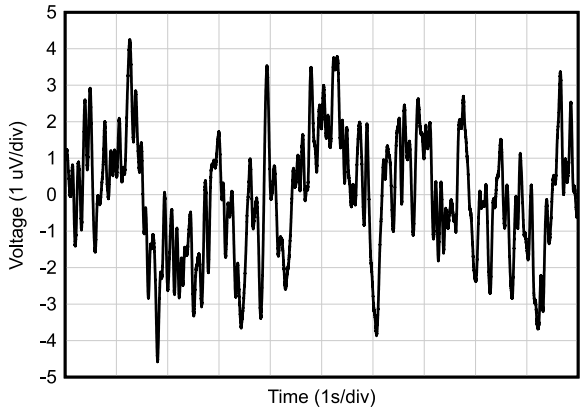


Figure 6-17. 0.1-Hz to 10-Hz Noise

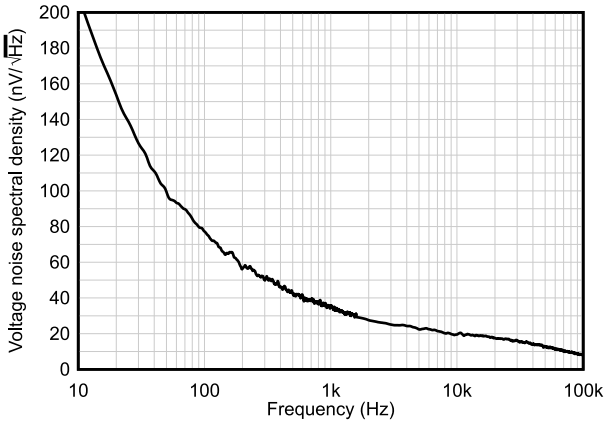
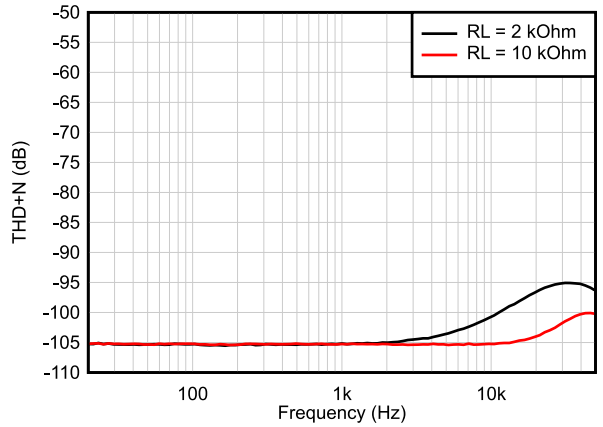
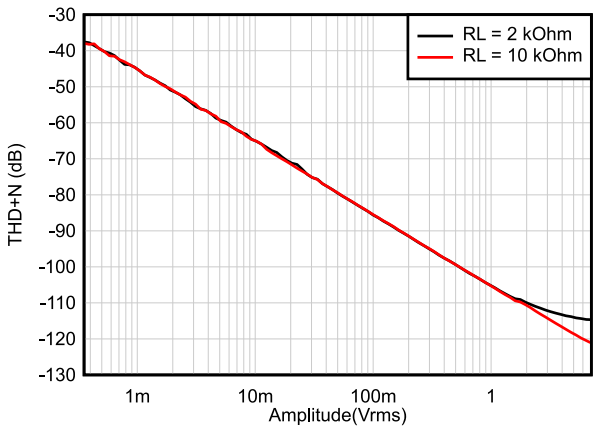


Figure 6-18. Input Voltage Noise Spectral Density vs Frequency



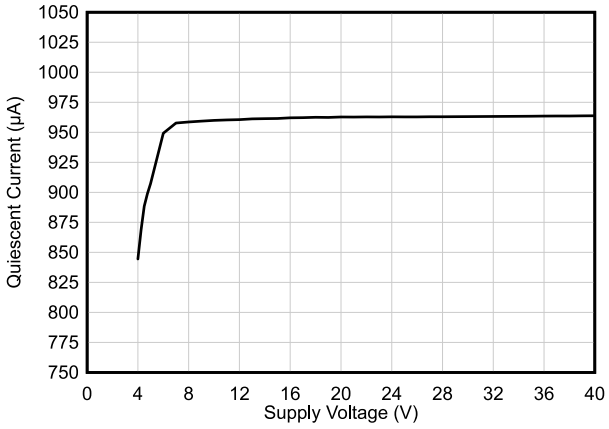
BW = 80 kHz, V_{OUT} = 1 V_{RMS}

Figure 6-19. THD+N Ratio vs Frequency



BW = 80 kHz, f = 1 kHz

Figure 6-20. THD+N vs Output Amplitude



V_{CM} = V_S / 2

Figure 6-21. Quiescent Current vs Supply Voltage

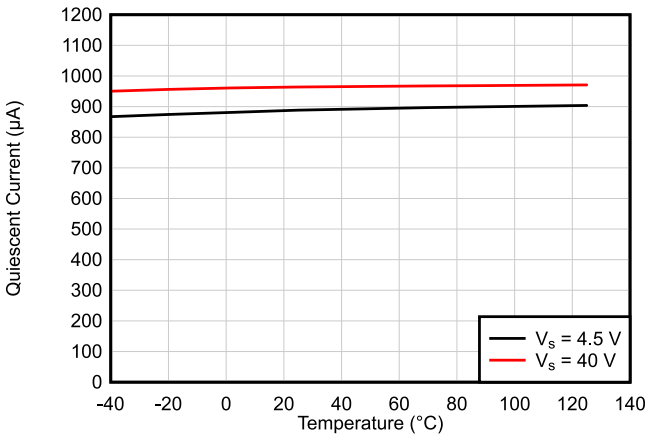


Figure 6-22. Quiescent Current vs Temperature

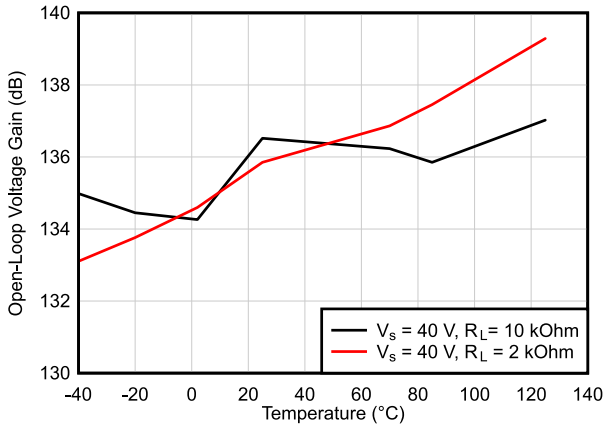


Figure 6-23. Open-Loop Voltage Gain vs Temperature (dB)

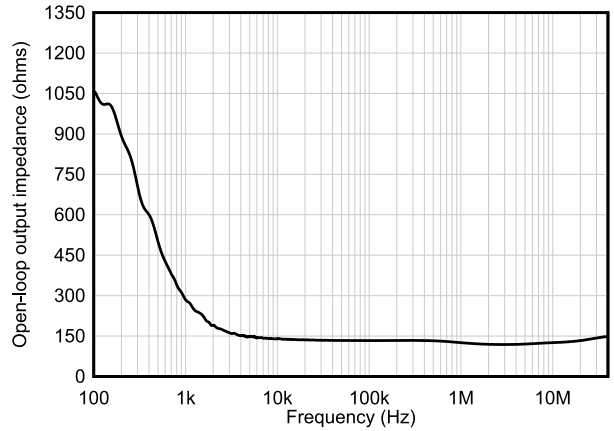
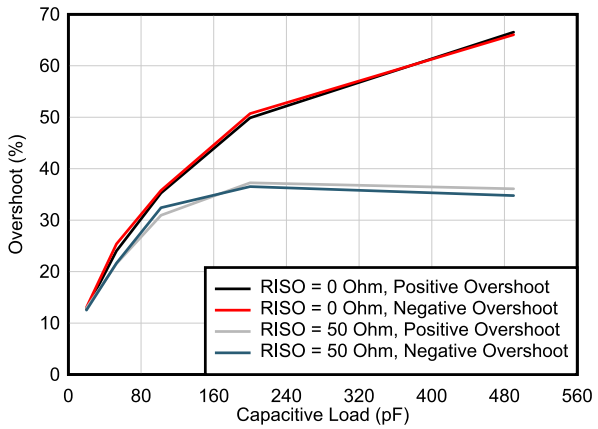
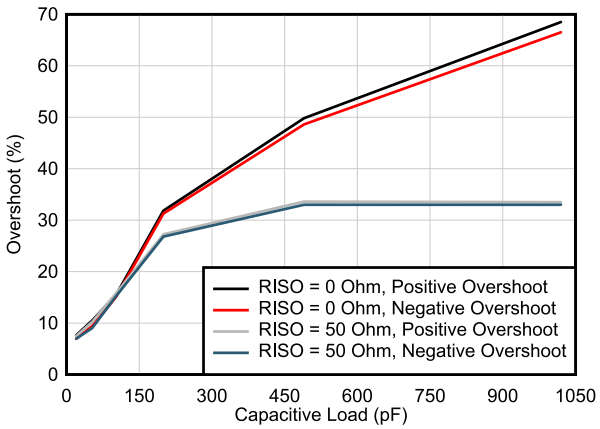


Figure 6-24. Open-Loop Output Impedance vs Frequency



G = –1, 25-mV output step

Figure 6-25. Small-Signal Overshoot vs Capacitive Load



G = 1, 10-mV output step

Figure 6-26. Small-Signal Overshoot vs Capacitive Load

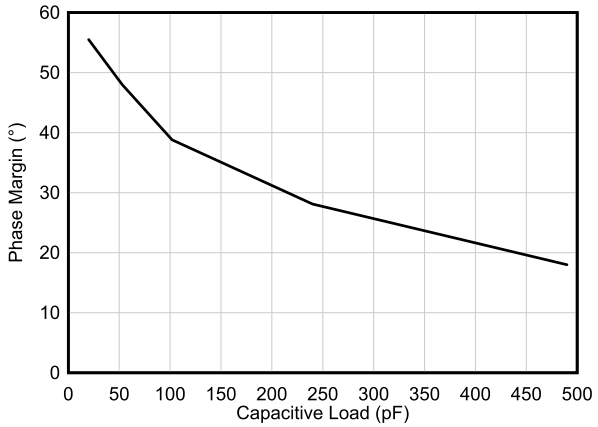
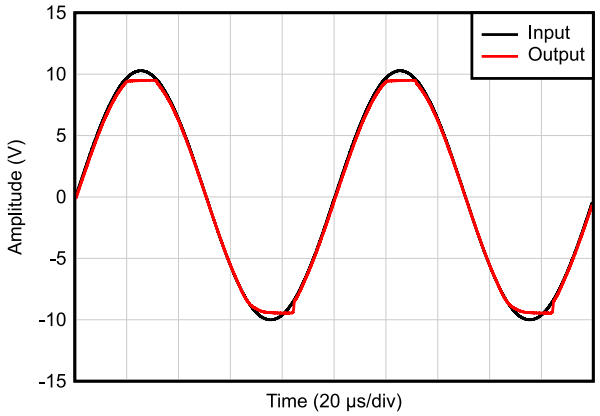
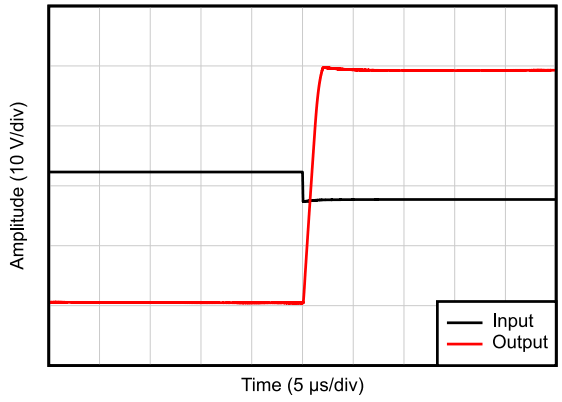


Figure 6-27. Phase Margin vs Capacitive Load



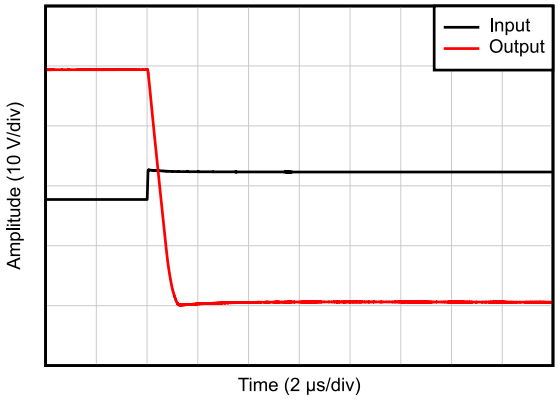
V_S = ±10 V, V_{IN} = V_{OUT}

Figure 6-28. No Phase Reversal



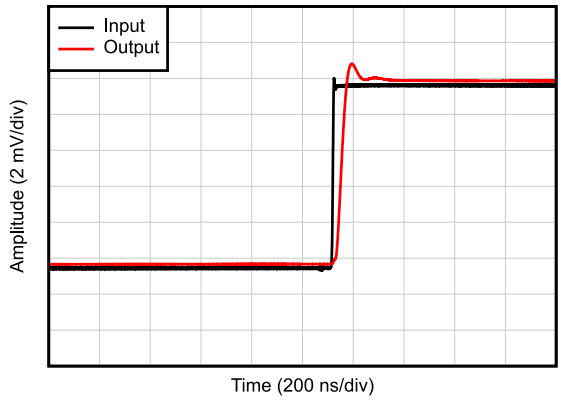
G = –10

Figure 6-29. Positive Overload Recovery



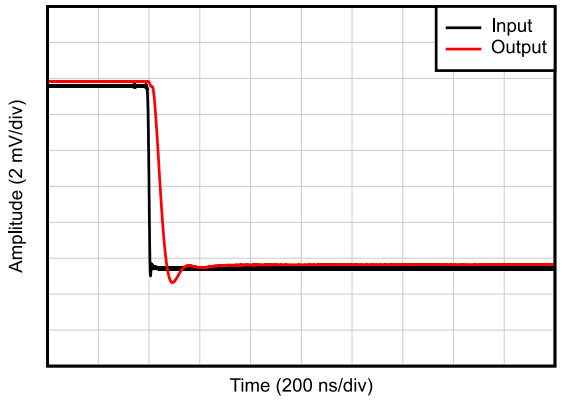
G = –10

Figure 6-30. Negative Overload Recovery



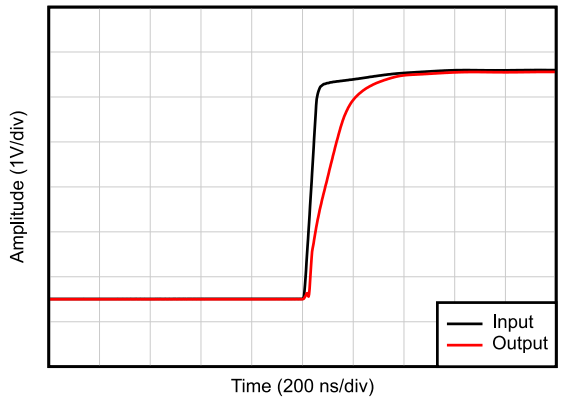
C_L = 20 pF, G = 1, 10-mV step response

Figure 6-31. Small-Signal Step Response, Rising



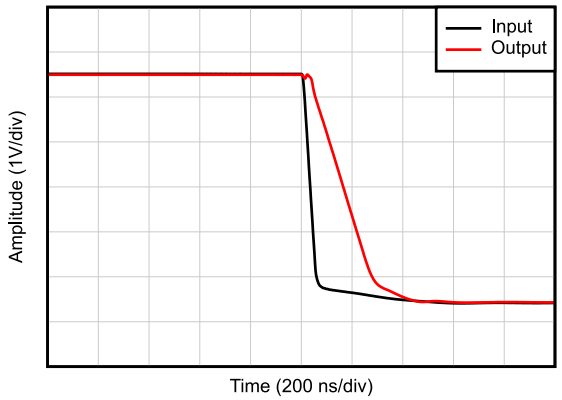
C_L = 20 pF, G = 1, 10-mV step response

Figure 6-32. Small-Signal Step Response, Falling



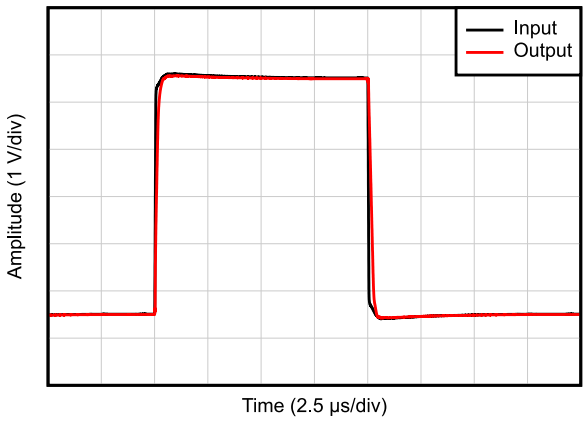
C_L = 20 pF, G = 1

Figure 6-33. Large-Signal Step Response (Rising)



C_L = 20 pF, G = 1

Figure 6-34. Large-Signal Step Response (Falling)



C_L = 20 pF, G = 1

Figure 6-35. Large-Signal Step Response

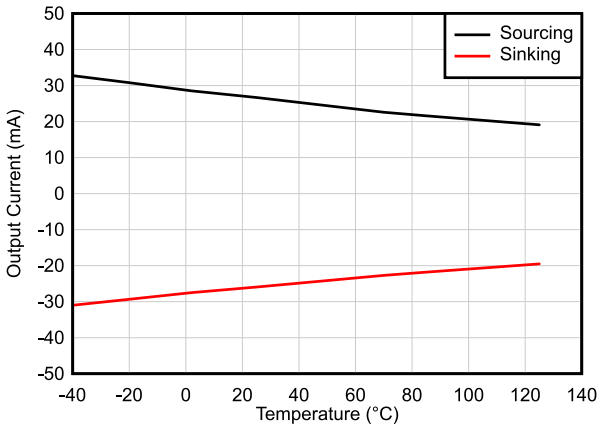


Figure 6-36. Short-Circuit Current vs Temperature

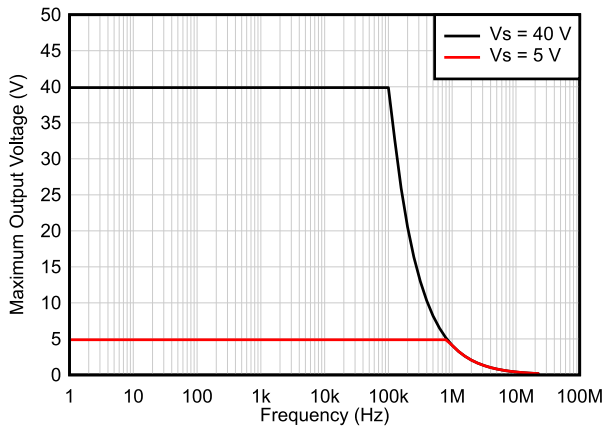


Figure 6-37. Maximum Output Voltage vs Frequency

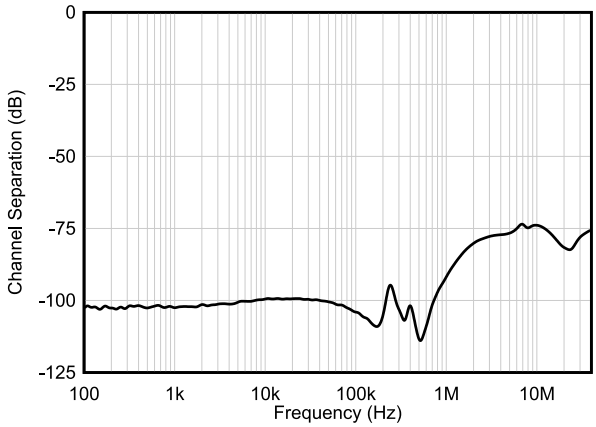


Figure 6-38. Channel Separation vs Frequency

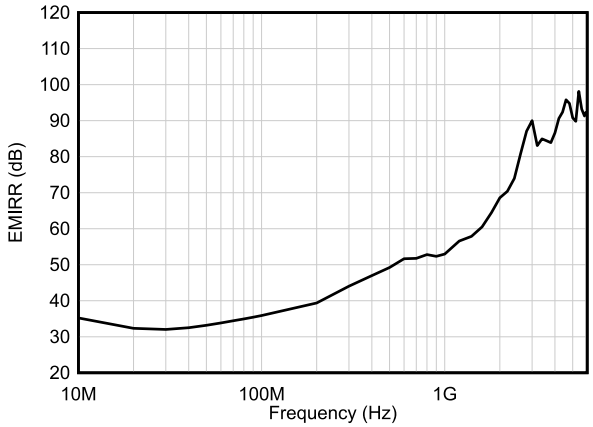


Figure 6-39. EMIRR (Electromagnetic Interference Rejection Ratio) vs Frequency

6.17 Typical Characteristics: All Other Devices

Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices. The Figure numbers referenced in the following graphs are located in Section 7.

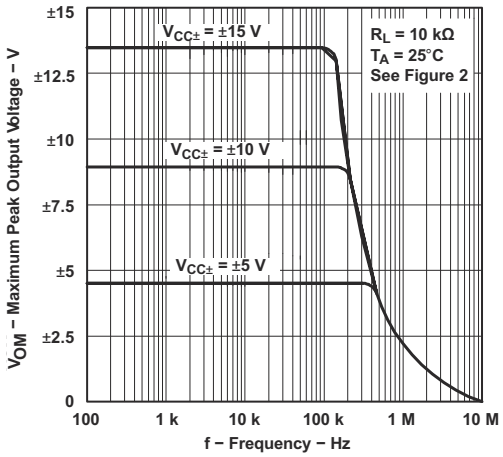


Figure 6-40. Maximum Peak Output Voltage vs Frequency

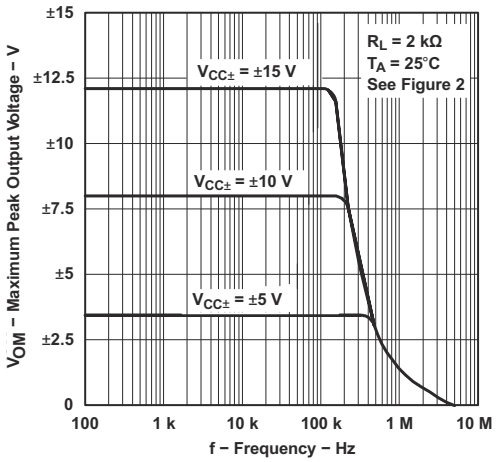


Figure 6-41. Maximum Peak Output Voltage vs Frequency

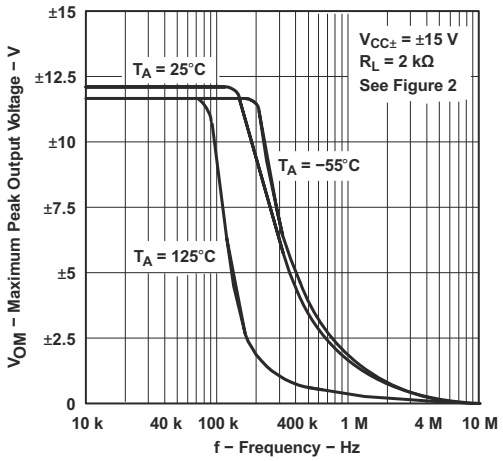


Figure 6-42. Maximum Peak Output Voltage vs Frequency

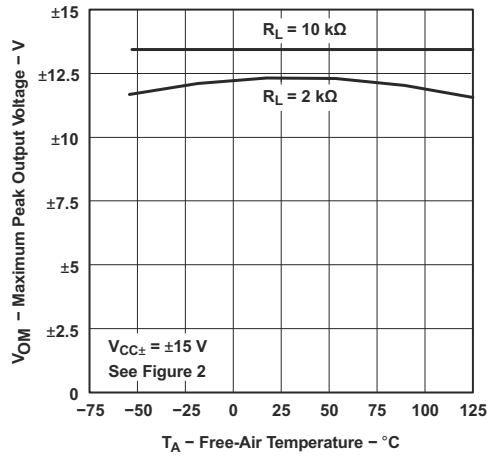


Figure 6-43. Maximum Peak Output Voltage vs Free-Air Temperature

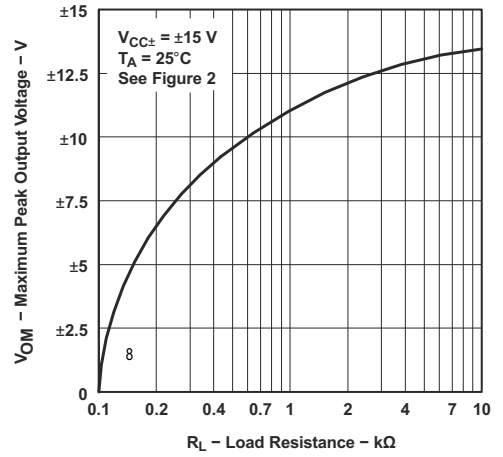


Figure 6-44. Maximum Peak Output Voltage vs Load Resistance

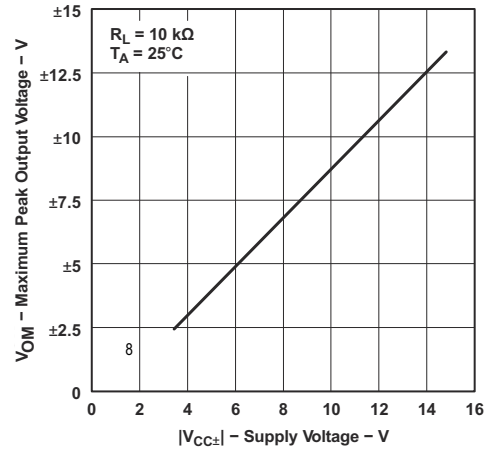


Figure 6-45. Maximum Peak Output Voltage vs Supply Voltage

6.17 Typical Characteristics: All Other Devices (continued)

Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices. The Figure numbers referenced in the following graphs are located in Section 7.

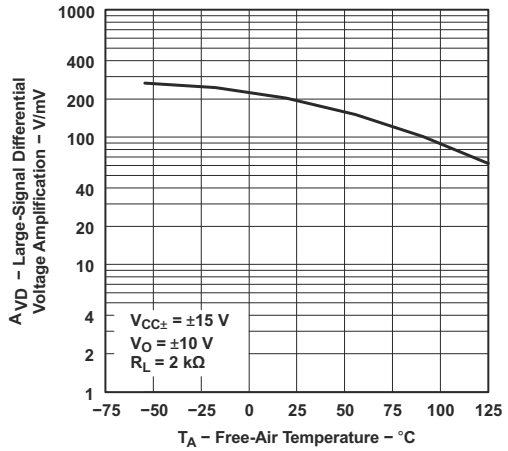


Figure 6-46. Large-Signal Differential Voltage Amplification vs Free-Air Temperature

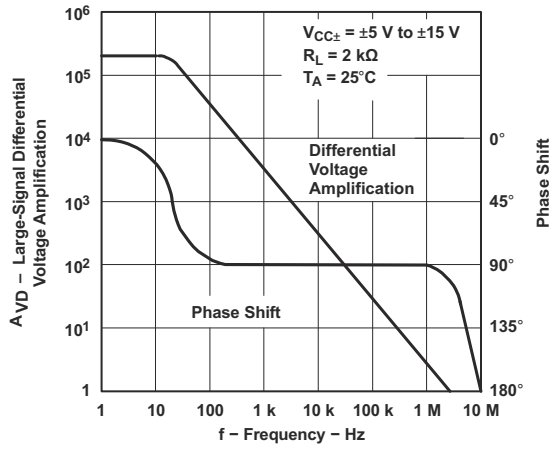


Figure 6-47. Large-Signal Differential Voltage Amplification and Phase Shift vs Frequency

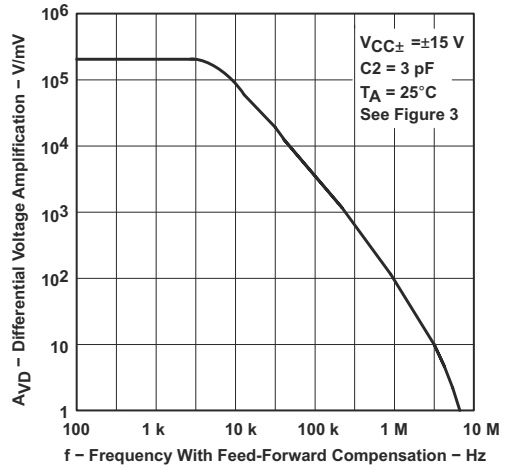


Figure 6-48. Differential Voltage Amplification vs Frequency with Feed-Forward Compensation

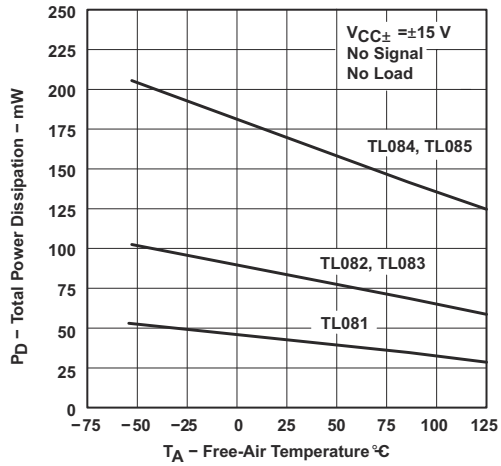


Figure 6-49. Total Power Dissipation vs Free-Air Temperature

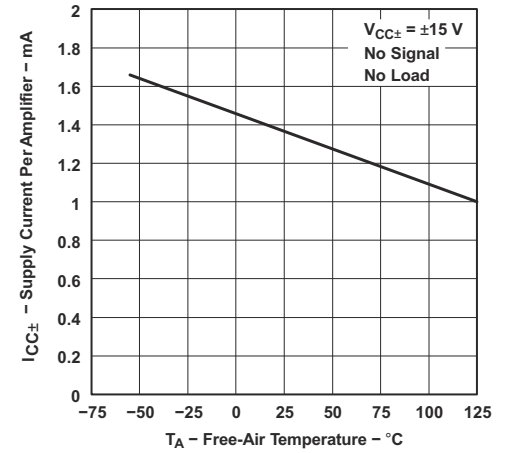


Figure 6-50. Supply Current per Amplifier vs Free-Air Temperature

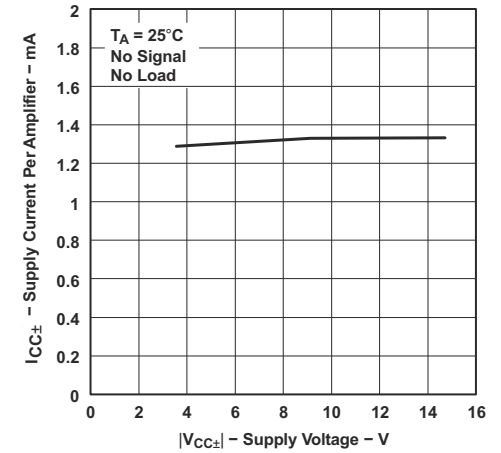


Figure 6-51. Supply Current per Amplifier vs Supply Voltage

6.17 Typical Characteristics: All Other Devices (continued)

Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices. The Figure numbers referenced in the following graphs are located in Section 7.

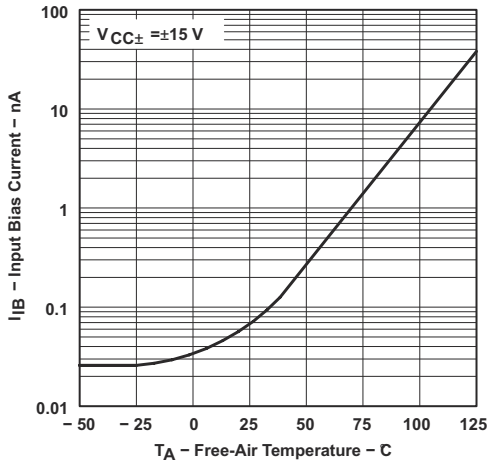


Figure 6-52. Input Bias Current vs Free-Air Temperature

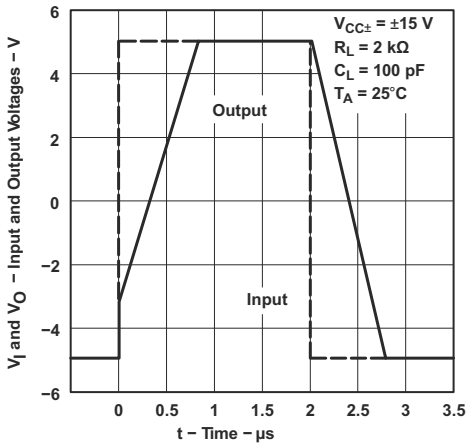


Figure 6-53. Voltage-Follower Large-Signal Pulse Response

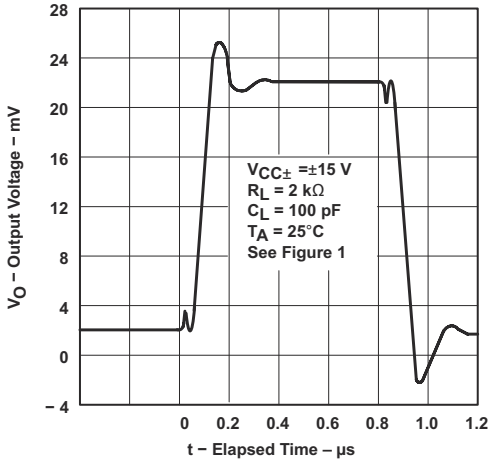


Figure 6-54. Output Voltage vs Elapsed Time

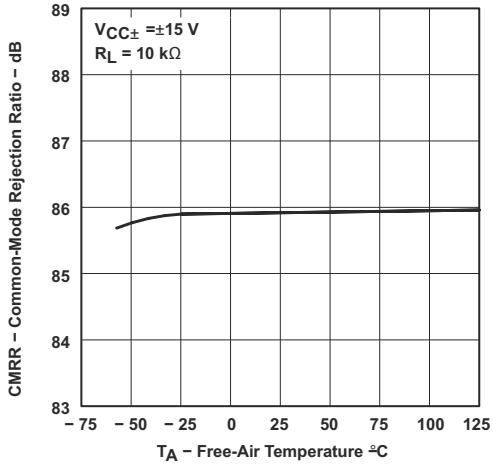


Figure 6-55. Common-Mode Rejection Ratio vs Free-Air Temperature

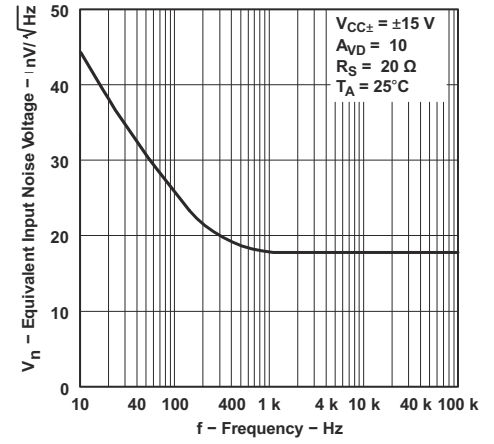


Figure 6-56. Equivalent Input Noise Voltage vs Frequency

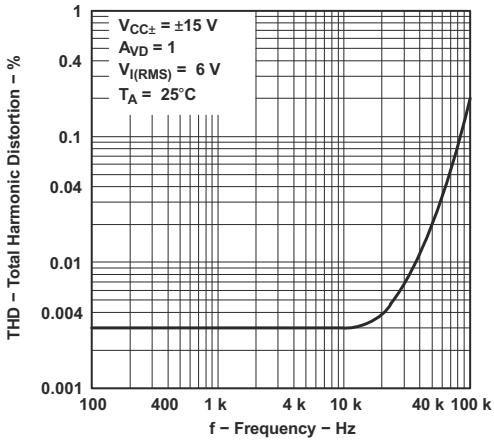


Figure 6-57. Total Harmonic Distortion vs Frequency

7 Parameter Measurement Information

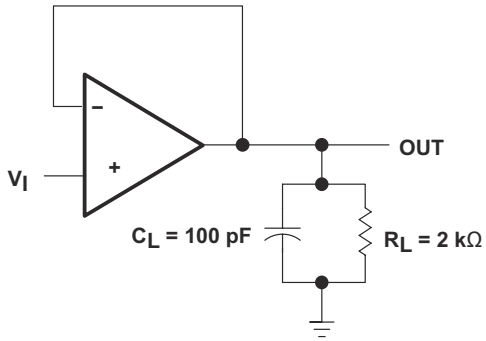


Figure 7-1. Test Figure 1

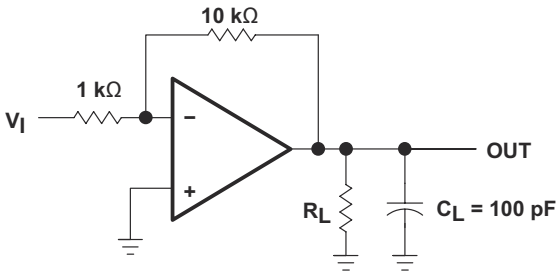


Figure 7-2. Test Figure 2

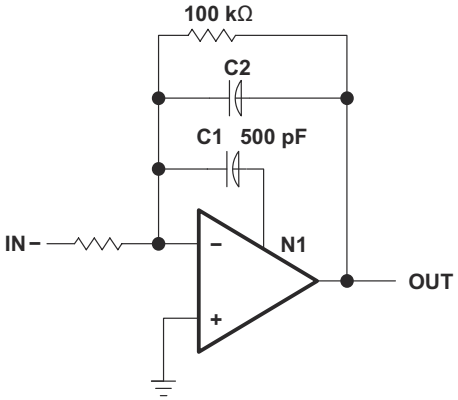


Figure 7-3. Test Figure 3

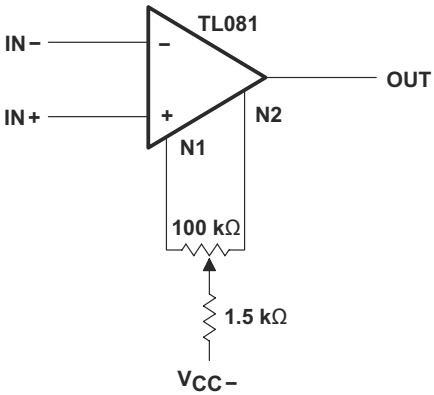


Figure 7-4. Test Figure 4

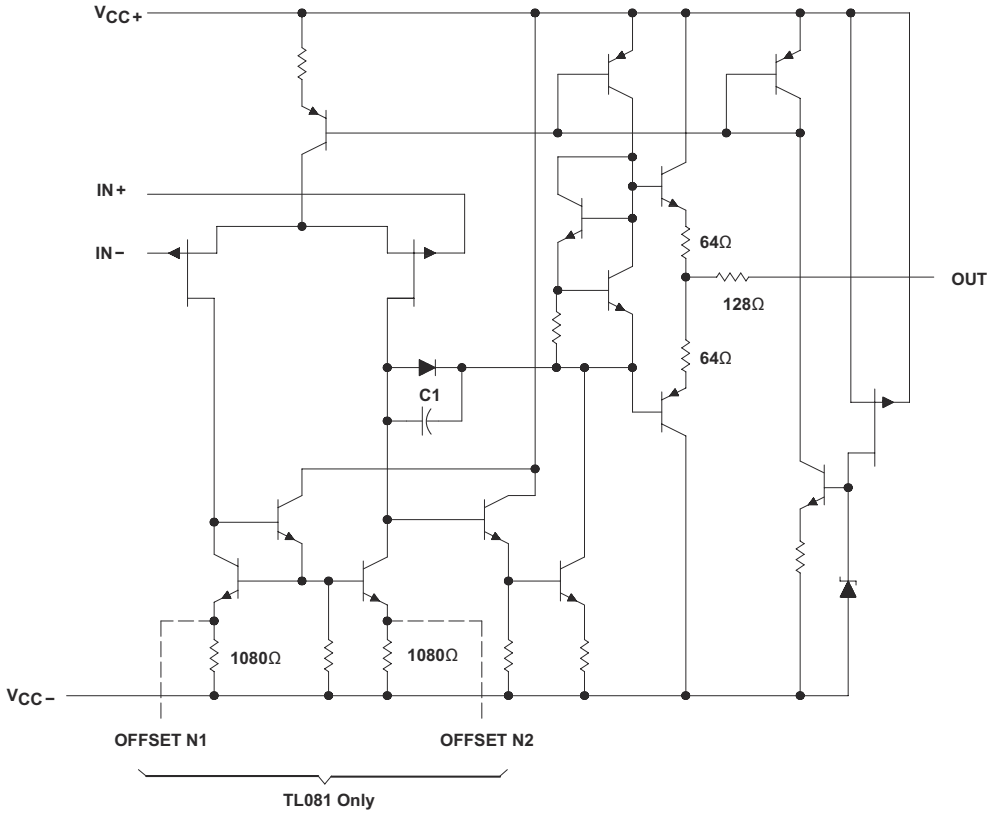
8 Detailed Description

8.1 Overview

The TL08xH family (TL081H, TL082H, and TL084H) is the next-generation family of the industry standard TL08x (TL081, TL082, and TL084) high-voltage general purpose amplifiers. These devices provide outstanding value for cost-sensitive applications requiring high slew rate with high voltage signals, such as motor drive and inverter systems.

A robust MUX-friendly input stage enhances flexibility in design, with common-mode voltage range extending to the positive rail as well as improved settling time in multi-channel applications. Low offset voltage (1 mV, typ) and low offset voltage drift (2 µV/°C) allows the TL08xH family to be used in rugged applications requiring precision current and voltage sensing. High voltage operation (up to 40 V) and high slew rate (20 V/µs) make the TL08xH family a premier choice for high-voltage applications with fast transients.

8.2 Functional Block Diagram



8.3 Feature Description

8.3.1 Total Harmonic Distortion

Harmonic distortions to an audio signal are created by electronic components in a circuit. Total harmonic distortion (THD) is a measure of harmonic distortions accumulated by a signal in an audio system. These devices have a very low THD of 0.003% meaning that the TL08x devices will add little harmonic distortion when used in audio signal applications.

8.3.2 Slew Rate

The slew rate is the rate at which an operational amplifier can change its output when there is a change on the input. These devices have a 13-V/µs slew rate.

8.4 Device Functional Modes

These devices are powered on when the supply is connected. This device can be operated as a single-supply operational amplifier or dual-supply amplifier depending on the application.

9 Applications and Implementation

Note

Information in the following applications sections is not part of the TI component specification, and TI does not warrant its accuracy or completeness. TI's customers are responsible for determining suitability of components for their purposes, as well as validating and testing their design implementation to confirm system functionality.

9.1 Application Information

The TL08x series of operational amplifiers can be used in countless applications. The few applications in this section show principles used in all applications of these parts.

9.2 Typical Applications

9.2.1 Inverting Amplifier Application

A typical application for an operational amplifier in an inverting amplifier. This amplifier takes a positive voltage on the input, and makes it a negative voltage of the same magnitude. In the same manner, it also makes negative voltages positive.

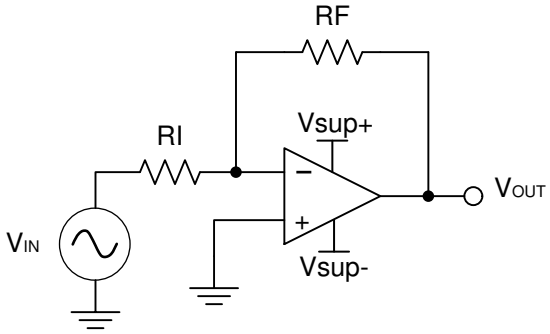


Figure 9-1. Schematic for Inverting Amplifier Application

9.2.1.1 Design Requirements

The supply voltage must be chosen such that it is larger than the input voltage range and output range. For instance, this application will scale a signal of ±0.5 V to ±1.8 V. Setting the supply at ±12 V is sufficient to accommodate this application.

9.2.1.2 Detailed Design Procedure

Determine the gain required by the inverting amplifier:

$$A_V = \frac{VOUT}{VIN} \tag{1}$$

$$A_V = \frac{1.8}{-0.5} = -3.6 \tag{2}$$

Once the desired gain is determined, choose a value for RI or RF. Choosing a value in the kΩ range is desirable because the amplifier circuit will use currents in the milliamp range. This ensures the part will not draw too much current. This example will choose 10 kΩ for RI which means 36 kΩ will be used for RF. This was determined by Equation 3.

$$A_V = -\frac{RF}{RI} \tag{3}$$

9.2.1.3 Application Curve

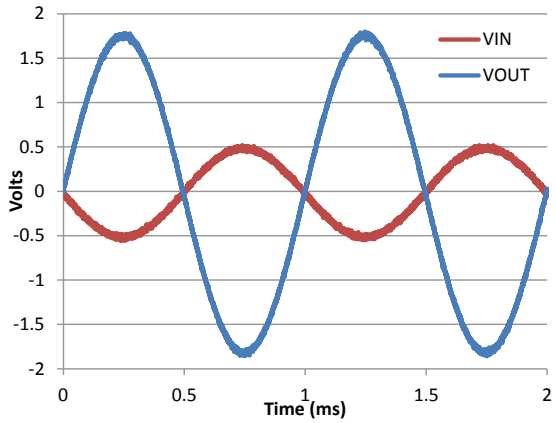


Figure 9-2. Input and Output Voltages of the Inverting Amplifier

9.3 System Examples

9.3.1 General Applications

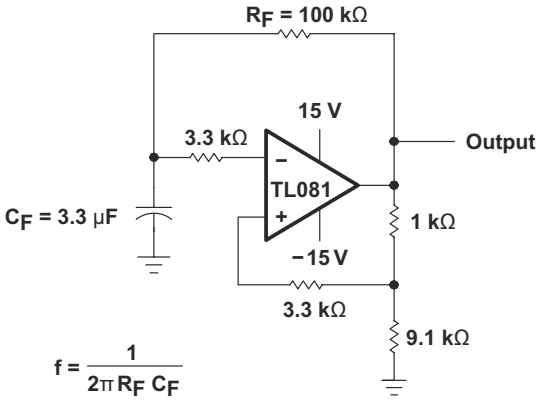


Figure 9-3. 0.5-Hz Square-Wave Oscillator

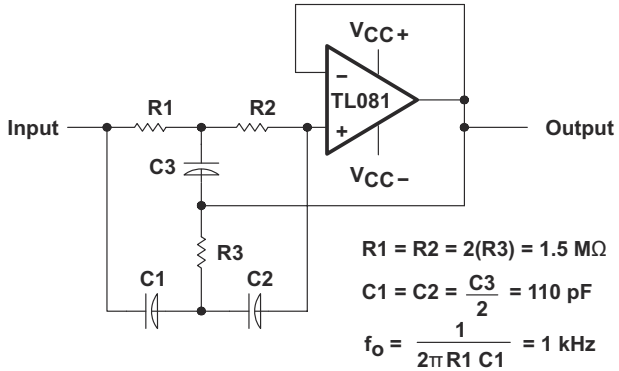


Figure 9-4. High-Q Notch Filter

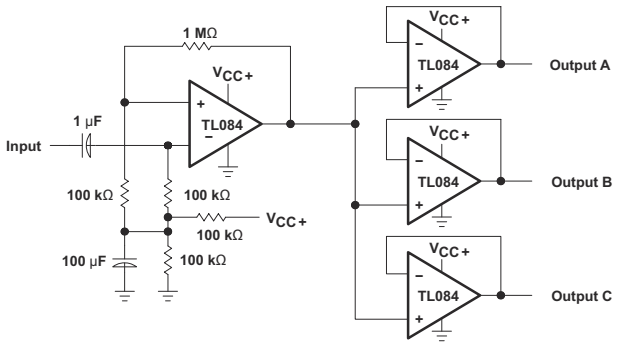
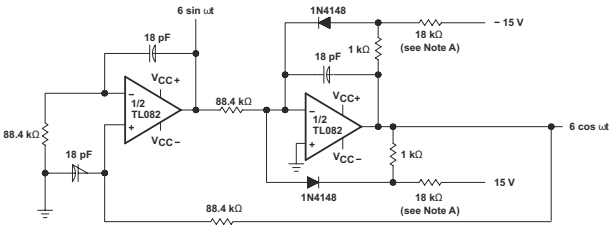


Figure 9-5. Audio-Distribution Amplifier



A. These resistor values may be adjusted for a symmetrical output.

Figure 9-6. 100-kHz Quadrature Oscillator

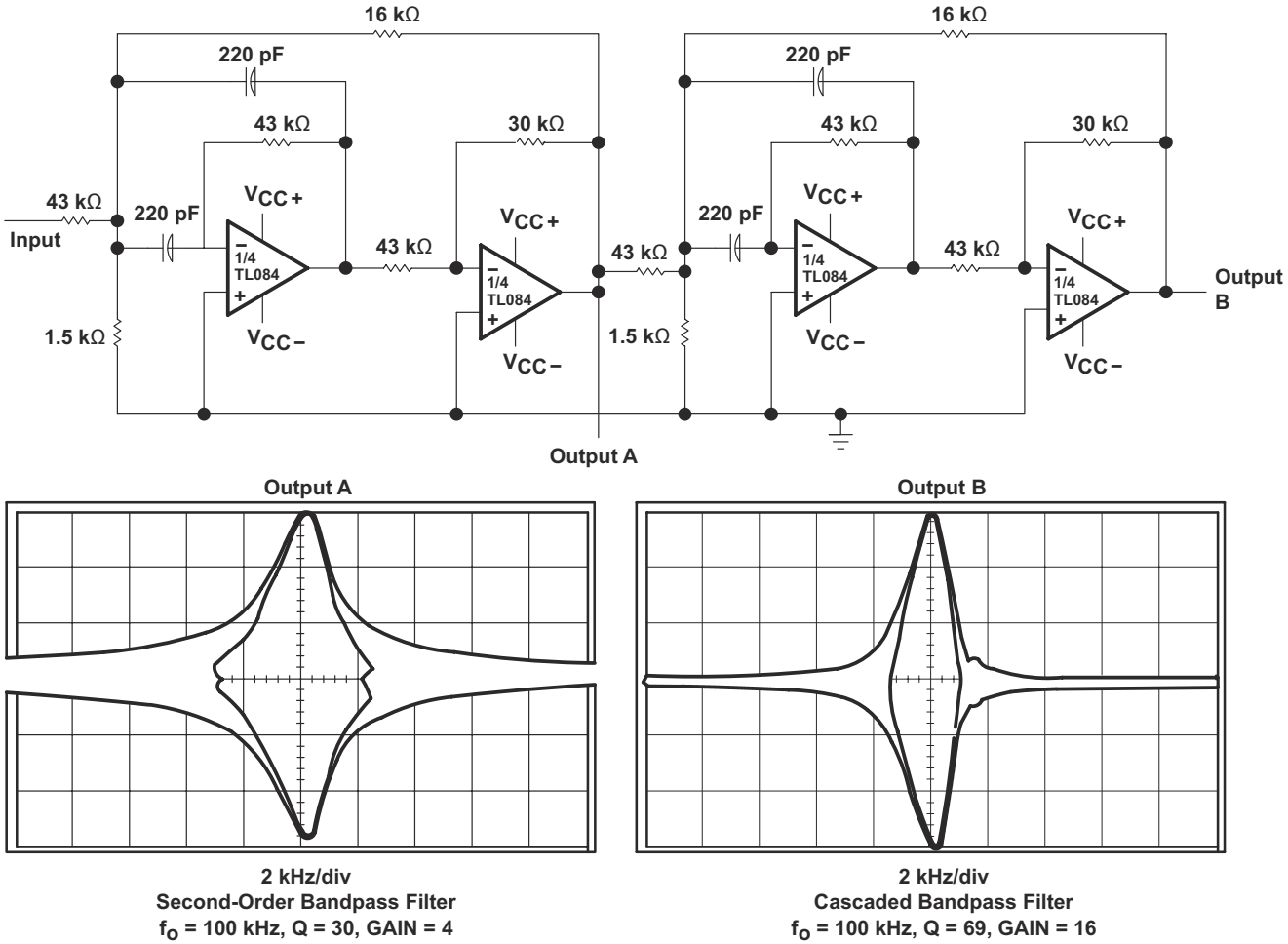


Figure 9-7. Positive-Feedback Bandpass Filter

10 Power Supply Recommendations

CAUTION

Supply voltages larger than 36 V for a single-supply or outside the range of ±18 V for a dual-supply can permanently damage the device (see Section 6.2).

Place 0.1-µF bypass capacitors close to the power-supply pins to reduce errors coupling in from noisy or high impedance power supplies. For more detailed information on bypass capacitor placement, refer to Section 11.

11 Layout

11.1 Layout Guidelines

For best operational performance of the device, use good PCB layout practices, including:

- Noise can propagate into analog circuitry through the power pins of the circuit as a whole, as well as the operational amplifier. Bypass capacitors are used to reduce the coupled noise by providing low impedance power sources local to the analog circuitry.
  - Connect low-ESR, 0.1-µF ceramic bypass capacitors between each supply pin and ground, placed as close to the device as possible. A single bypass capacitor from V+ to ground is applicable for single-supply applications.
- Separate grounding for analog and digital portions of circuitry is one of the simplest and most-effective methods of noise suppression. One or more layers on multilayer PCBs are usually devoted to ground planes. A ground plane helps distribute heat and reduces EMI noise pickup. Make sure to physically separate digital and analog grounds, paying attention to the flow of the ground current.
- To reduce parasitic coupling, run the input traces as far away from the supply or output traces as possible. If it is not possible to keep them separate, it is much better to cross the sensitive trace perpendicular as opposed to in parallel with the noisy trace.
- Place the external components as close to the device as possible. Keeping RF and RG close to the inverting input minimizes parasitic capacitance, as shown in Section 11.2.
- Keep the length of input traces as short as possible. Always remember that the input traces are the most sensitive part of the circuit.
- Consider a driven, low-impedance guard ring around the critical traces. A guard ring can significantly reduce leakage currents from nearby traces that are at different potentials.

11.2 Layout Examples

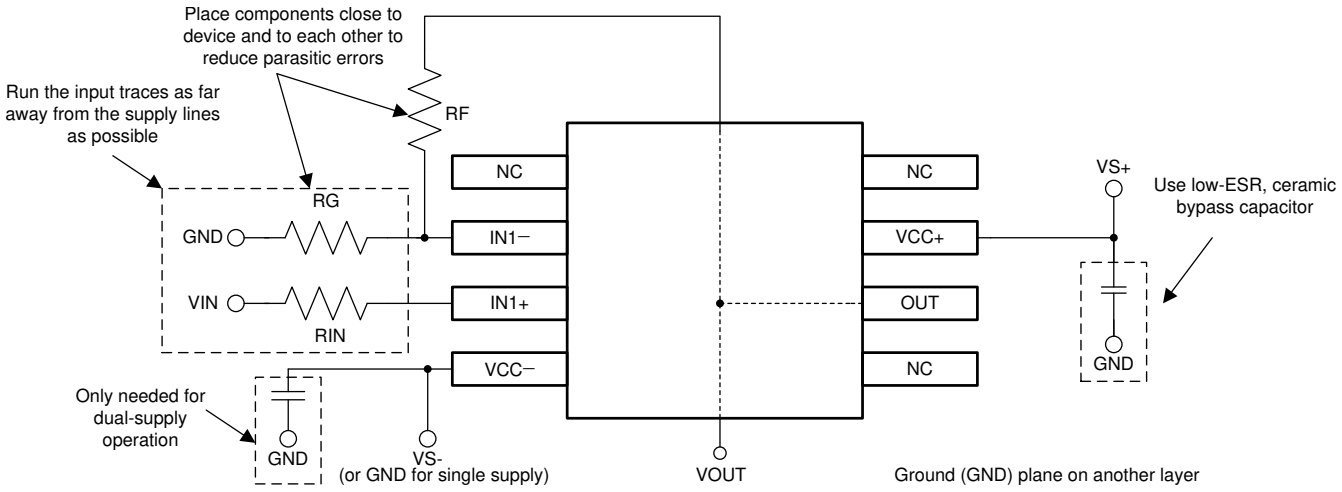


Figure 11-1. Operational Amplifier Board Layout for Noninverting Configuration

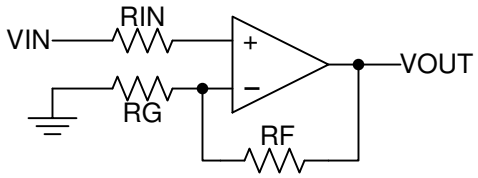


Figure 11-2. Operational Amplifier Schematic for Noninverting Configuration

12 Device and Documentation Support

12.1 Receiving Notification of Documentation Updates

To receive notification of documentation updates, navigate to the device product folder on ti.com. Click on *Subscribe to updates* to register and receive a weekly digest of any product information that has changed. For change details, review the revision history included in any revised document.

12.2 Support Resources

TI E2E™ support forums are an engineer's go-to source for fast, verified answers and design help — straight from the experts. Search existing answers or ask your own question to get the quick design help you need.

Linked content is provided "AS IS" by the respective contributors. They do not constitute TI specifications and do not necessarily reflect TI's views; see TI's Terms of Use.

12.3 Trademarks

TI E2E™ is a trademark of Texas Instruments.
All trademarks are the property of their respective owners.

12.4 Electrostatic Discharge Caution

This integrated circuit can be damaged by ESD. Texas Instruments recommends that all integrated circuits be handled with appropriate precautions. Failure to observe proper handling and installation procedures can cause damage.

ESD damage can range from subtle performance degradation to complete device failure. Precision integrated circuits may be more susceptible to damage because very small parametric changes could cause the device not to meet its published specifications.

12.5 Glossary

TI Glossary	This glossary lists and explains terms, acronyms, and definitions.

13 Mechanical, Packaging, and Orderable Information

The following pages include mechanical, packaging, and orderable information. This information is the most current data available for the designated devices. This data is subject to change without notice and revision of this document. For browser-based versions of this data sheet, refer to the left-hand navigation.

PACKAGING INFORMATION

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead finish/ Ball material (6)	MSL Peak Temp (3)	Op Temp (°C)	Device Marking (4/5)	Samples
5962-9851501Q2A	ACTIVE	LCCC	FK	20	1	Non-RoHS & Green	SNPB	N / A for Pkg Type	-55 to 125	5962-9851501Q2A TL082MFKB	Samples
5962-9851501QPA	ACTIVE	CDIP	JG	8	1	Non-RoHS & Green	SNPB	N / A for Pkg Type	-55 to 125	9851501QPA TL082M	Samples
5962-9851503Q2A	ACTIVE	LCCC	FK	20	1	Non-RoHS & Green	SNPB	N / A for Pkg Type	-55 to 125	5962-9851503Q2A TL084 MFKB	Samples
5962-9851503QCA	ACTIVE	CDIP	J	14	1	Non-RoHS & Green	SNPB	N / A for Pkg Type	-55 to 125	5962-9851503QC A TL084MJB	Samples
TL081ACD	LIFEBUY	SOIC	D	8	75	RoHS & Green	NIPDAU	Level-1-260C-UNLIM	0 to 70	081AC	
TL081ACDR	ACTIVE	SOIC	D	8	2500	RoHS & Green	NIPDAU	Level-1-260C-UNLIM	0 to 70	081AC	Samples
TL081ACP	ACTIVE	PDIP	P	8	50	RoHS & Green	NIPDAU	N / A for Pkg Type	0 to 70	TL081ACP	Samples
TL081BCD	LIFEBUY	SOIC	D	8	75	RoHS & Green	NIPDAU	Level-1-260C-UNLIM	0 to 70	081BC	
TL081BCDR	ACTIVE	SOIC	D	8	2500	RoHS & Green	NIPDAU	Level-1-260C-UNLIM	0 to 70	081BC	Samples
TL081BCP	ACTIVE	PDIP	P	8	50	RoHS & Green	NIPDAU	N / A for Pkg Type	0 to 70	TL081BCP	Samples
TL081CD	LIFEBUY	SOIC	D	8	75	RoHS & Green	NIPDAU	Level-1-260C-UNLIM	0 to 70	TL081C	
TL081CDR	ACTIVE	SOIC	D	8	2500	RoHS & Green	NIPDAU	Level-1-260C-UNLIM	0 to 70	TL081C	Samples
TL081CP	ACTIVE	PDIP	P	8	50	RoHS & Green	NIPDAU	N / A for Pkg Type	0 to 70	TL081CP	Samples
TL081CPE4	ACTIVE	PDIP	P	8	50	RoHS & Green	NIPDAU	N / A for Pkg Type	0 to 70	TL081CP	Samples
TL081CPSR	ACTIVE	SO	PS	8	2000	RoHS & Green	NIPDAU	Level-1-260C-UNLIM	0 to 70	T081	Samples
TL081HIDBVR	ACTIVE	SOT-23	DBV	5	3000	RoHS & Green	NIPDAU	Level-1-260C-UNLIM	-40 to 125	T81V	Samples
TL081HIDCKR	ACTIVE	SC70	DCK	5	3000	RoHS & Green	SN	Level-1-260C-UNLIM	-40 to 125	1IP	Samples
TL081HIDR	ACTIVE	SOIC	D	8	3000	RoHS & Green	NIPDAU	Level-1-260C-UNLIM	-40 to 125	TL081D	Samples

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead finish/ Ball material (6)	MSL Peak Temp (3)	Op Temp (°C)	Device Marking (4/5)	Samples
TL081ID	LIFEBUY	SOIC	D	8	75	RoHS & Green	NIPDAU	Level-1-260C-UNLIM	-40 to 85	TL081I	
TL081IDR	ACTIVE	SOIC	D	8	2500	RoHS & Green	NIPDAU	Level-1-260C-UNLIM	-40 to 85	TL081I	Samples
TL081IP	ACTIVE	PDIP	P	8	50	RoHS & Green	NIPDAU	N / A for Pkg Type	-40 to 85	TL081IP	Samples
TL082ACD	LIFEBUY	SOIC	D	8	75	RoHS & Green	NIPDAU	Level-1-260C-UNLIM	0 to 70	082AC	
TL082ACDE4	LIFEBUY	SOIC	D	8	75	RoHS & Green	NIPDAU	Level-1-260C-UNLIM	0 to 70	082AC	
TL082ACDG4	LIFEBUY	SOIC	D	8	75	RoHS & Green	NIPDAU	Level-1-260C-UNLIM	0 to 70	082AC	
TL082ACDR	ACTIVE	SOIC	D	8	2500	RoHS & Green	NIPDAU	Level-1-260C-UNLIM	0 to 70	082AC	Samples
TL082ACDRE4	ACTIVE	SOIC	D	8	2500	RoHS & Green	NIPDAU	Level-1-260C-UNLIM	0 to 70	082AC	Samples
TL082ACDRG4	ACTIVE	SOIC	D	8	2500	RoHS & Green	NIPDAU	Level-1-260C-UNLIM	0 to 70	082AC	Samples
TL082ACP	ACTIVE	PDIP	P	8	50	RoHS & Green	NIPDAU	N / A for Pkg Type	0 to 70	TL082ACP	Samples
TL082ACPSR	ACTIVE	SO	PS	8	2000	RoHS & Green	NIPDAU	Level-1-260C-UNLIM	0 to 70	T082A	Samples
TL082BCD	ACTIVE	SOIC	D	8	75	RoHS & Green	NIPDAU	Level-1-260C-UNLIM	0 to 70	082BC	Samples
TL082BCDE4	ACTIVE	SOIC	D	8	75	RoHS & Green	NIPDAU	Level-1-260C-UNLIM	0 to 70	082BC	Samples
TL082BCDR	ACTIVE	SOIC	D	8	2500	RoHS & Green	NIPDAU	Level-1-260C-UNLIM	0 to 70	082BC	Samples
TL082BCP	ACTIVE	PDIP	P	8	50	RoHS & Green	NIPDAU	N / A for Pkg Type	0 to 70	TL082BCP	Samples
TL082BCPE4	ACTIVE	PDIP	P	8	50	RoHS & Green	NIPDAU	N / A for Pkg Type	0 to 70	TL082BCP	Samples
TL082CD	LIFEBUY	SOIC	D	8	75	RoHS & Green	NIPDAU	Level-1-260C-UNLIM	0 to 70	TL082C	
TL082CDE4	LIFEBUY	SOIC	D	8	75	RoHS & Green	NIPDAU	Level-1-260C-UNLIM	0 to 70	TL082C	
TL082CDR	ACTIVE	SOIC	D	8	2500	RoHS & Green	NIPDAU	Level-1-260C-UNLIM	0 to 70	TL082C	Samples
TL082CDRE4	ACTIVE	SOIC	D	8	2500	RoHS & Green	NIPDAU	Level-1-260C-UNLIM	0 to 70	TL082C	Samples
TL082CDRG4	ACTIVE	SOIC	D	8	2500	RoHS & Green	NIPDAU	Level-1-260C-UNLIM	0 to 70	TL082C	Samples
TL082CP	ACTIVE	PDIP	P	8	50	RoHS & Green	NIPDAU	N / A for Pkg Type	0 to 70	TL082CP	Samples
TL082CPSR	ACTIVE	SO	PS	8	2000	RoHS & Green	NIPDAU	Level-1-260C-UNLIM	0 to 70	T082	Samples

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead finish/ Ball material (6)	MSL Peak Temp (3)	Op Temp (°C)	Device Marking (4/5)	Samples
TL082CPSRG4	ACTIVE	SO	PS	8	2000	RoHS & Green	NIPDAU	Level-1-260C-UNLIM	0 to 70	T082	Samples
TL082CPW	LIFEBUY	TSSOP	PW	8	150	RoHS & Green	NIPDAU	Level-1-260C-UNLIM	0 to 70	T082	
TL082CPWR	ACTIVE	TSSOP	PW	8	2000	RoHS & Green	NIPDAU	Level-1-260C-UNLIM	0 to 70	T082	Samples
TL082CPWRG4	ACTIVE	TSSOP	PW	8	2000	RoHS & Green	NIPDAU	Level-1-260C-UNLIM	0 to 70	T082	Samples
TL082HIDDFR	ACTIVE	SOT-23-THIN	DDF	8	3000	RoHS & Green	NIPDAU	Level-1-260C-UNLIM	-40 to 125	082F	Samples
TL082HIDR	ACTIVE	SOIC	D	8	3000	RoHS & Green	NIPDAU	Level-1-260C-UNLIM	-40 to 125	TL082D	Samples
TL082HIPWR	ACTIVE	TSSOP	PW	8	3000	RoHS & Green	NIPDAU	Level-1-260C-UNLIM	-40 to 125	082HPW	Samples
TL082ID	LIFEBUY	SOIC	D	8	75	RoHS & Green	NIPDAU	Level-1-260C-UNLIM	-40 to 85	TL082I	
TL082IDG4	LIFEBUY	SOIC	D	8	75	RoHS & Green	NIPDAU	Level-1-260C-UNLIM	-40 to 85	TL082I	
TL082IDR	ACTIVE	SOIC	D	8	2500	RoHS & Green	NIPDAU	Level-1-260C-UNLIM	-40 to 85	TL082I	Samples
TL082IDRE4	ACTIVE	SOIC	D	8	2500	RoHS & Green	NIPDAU	Level-1-260C-UNLIM	-40 to 85	TL082I	Samples
TL082IDRG4	ACTIVE	SOIC	D	8	2500	RoHS & Green	NIPDAU	Level-1-260C-UNLIM	-40 to 85	TL082I	Samples
TL082IP	ACTIVE	PDIP	P	8	50	RoHS & Green	NIPDAU	N / A for Pkg Type	-40 to 85	TL082IP	Samples
TL082IPE4	ACTIVE	PDIP	P	8	50	RoHS & Green	NIPDAU	N / A for Pkg Type	-40 to 85	TL082IP	Samples
TL082IPWR	ACTIVE	TSSOP	PW	8	2000	RoHS & Green	NIPDAU	Level-1-260C-UNLIM	-40 to 85	Z082	Samples
TL082MFKB	ACTIVE	LCCC	FK	20	1	Non-RoHS & Green	SNPB	N / A for Pkg Type	-55 to 125	5962-9851501Q2A TL082MFKB	Samples
TL082MJG	ACTIVE	CDIP	JG	8	1	Non-RoHS & Green	SNPB	N / A for Pkg Type	-55 to 125	TL082MJG	Samples
TL082MJGB	ACTIVE	CDIP	JG	8	1	Non-RoHS & Green	SNPB	N / A for Pkg Type	-55 to 125	9851501QPA TL082M	Samples
TL084ACD	ACTIVE	SOIC	D	14	50	RoHS & Green	NIPDAU	Level-1-260C-UNLIM	0 to 70	TL084AC	Samples
TL084ACDE4	ACTIVE	SOIC	D	14	50	RoHS & Green	NIPDAU	Level-1-260C-UNLIM	0 to 70	TL084AC	Samples
TL084ACDR	ACTIVE	SOIC	D	14	2500	RoHS & Green	NIPDAU	Level-1-260C-UNLIM	0 to 70	TL084AC	Samples

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead finish/ Ball material (6)	MSL Peak Temp (3)	Op Temp (°C)	Device Marking (4/5)	Samples
TL084ACDRE4	ACTIVE	SOIC	D	14	2500	RoHS & Green	NIPDAU	Level-1-260C-UNLIM	0 to 70	TL084AC	Samples
TL084ACDRG4	ACTIVE	SOIC	D	14	2500	RoHS & Green	NIPDAU	Level-1-260C-UNLIM	0 to 70	TL084AC	Samples
TL084ACN	ACTIVE	PDIP	N	14	25	RoHS & Green	NIPDAU	N / A for Pkg Type	0 to 70	TL084ACN	Samples
TL084ACNSR	ACTIVE	SO	NS	14	2000	RoHS & Green	NIPDAU	Level-1-260C-UNLIM	0 to 70	TL084A	Samples
TL084BCD	ACTIVE	SOIC	D	14	50	RoHS & Green	NIPDAU	Level-1-260C-UNLIM	0 to 70	TL084BC	Samples
TL084BCDR	ACTIVE	SOIC	D	14	2500	RoHS & Green	NIPDAU	Level-1-260C-UNLIM	0 to 70	TL084BC	Samples
TL084BCDRG4	ACTIVE	SOIC	D	14	2500	RoHS & Green	NIPDAU	Level-1-260C-UNLIM	0 to 70	TL084BC	Samples
TL084BCN	ACTIVE	PDIP	N	14	25	RoHS & Green	NIPDAU	N / A for Pkg Type	0 to 70	TL084BCN	Samples
TL084BCNE4	ACTIVE	PDIP	N	14	25	RoHS & Green	NIPDAU	N / A for Pkg Type	0 to 70	TL084BCN	Samples
TL084CD	ACTIVE	SOIC	D	14	50	RoHS & Green	NIPDAU	Level-1-260C-UNLIM	0 to 70	TL084C	Samples
TL084CDE4	ACTIVE	SOIC	D	14	50	RoHS & Green	NIPDAU	Level-1-260C-UNLIM	0 to 70	TL084C	Samples
TL084CDG4	ACTIVE	SOIC	D	14	50	RoHS & Green	NIPDAU	Level-1-260C-UNLIM	0 to 70	TL084C	Samples
TL084CDR	ACTIVE	SOIC	D	14	2500	RoHS & Green	NIPDAU	Level-1-260C-UNLIM	0 to 70	TL084C	Samples
TL084CDRG4	ACTIVE	SOIC	D	14	2500	RoHS & Green	NIPDAU	Level-1-260C-UNLIM	0 to 70	TL084C	Samples
TL084CN	ACTIVE	PDIP	N	14	25	RoHS & Green	NIPDAU	N / A for Pkg Type	0 to 70	TL084CN	Samples
TL084CNE4	ACTIVE	PDIP	N	14	25	RoHS & Green	NIPDAU	N / A for Pkg Type	0 to 70	TL084CN	Samples
TL084CNSR	ACTIVE	SO	NS	14	2000	RoHS & Green	NIPDAU	Level-1-260C-UNLIM	0 to 70	TL084	Samples
TL084CPW	ACTIVE	TSSOP	PW	14	90	RoHS & Green	NIPDAU	Level-1-260C-UNLIM	0 to 70	T084	Samples
TL084CPWE4	ACTIVE	TSSOP	PW	14	90	RoHS & Green	NIPDAU	Level-1-260C-UNLIM	0 to 70	T084	Samples
TL084CPWR	ACTIVE	TSSOP	PW	14	2000	RoHS & Green	NIPDAU	Level-1-260C-UNLIM	0 to 70	T084	Samples
TL084HIDR	ACTIVE	SOIC	D	14	2500	RoHS & Green	NIPDAU	Level-1-260C-UNLIM	-40 to 125	TL084HID	Samples

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead finish/ Ball material (6)	MSL Peak Temp (3)	Op Temp (°C)	Device Marking (4/5)	Samples
TL084HIDYYR	ACTIVE	SOT-23-THIN	DYY	14	3000	RoHS & Green	NIPDAU	Level-1-260C-UNLIM	-40 to 125	T084HDYY	Samples
TL084HIPWR	ACTIVE	TSSOP	PW	14	2000	RoHS & Green	NIPDAU	Level-1-260C-UNLIM	-40 to 125	TL084PW	Samples
TL084ID	ACTIVE	SOIC	D	14	50	RoHS & Green	NIPDAU	Level-1-260C-UNLIM	-40 to 85	TL084I	Samples
TL084IDR	ACTIVE	SOIC	D	14	2500	RoHS & Green	NIPDAU	Level-1-260C-UNLIM	-40 to 85	TL084I	Samples
TL084IDRE4	ACTIVE	SOIC	D	14	2500	RoHS & Green	NIPDAU	Level-1-260C-UNLIM	-40 to 85	TL084I	Samples
TL084IDRG4	ACTIVE	SOIC	D	14	2500	RoHS & Green	NIPDAU	Level-1-260C-UNLIM	-40 to 85	TL084I	Samples
TL084IN	ACTIVE	PDIP	N	14	25	RoHS & Green	NIPDAU	N / A for Pkg Type	-40 to 85	TL084IN	Samples
TL084INE4	ACTIVE	PDIP	N	14	25	RoHS & Green	NIPDAU	N / A for Pkg Type	-40 to 85	TL084IN	Samples
TL084MFK	ACTIVE	LCCC	FK	20	1	Non-RoHS & Green	SNPB	N / A for Pkg Type	-55 to 125	TL084MFK	Samples
TL084MFKB	ACTIVE	LCCC	FK	20	1	Non-RoHS & Green	SNPB	N / A for Pkg Type	-55 to 125	5962-9851503Q2A TL084 MFKB	Samples
TL084MJ	ACTIVE	CDIP	J	14	1	Non-RoHS & Green	SNPB	N / A for Pkg Type	-55 to 125	TL084MJ	Samples
TL084MJB	ACTIVE	CDIP	J	14	1	Non-RoHS & Green	SNPB	N / A for Pkg Type	-55 to 125	5962-9851503QC A TL084MJB	Samples
TL084QD	ACTIVE	SOIC	D	14	50	RoHS & Green	NIPDAU	Level-1-260C-UNLIM	-40 to 125	TL084Q	Samples
TL084QDG4	ACTIVE	SOIC	D	14	50	RoHS & Green	NIPDAU	Level-1-260C-UNLIM	-40 to 125	TL084Q	Samples
TL084QDR	ACTIVE	SOIC	D	14	2500	RoHS & Green	NIPDAU	Level-1-260C-UNLIM	-40 to 125	TL084Q	Samples
TL084QDRG4	ACTIVE	SOIC	D	14	2500	RoHS & Green	NIPDAU	Level-1-260C-UNLIM	-40 to 125	TL084Q	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) **RoHS:** TI defines "RoHS" to mean semiconductor products that are compliant with the current EU RoHS requirements for all 10 RoHS substances, including the requirement that RoHS substance do not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, "RoHS" products are suitable for use in specified lead-free processes. TI may reference these types of products as "Pb-Free".
RoHS Exempt: TI defines "RoHS Exempt" to mean products that contain lead but are compliant with EU RoHS pursuant to a specific EU RoHS exemption.
Green: TI defines "Green" to mean the content of Chlorine (Cl) and Bromine (Br) based flame retardants meet JS709B low halogen requirements of <=1000ppm threshold. Antimony trioxide based flame retardants must also meet the <=1000ppm threshold requirement.

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

(4) There may be additional marking, which relates to the logo, the lot trace code information, or the environmental category on the device.

(5) Multiple Device Markings will be inside parentheses. Only one Device Marking contained in parentheses and separated by a "~" will appear on a device. If a line is indented then it is a continuation of the previous line and the two combined represent the entire Device Marking for that device.

(6) Lead finish/Ball material - Orderable Devices may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead finish/Ball material values may wrap to two lines if the finish value exceeds the maximum column width.

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 TL082, TL082M, TL084, TL084M :

- Catalog : TL082, TL084
- Automotive : TL082-Q1, TL082-Q1
- Military : TL082M, TL084M

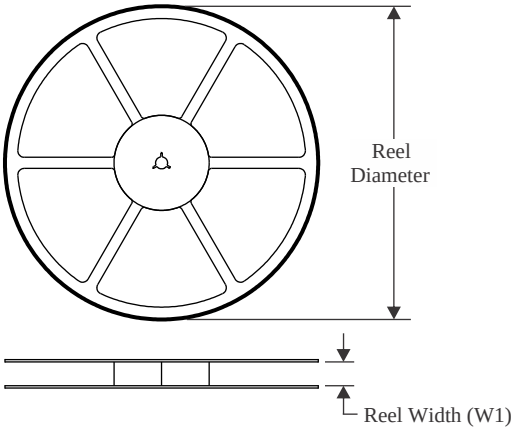
NOTE: Qualified Version Definitions:

- Catalog - TI's standard catalog product

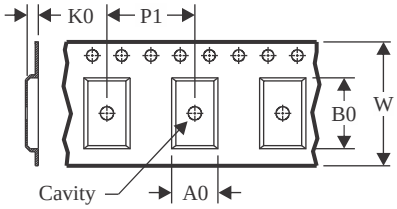
- Automotive - Q100 devices qualified for high-reliability automotive applications targeting zero defects
- Military - QML certified for Military and Defense Applications

TAPE AND REEL INFORMATION

REEL DIMENSIONS

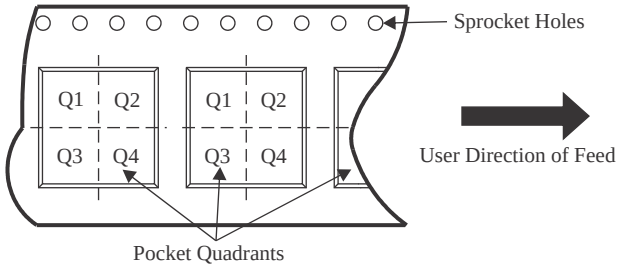


TAPE DIMENSIONS



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

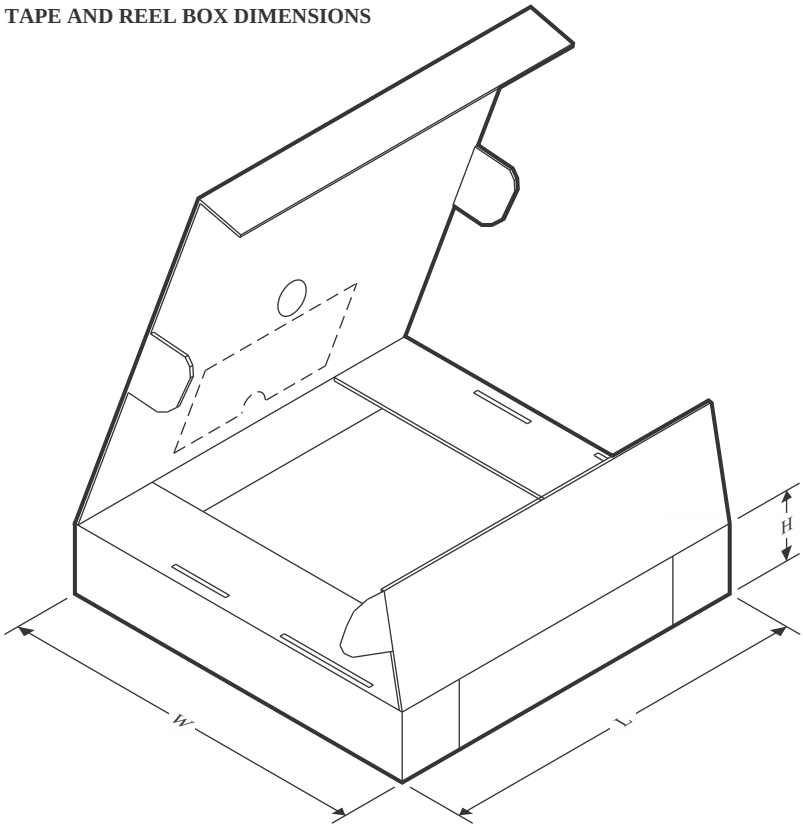


*All dimensions are nominal

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
TL081ACDR	SOIC	D	8	2500	330.0	12.4	6.4	5.2	2.1	8.0	12.0	Q1
TL081BCDR	SOIC	D	8	2500	330.0	12.4	6.4	5.2	2.1	8.0	12.0	Q1
TL081CDR	SOIC	D	8	2500	330.0	12.4	6.4	5.2	2.1	8.0	12.0	Q1
TL081CPSR	SO	PS	8	2000	330.0	16.4	8.35	6.6	2.4	12.0	16.0	Q1
TL081HIDBVR	SOT-23	DBV	5	3000	180.0	8.4	3.2	3.2	1.4	4.0	8.0	Q3
TL081HIDCKR	SC70	DCK	5	3000	178.0	9.0	2.4	2.5	1.2	4.0	8.0	Q3
TL081HIDR	SOIC	D	8	3000	330.0	12.4	6.4	5.2	2.1	8.0	12.0	Q1
TL081IDR	SOIC	D	8	2500	330.0	12.4	6.4	5.2	2.1	8.0	12.0	Q1
TL082ACDR	SOIC	D	8	2500	330.0	12.4	6.4	5.2	2.1	8.0	12.0	Q1
TL082ACDR	SOIC	D	8	2500	330.0	12.4	6.4	5.2	2.1	8.0	12.0	Q1
TL082ACPSR	SO	PS	8	2000	330.0	16.4	8.35	6.6	2.4	12.0	16.0	Q1
TL082BCDR	SOIC	D	8	2500	330.0	12.4	6.4	5.2	2.1	8.0	12.0	Q1
TL082CDR	SOIC	D	8	2500	330.0	12.4	6.4	5.2	2.1	8.0	12.0	Q1
TL082CDR	SOIC	D	8	2500	330.0	12.4	6.4	5.2	2.1	8.0	12.0	Q1
TL082CPSR	SO	PS	8	2000	330.0	16.4	8.35	6.6	2.4	12.0	16.0	Q1
TL082CPWR	TSSOP	PW	8	2000	330.0	12.4	7.0	3.6	1.6	8.0	12.0	Q1

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
TL082HIDDFR	SOT-23-THIN	DDF	8	3000	180.0	8.4	3.2	3.2	1.4	4.0	8.0	Q3
TL082HIDR	SOIC	D	8	3000	330.0	12.4	6.4	5.2	2.1	8.0	12.0	Q1
TL082HIPWR	TSSOP	PW	8	3000	330.0	12.4	7.0	3.6	1.6	8.0	12.0	Q1
TL082IDR	SOIC	D	8	2500	330.0	12.4	6.4	5.2	2.1	8.0	12.0	Q1
TL082IDR	SOIC	D	8	2500	330.0	12.4	6.4	5.2	2.1	8.0	12.0	Q1
TL082IPWR	TSSOP	PW	8	2000	330.0	12.4	7.0	3.6	1.6	8.0	12.0	Q1
TL084ACDR	SOIC	D	14	2500	330.0	16.4	6.5	9.0	2.1	8.0	16.0	Q1
TL084ACDR	SOIC	D	14	2500	330.0	16.4	6.5	9.0	2.1	8.0	16.0	Q1
TL084ACNSR	SO	NS	14	2000	330.0	16.4	8.2	10.5	2.5	12.0	16.0	Q1
TL084BCDR	SOIC	D	14	2500	330.0	16.4	6.5	9.0	2.1	8.0	16.0	Q1
TL084CDR	SOIC	D	14	2500	330.0	16.4	6.5	9.0	2.1	8.0	16.0	Q1
TL084CDR	SOIC	D	14	2500	330.0	16.4	6.5	9.0	2.1	8.0	16.0	Q1
TL084CDRG4	SOIC	D	14	2500	330.0	16.4	6.5	9.0	2.1	8.0	16.0	Q1
TL084CNSR	SO	NS	14	2000	330.0	16.4	8.2	10.5	2.5	12.0	16.0	Q1
TL084CPWR	TSSOP	PW	14	2000	330.0	12.4	6.9	5.6	1.6	8.0	12.0	Q1
TL084HIDR	SOIC	D	14	2500	330.0	16.4	6.5	9.0	2.1	8.0	16.0	Q1
TL084HIDYYR	SOT-23-THIN	DYY	14	3000	330.0	12.4	4.8	3.6	1.6	8.0	12.0	Q3
TL084HIPWR	TSSOP	PW	14	2000	330.0	12.4	6.9	5.6	1.6	8.0	12.0	Q1
TL084IDR	SOIC	D	14	2500	330.0	16.4	6.5	9.0	2.1	8.0	16.0	Q1
TL084QDR	SOIC	D	14	2500	330.0	16.4	6.5	9.0	2.1	8.0	16.0	Q1
TL084QDRG4	SOIC	D	14	2500	330.0	16.4	6.5	9.0	2.1	8.0	16.0	Q1

TAPE AND REEL BOX DIMENSIONS

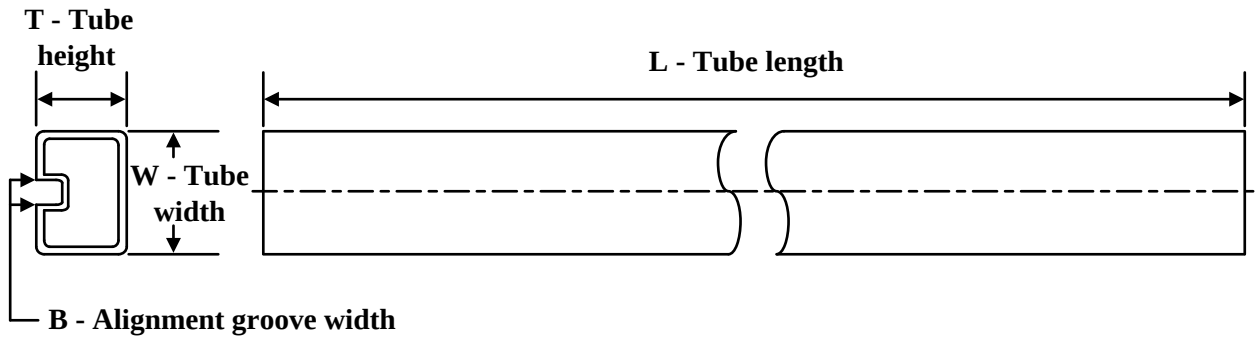


*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
TL081ACDR	SOIC	D	8	2500	340.5	336.1	25.0
TL081BCDR	SOIC	D	8	2500	340.5	336.1	25.0
TL081CDR	SOIC	D	8	2500	340.5	336.1	25.0
TL081CPSR	SO	PS	8	2000	356.0	356.0	35.0
TL081HIDBVR	SOT-23	DBV	5	3000	210.0	185.0	35.0
TL081HIDCKR	SC70	DCK	5	3000	190.0	190.0	30.0
TL081HIDR	SOIC	D	8	3000	356.0	356.0	35.0
TL081IDR	SOIC	D	8	2500	340.5	336.1	25.0
TL082ACDR	SOIC	D	8	2500	340.5	336.1	25.0
TL082ACDR	SOIC	D	8	2500	356.0	356.0	35.0
TL082ACPSR	SO	PS	8	2000	356.0	356.0	35.0
TL082BCDR	SOIC	D	8	2500	340.5	336.1	25.0
TL082CDR	SOIC	D	8	2500	356.0	356.0	35.0
TL082CDR	SOIC	D	8	2500	340.5	336.1	25.0
TL082CPSR	SO	PS	8	2000	356.0	356.0	35.0
TL082CPWR	TSSOP	PW	8	2000	356.0	356.0	35.0
TL082HIDDFR	SOT-23-THIN	DDF	8	3000	210.0	185.0	35.0
TL082HIDR	SOIC	D	8	3000	356.0	356.0	35.0

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
TL082HIPWR	TSSOP	PW	8	3000	356.0	356.0	35.0
TL082IDR	SOIC	D	8	2500	340.5	336.1	25.0
TL082IDR	SOIC	D	8	2500	356.0	356.0	35.0
TL082IPWR	TSSOP	PW	8	2000	356.0	356.0	35.0
TL084ACDR	SOIC	D	14	2500	356.0	356.0	35.0
TL084ACDR	SOIC	D	14	2500	340.5	336.1	32.0
TL084ACNSR	SO	NS	14	2000	356.0	356.0	35.0
TL084BCDR	SOIC	D	14	2500	340.5	336.1	32.0
TL084CDR	SOIC	D	14	2500	356.0	356.0	35.0
TL084CDR	SOIC	D	14	2500	340.5	336.1	32.0
TL084CDRG4	SOIC	D	14	2500	340.5	336.1	32.0
TL084CNSR	SO	NS	14	2000	356.0	356.0	35.0
TL084CPWR	TSSOP	PW	14	2000	356.0	356.0	35.0
TL084HIDR	SOIC	D	14	2500	356.0	356.0	35.0
TL084HIDYYR	SOT-23-THIN	DYY	14	3000	336.6	336.6	31.8
TL084HIPWR	TSSOP	PW	14	2000	356.0	356.0	35.0
TL084IDR	SOIC	D	14	2500	340.5	336.1	32.0
TL084QDR	SOIC	D	14	2500	350.0	350.0	43.0
TL084QDRG4	SOIC	D	14	2500	350.0	350.0	43.0

TUBE



*All dimensions are nominal

Device	Package Name	Package Type	Pins	SPQ	L (mm)	W (mm)	T (µm)	B (mm)
5962-9851501Q2A	FK	LCCC	20	1	506.98	12.06	2030	NA
5962-9851503Q2A	FK	LCCC	20	1	506.98	12.06	2030	NA
TL081ACD	D	SOIC	8	75	507	8	3940	4.32
TL081ACP	P	PDIP	8	50	506	13.97	11230	4.32
TL081BCD	D	SOIC	8	75	507	8	3940	4.32
TL081BCP	P	PDIP	8	50	506	13.97	11230	4.32
TL081CD	D	SOIC	8	75	507	8	3940	4.32
TL081CP	P	PDIP	8	50	506	13.97	11230	4.32
TL081CPE4	P	PDIP	8	50	506	13.97	11230	4.32
TL081ID	D	SOIC	8	75	507	8	3940	4.32
TL081IP	P	PDIP	8	50	506	13.97	11230	4.32
TL082ACD	D	SOIC	8	75	507	8	3940	4.32
TL082ACD	D	SOIC	8	75	506.6	8	3940	4.32
TL082ACDE4	D	SOIC	8	75	506.6	8	3940	4.32
TL082ACDE4	D	SOIC	8	75	507	8	3940	4.32
TL082ACDG4	D	SOIC	8	75	506.6	8	3940	4.32
TL082ACDG4	D	SOIC	8	75	507	8	3940	4.32
TL082ACP	P	PDIP	8	50	506	13.97	11230	4.32
TL082BCD	D	SOIC	8	75	507	8	3940	4.32
TL082BCDE4	D	SOIC	8	75	507	8	3940	4.32
TL082BCP	P	PDIP	8	50	506	13.97	11230	4.32
TL082BCPE4	P	PDIP	8	50	506	13.97	11230	4.32
TL082CD	D	SOIC	8	75	506.6	8	3940	4.32
TL082CD	D	SOIC	8	75	507	8	3940	4.32
TL082CDE4	D	SOIC	8	75	507	8	3940	4.32
TL082CDE4	D	SOIC	8	75	506.6	8	3940	4.32
TL082CP	P	PDIP	8	50	506	13.97	11230	4.32
TL082CPW	PW	TSSOP	8	150	530	10.2	3600	3.5
TL082ID	D	SOIC	8	75	506.6	8	3940	4.32

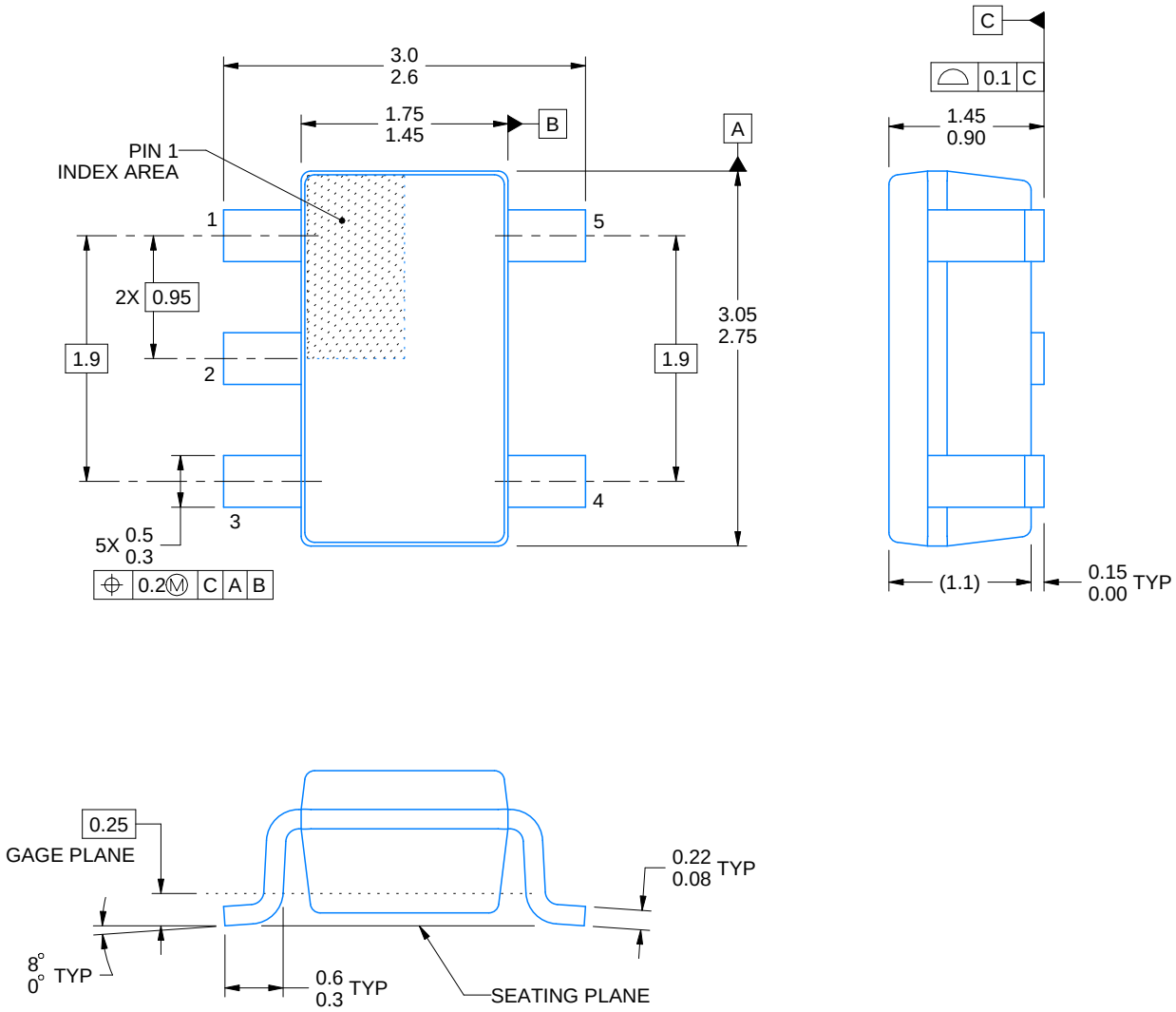
Device	Package Name	Package Type	Pins	SPQ	L (mm)	W (mm)	T (µm)	B (mm)
TL082ID	D	SOIC	8	75	507	8	3940	4.32
TL082IDG4	D	SOIC	8	75	506.6	8	3940	4.32
TL082IDG4	D	SOIC	8	75	507	8	3940	4.32
TL082IP	P	PDIP	8	50	506	13.97	11230	4.32
TL082IPE4	P	PDIP	8	50	506	13.97	11230	4.32
TL082MFKB	FK	LCCC	20	1	506.98	12.06	2030	NA
TL084ACD	D	SOIC	14	50	507	8	3940	4.32
TL084ACD	D	SOIC	14	50	506.6	8	3940	4.32
TL084ACDE4	D	SOIC	14	50	506.6	8	3940	4.32
TL084ACDE4	D	SOIC	14	50	507	8	3940	4.32
TL084ACN	N	PDIP	14	25	506	13.97	11230	4.32
TL084BCD	D	SOIC	14	50	507	8	3940	4.32
TL084BCN	N	PDIP	14	25	506	13.97	11230	4.32
TL084BCNE4	N	PDIP	14	25	506	13.97	11230	4.32
TL084CD	D	SOIC	14	50	507	8	3940	4.32
TL084CD	D	SOIC	14	50	506.6	8	3940	4.32
TL084CDE4	D	SOIC	14	50	506.6	8	3940	4.32
TL084CDE4	D	SOIC	14	50	507	8	3940	4.32
TL084CDG4	D	SOIC	14	50	507	8	3940	4.32
TL084CDG4	D	SOIC	14	50	506.6	8	3940	4.32
TL084CN	N	PDIP	14	25	506	13.97	11230	4.32
TL084CN	N	PDIP	14	25	506	13.97	11230	4.32
TL084CNE4	N	PDIP	14	25	506	13.97	11230	4.32
TL084CNE4	N	PDIP	14	25	506	13.97	11230	4.32
TL084CPW	PW	TSSOP	14	90	530	10.2	3600	3.5
TL084CPWE4	PW	TSSOP	14	90	530	10.2	3600	3.5
TL084ID	D	SOIC	14	50	507	8	3940	4.32
TL084IN	N	PDIP	14	25	506	13.97	11230	4.32
TL084INE4	N	PDIP	14	25	506	13.97	11230	4.32
TL084MFK	FK	LCCC	20	1	506.98	12.06	2030	NA
TL084MFKB	FK	LCCC	20	1	506.98	12.06	2030	NA
TL084QD	D	SOIC	14	50	505.46	6.76	3810	4
TL084QDG4	D	SOIC	14	50	505.46	6.76	3810	4

PACKAGE OUTLINE

DBV0005A

SOT-23 - 1.45 mm max height

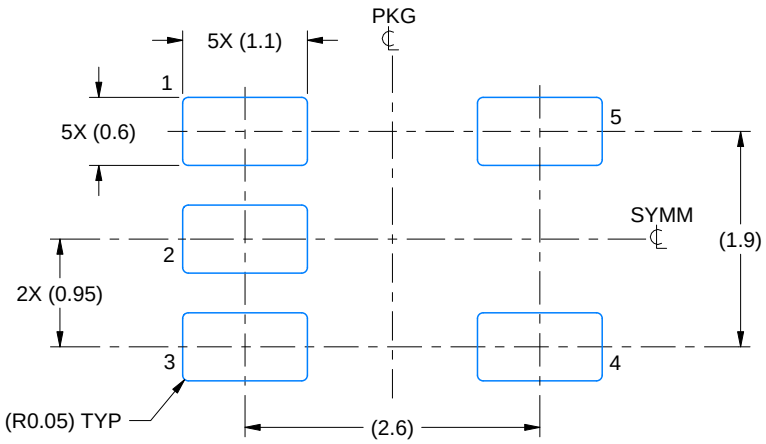
SMALL OUTLINE TRANSISTOR



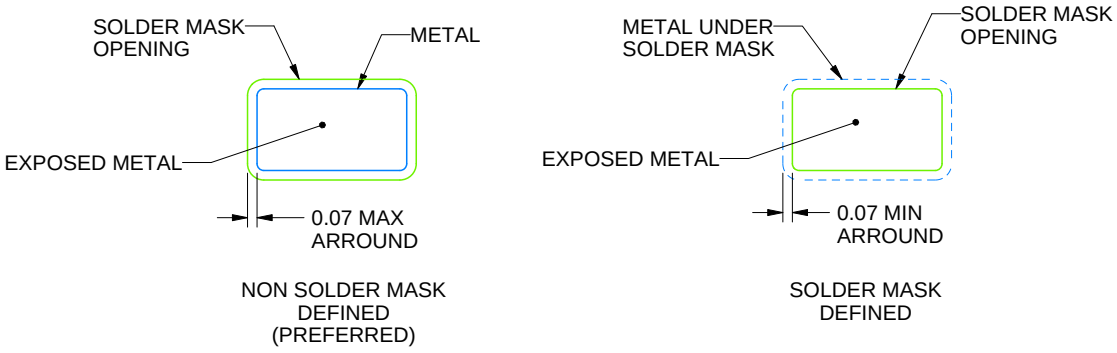
4214839/F 06/2021

NOTES:

1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. Refernce JEDEC MO-178.
4. Body dimensions do not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.25 mm per side.



LAND PATTERN EXAMPLE
EXPOSED METAL SHOWN
SCALE:15X

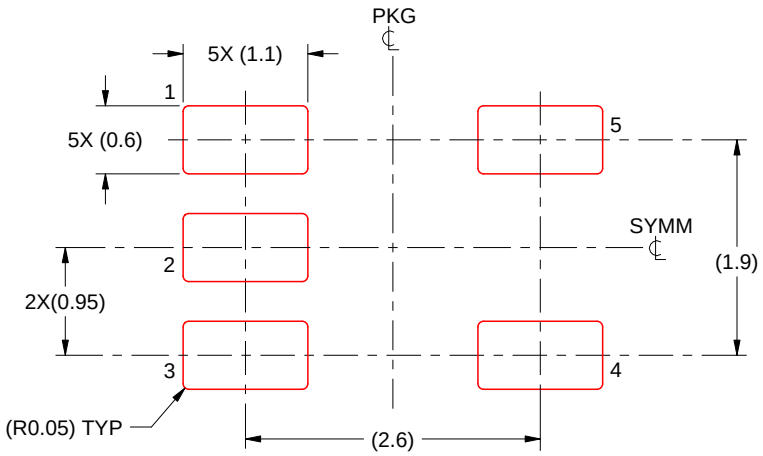


SOLDER MASK DETAILS

4214839/F 06/2021

NOTES: (continued)

5. Publication IPC-7351 may have alternate designs.
6. Solder mask tolerances between and around signal pads can vary based on board fabrication site.



SOLDER PASTE EXAMPLE
BASED ON 0.125 mm THICK STENCIL
SCALE:15X

4214839/F 06/2021

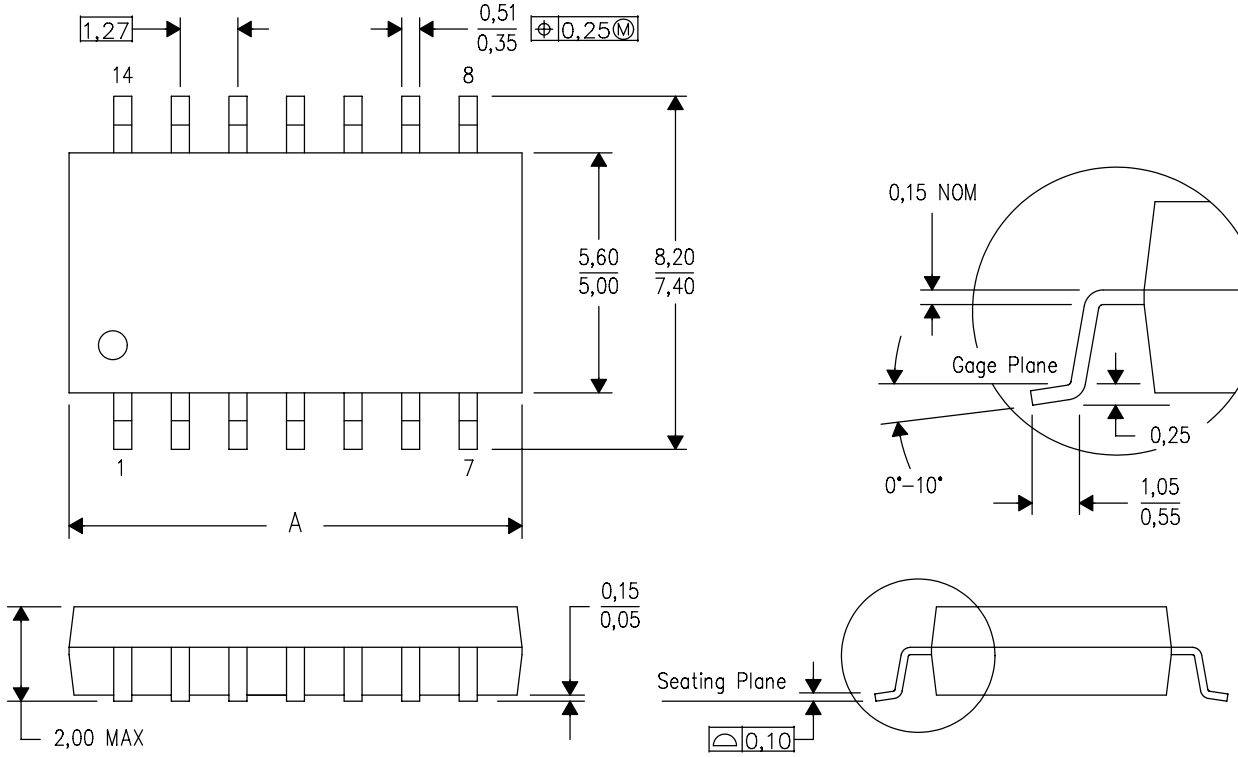
NOTES: (continued)

7. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.
8. Board assembly site may have different recommendations for stencil design.

MECHANICAL DATA

NS (R-PDSO-G)** **PLASTIC SMALL-OUTLINE PACKAGE**

14-PINS SHOWN



DIM \ PINS **	14	16	20	24
A MAX	10,50	10,50	12,90	15,30
A MIN	9,90	9,90	12,30	14,70

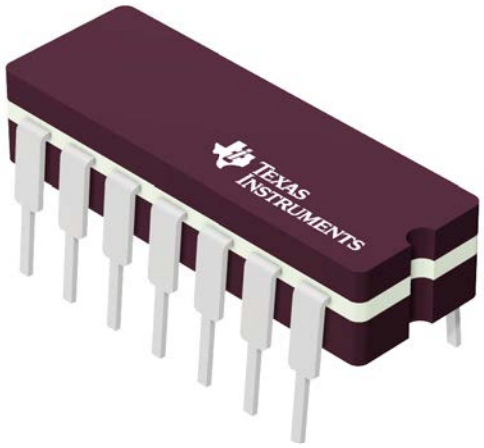
4040062/C 03/03

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.

GENERIC PACKAGE VIEW

J 14 CDIP - 5.08 mm max height

CERAMIC DUAL IN LINE PACKAGE



Images above are just a representation of the package family, actual package may vary.
Refer to the product data sheet for package details.

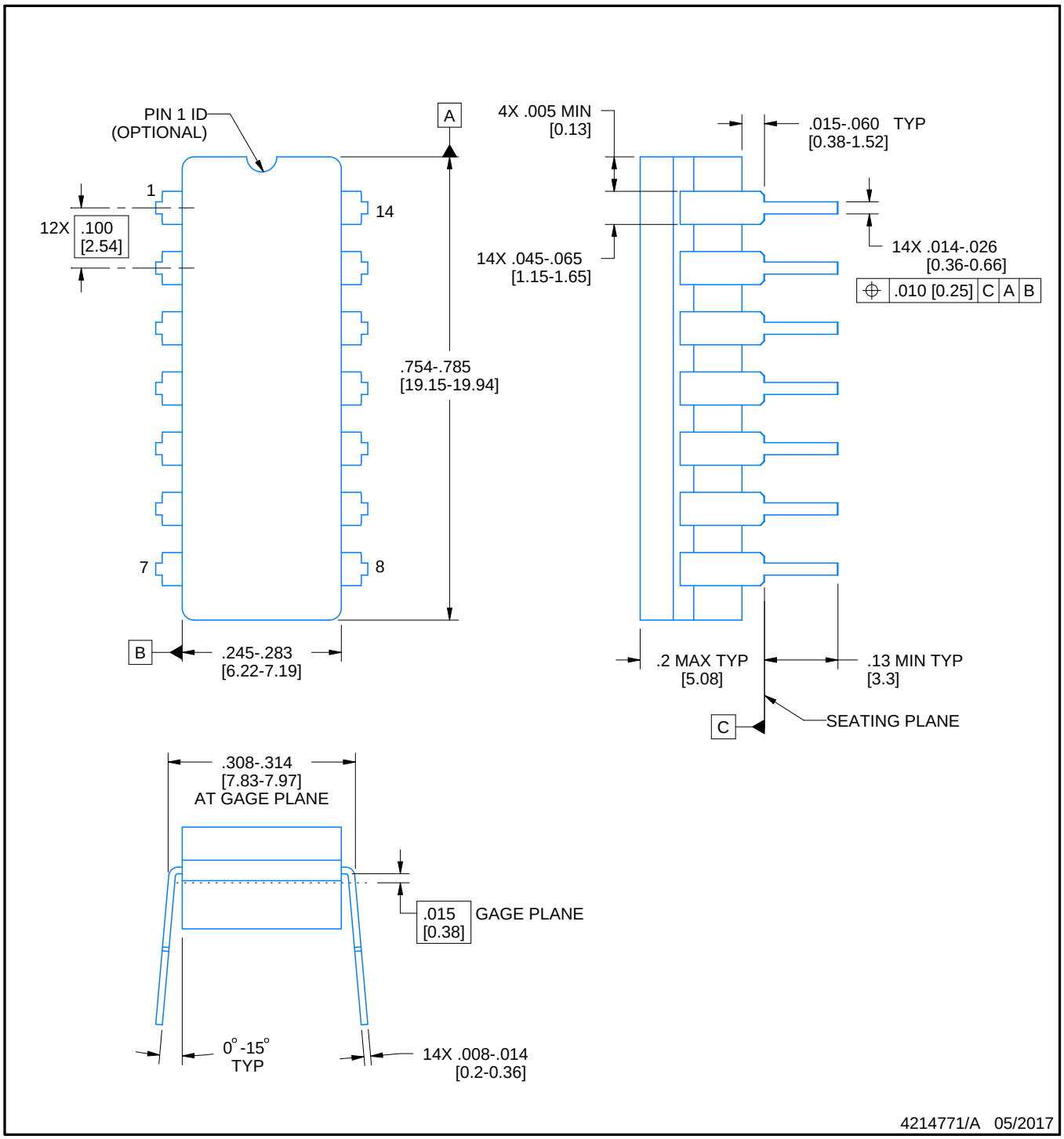
4040083-5/G

PACKAGE OUTLINE

J0014A

CDIP - 5.08 mm max height

CERAMIC DUAL IN LINE PACKAGE



NOTES:

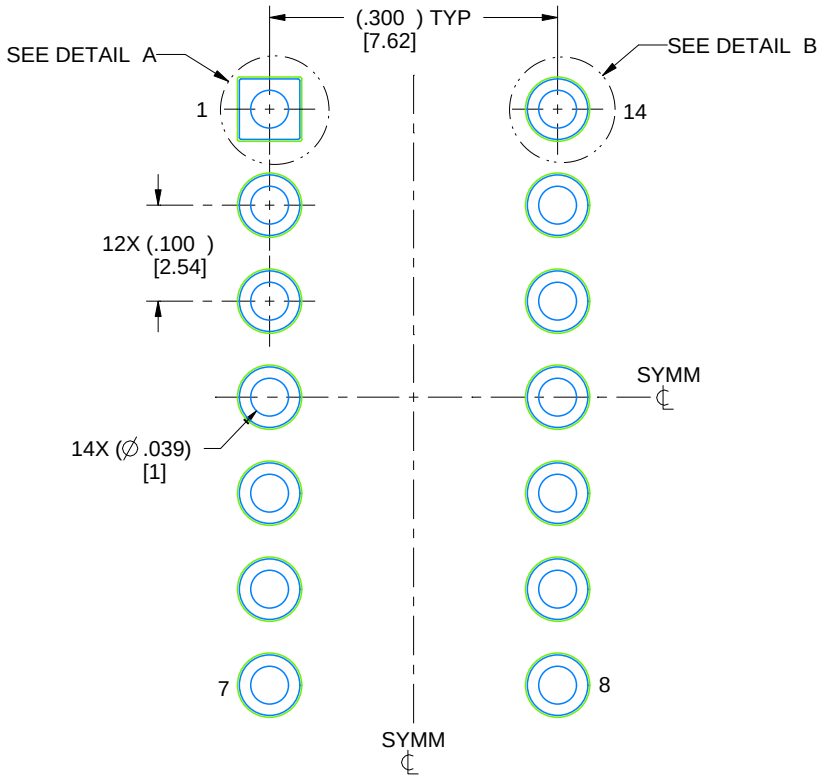
1. All controlling linear dimensions are in inches. Dimensions in brackets are in millimeters. Any dimension in brackets or parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. This package is hermitically sealed with a ceramic lid using glass frit.
4. Index point is provided on cap for terminal identification only and on press ceramic glass frit seal only.
5. Falls within MIL-STD-1835 and GDIP1-T14.

EXAMPLE BOARD LAYOUT

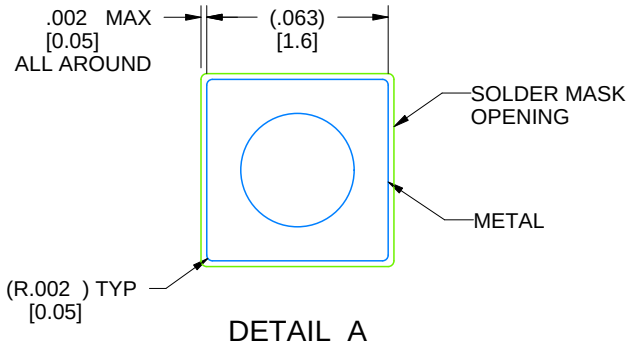
J0014A

CDIP - 5.08 mm max height

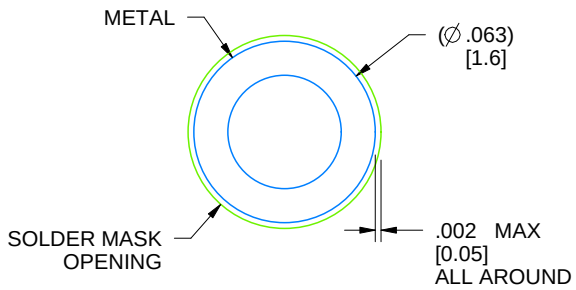
CERAMIC DUAL IN LINE PACKAGE



LAND PATTERN EXAMPLE
NON-SOLDER MASK DEFINED
SCALE: 5X



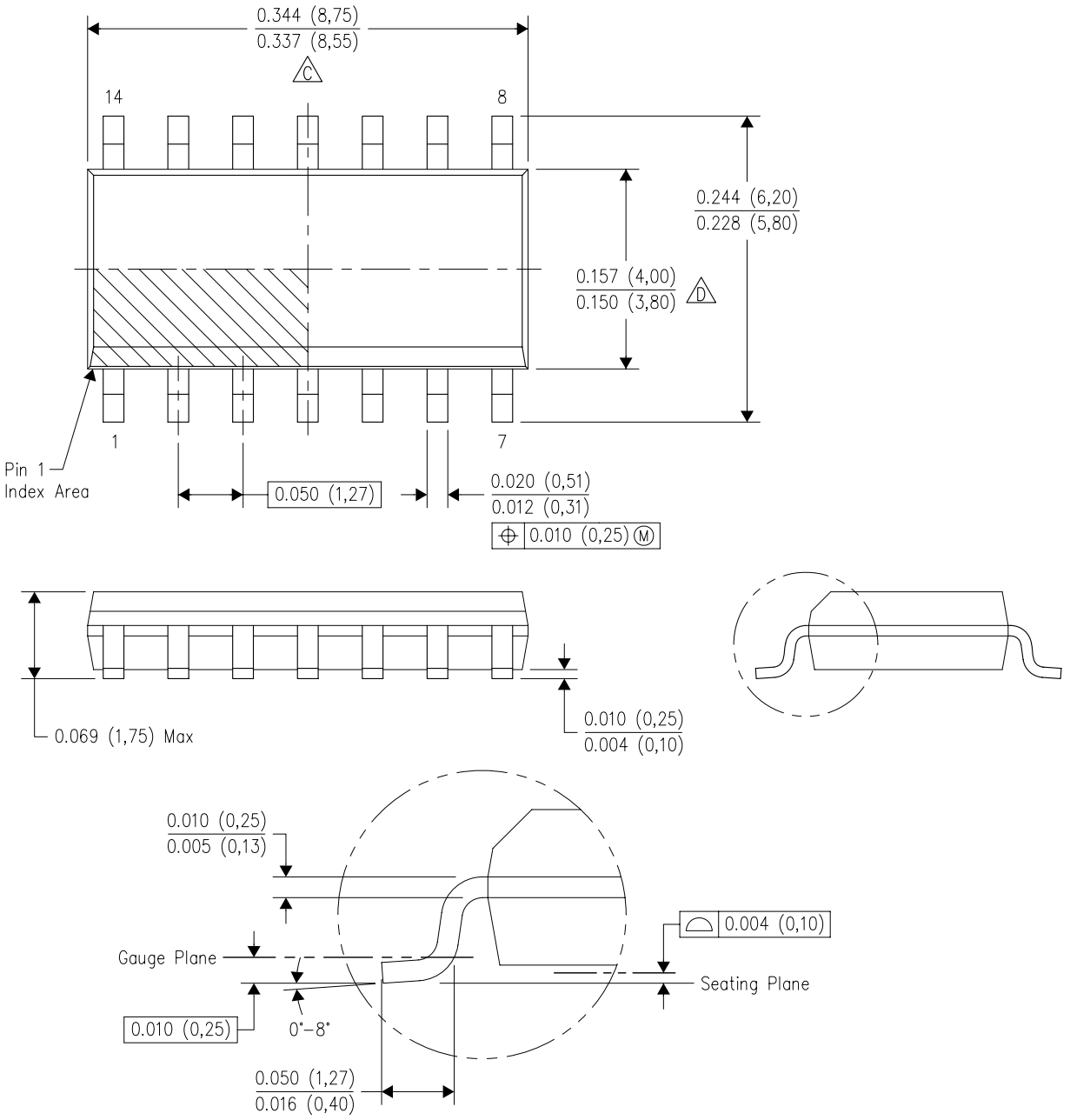
DETAIL A
SCALE: 15X



DETAIL B
13X, SCALE: 15X

4214771/A 05/2017

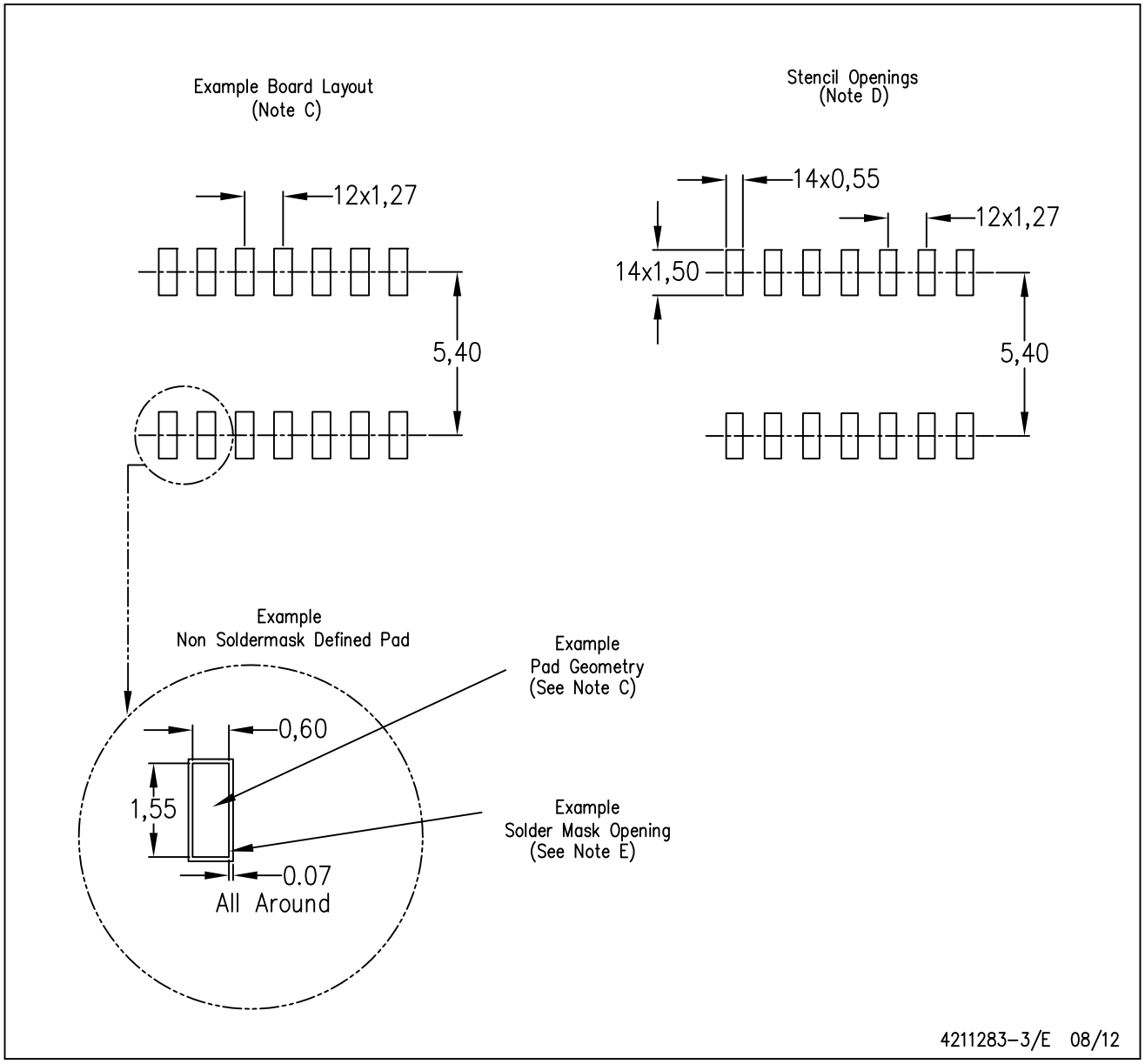
D (R–PDSO–G14) PLASTIC SMALL OUTLINE



4040047–5/M 06/11

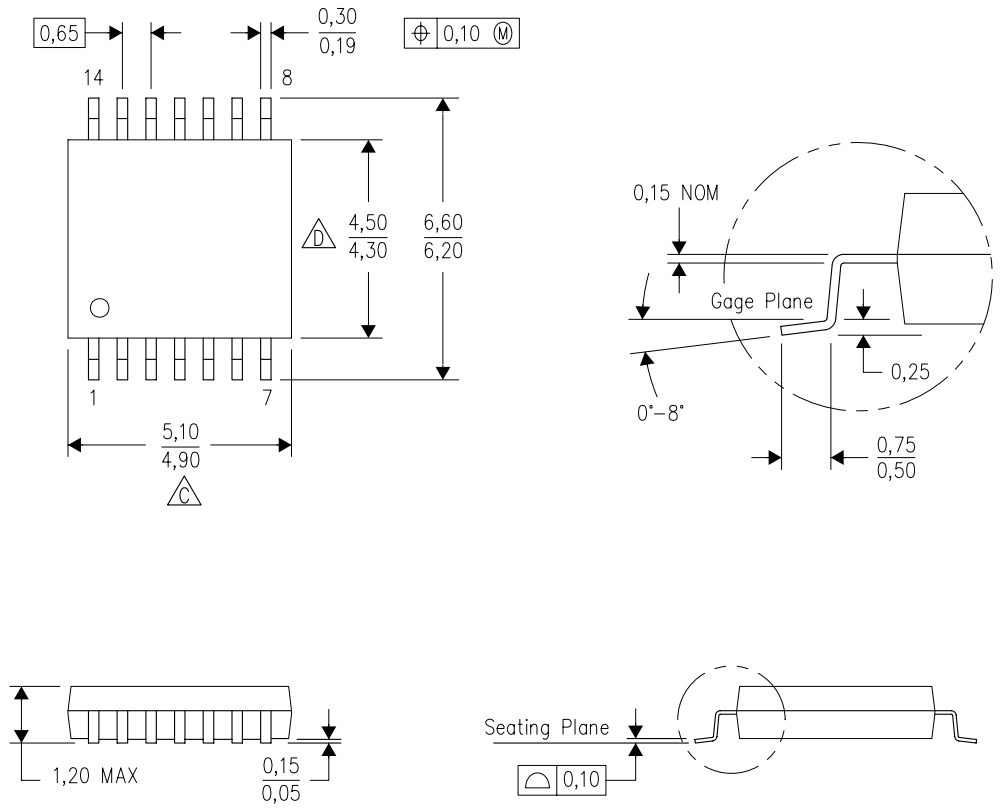
NOTES:
A. All linear dimensions are in inches (millimeters).
B. This drawing is subject to change without notice.
C. Body length does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.006 (0,15) each side.
D. Body width does not include interlead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

D (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.

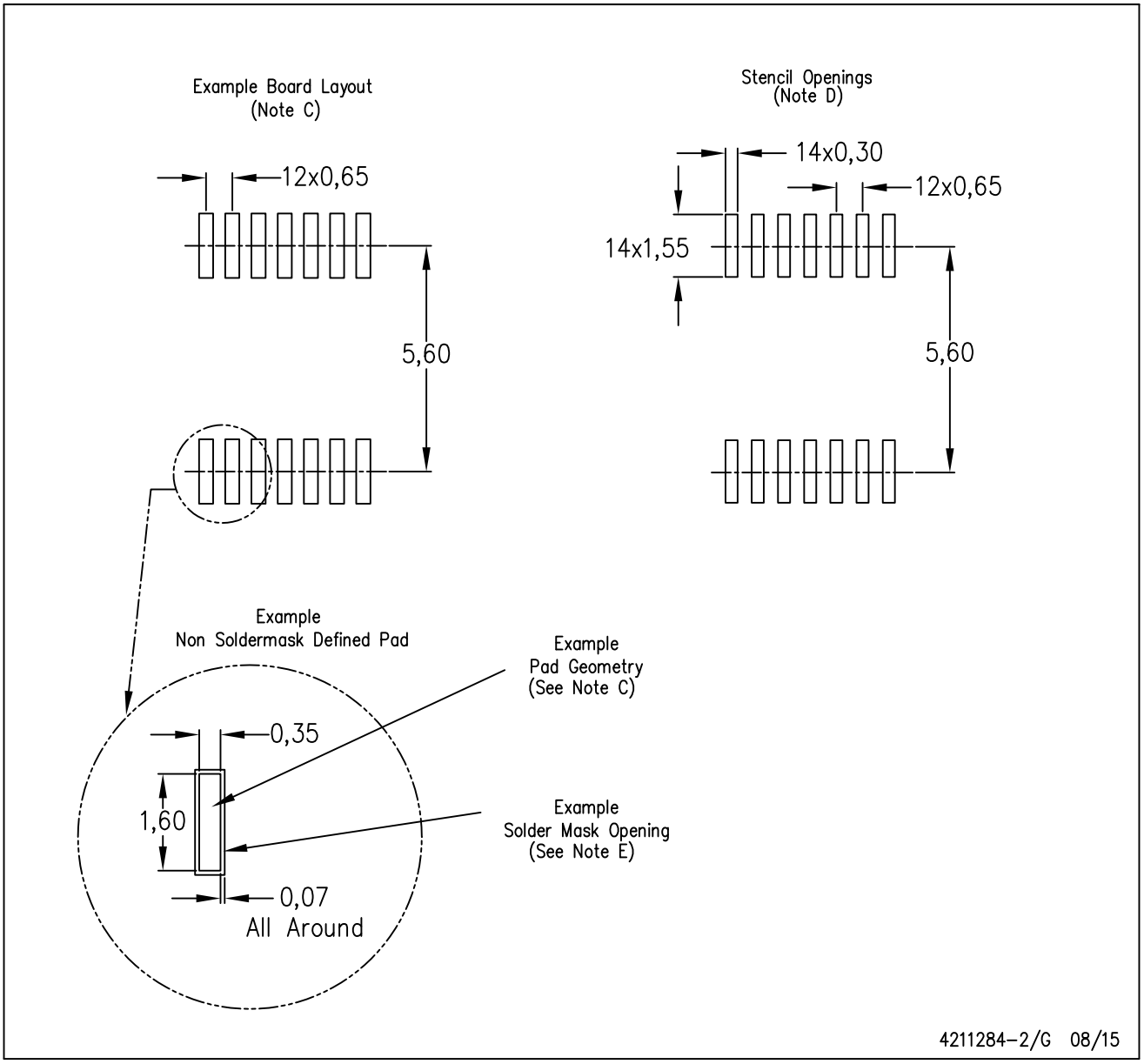
PW (R–PDSO–G14) PLASTIC SMALL OUTLINE



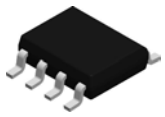
4040064–3/G 02/11

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.

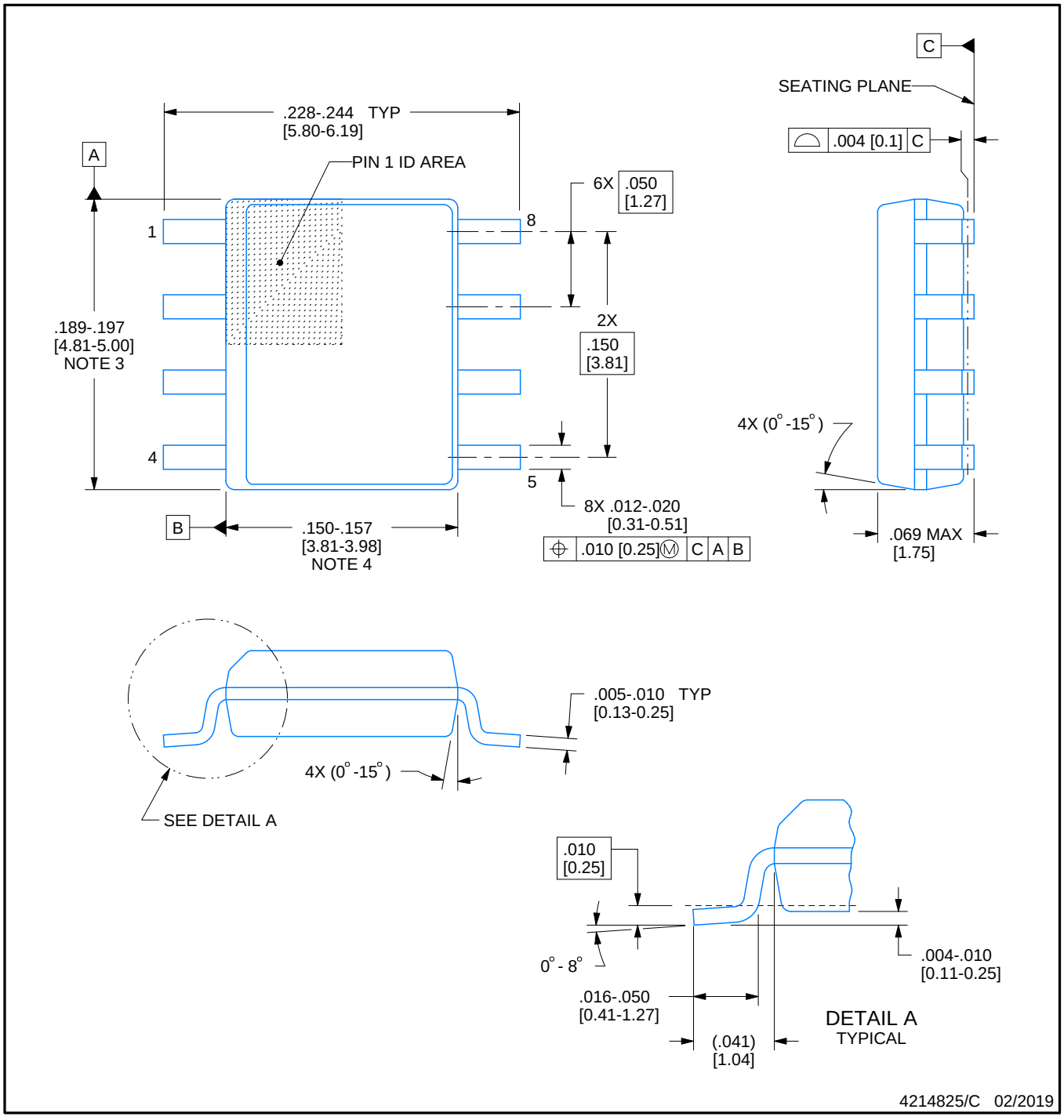


PACKAGE OUTLINE

D0008A

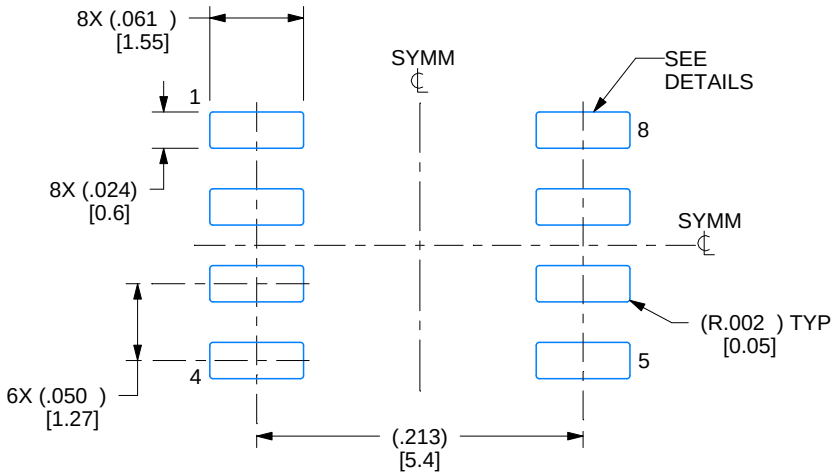
SOIC - 1.75 mm max height

SMALL OUTLINE INTEGRATED CIRCUIT

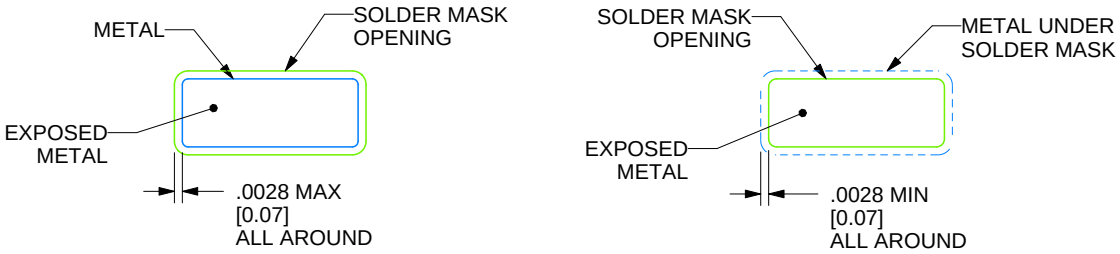


NOTES:

1. Linear dimensions are in inches [millimeters]. Dimensions in parenthesis are for reference only. Controlling dimensions are in inches. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. This dimension does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed .006 [0.15] per side.
4. This dimension does not include interlead flash.
5. Reference JEDEC registration MS-012, variation AA.



LAND PATTERN EXAMPLE
EXPOSED METAL SHOWN
SCALE:8X



SOLDER MASK DETAILS

4214825/C 02/2019

NOTES: (continued)

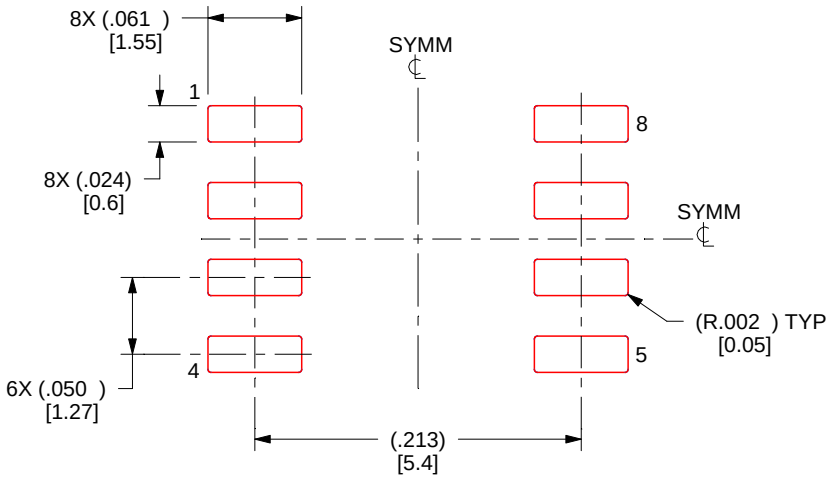
6. Publication IPC-7351 may have alternate designs.
7. Solder mask tolerances between and around signal pads can vary based on board fabrication site.

EXAMPLE STENCIL DESIGN

D0008A

SOIC - 1.75 mm max height

SMALL OUTLINE INTEGRATED CIRCUIT



SOLDER PASTE EXAMPLE
BASED ON .005 INCH [0.125 MM] THICK STENCIL
SCALE:8X

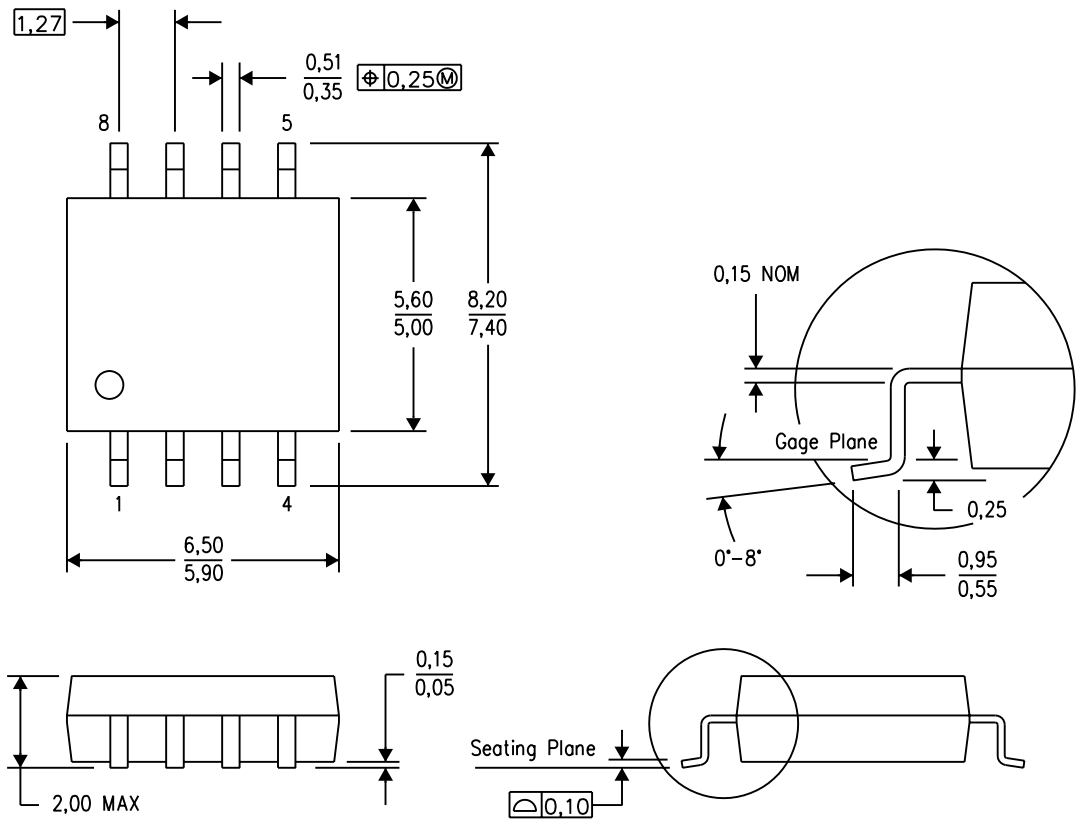
4214825/C 02/2019

NOTES: (continued)

8. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.
9. Board assembly site may have different recommendations for stencil design.

MECHANICAL DATA

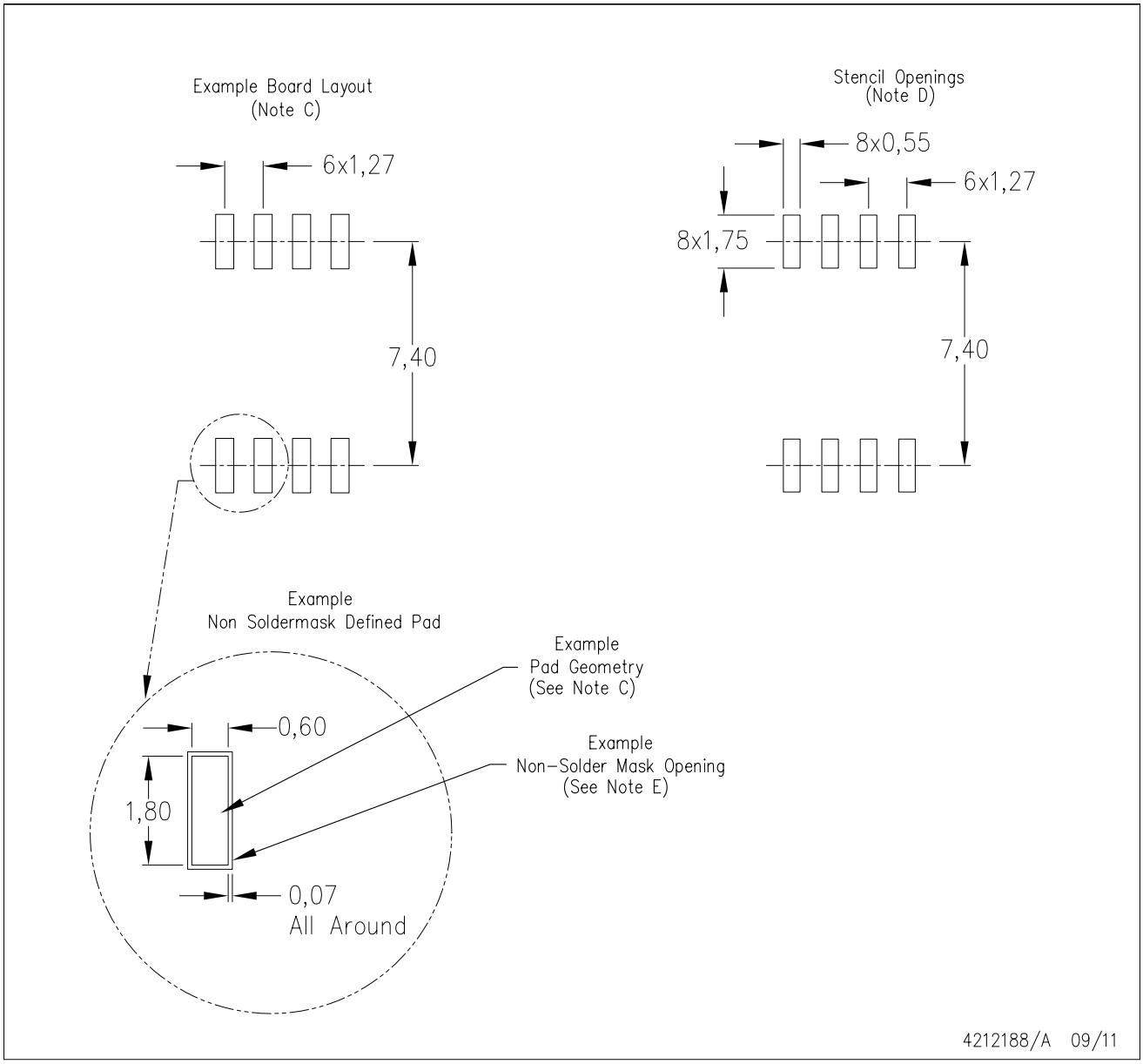
PS (R-PDSO-G8) **PLASTIC SMALL-OUTLINE PACKAGE**



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.

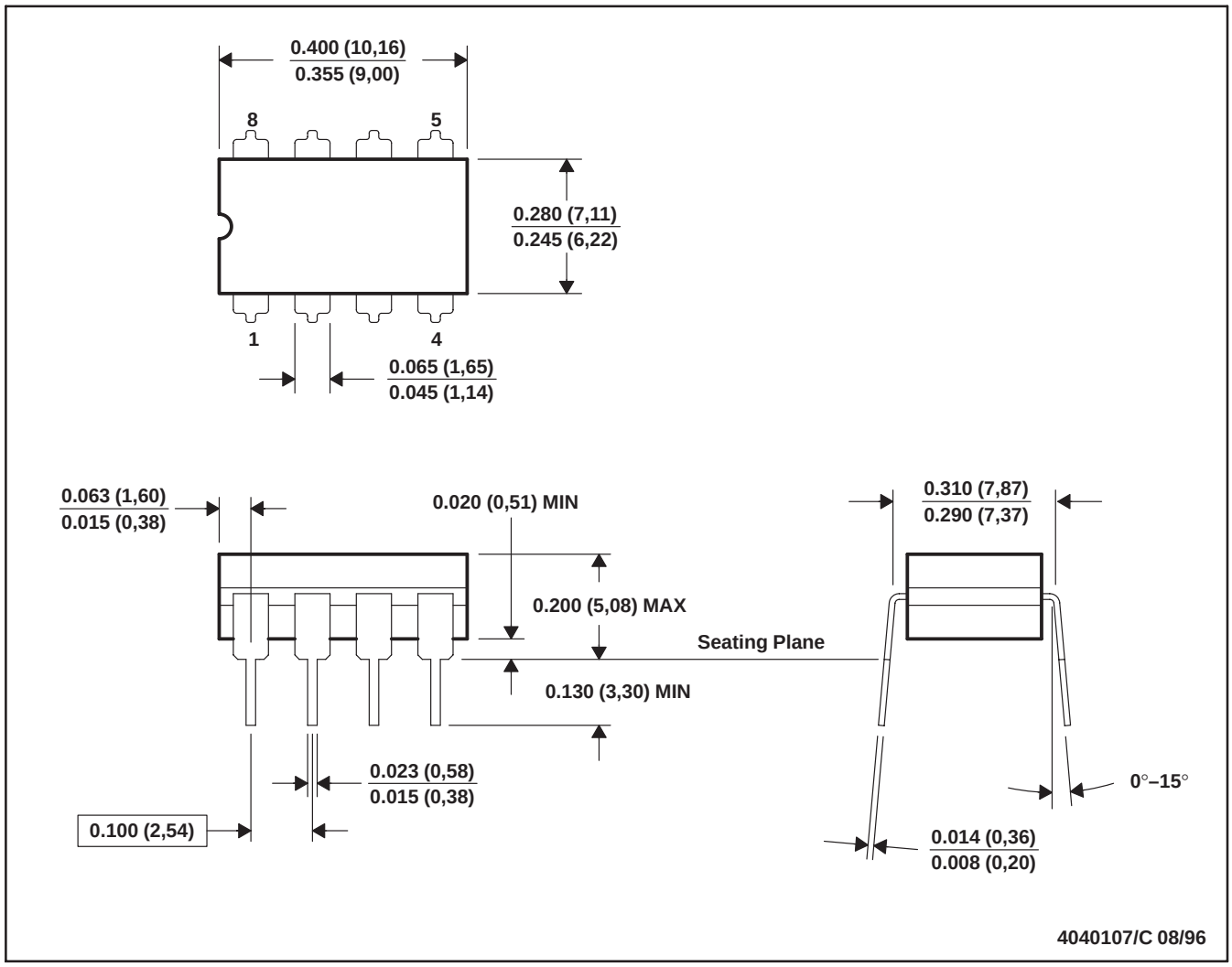
PS (R–PDSO–G8) PLASTIC SMALL OUTLINE



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.

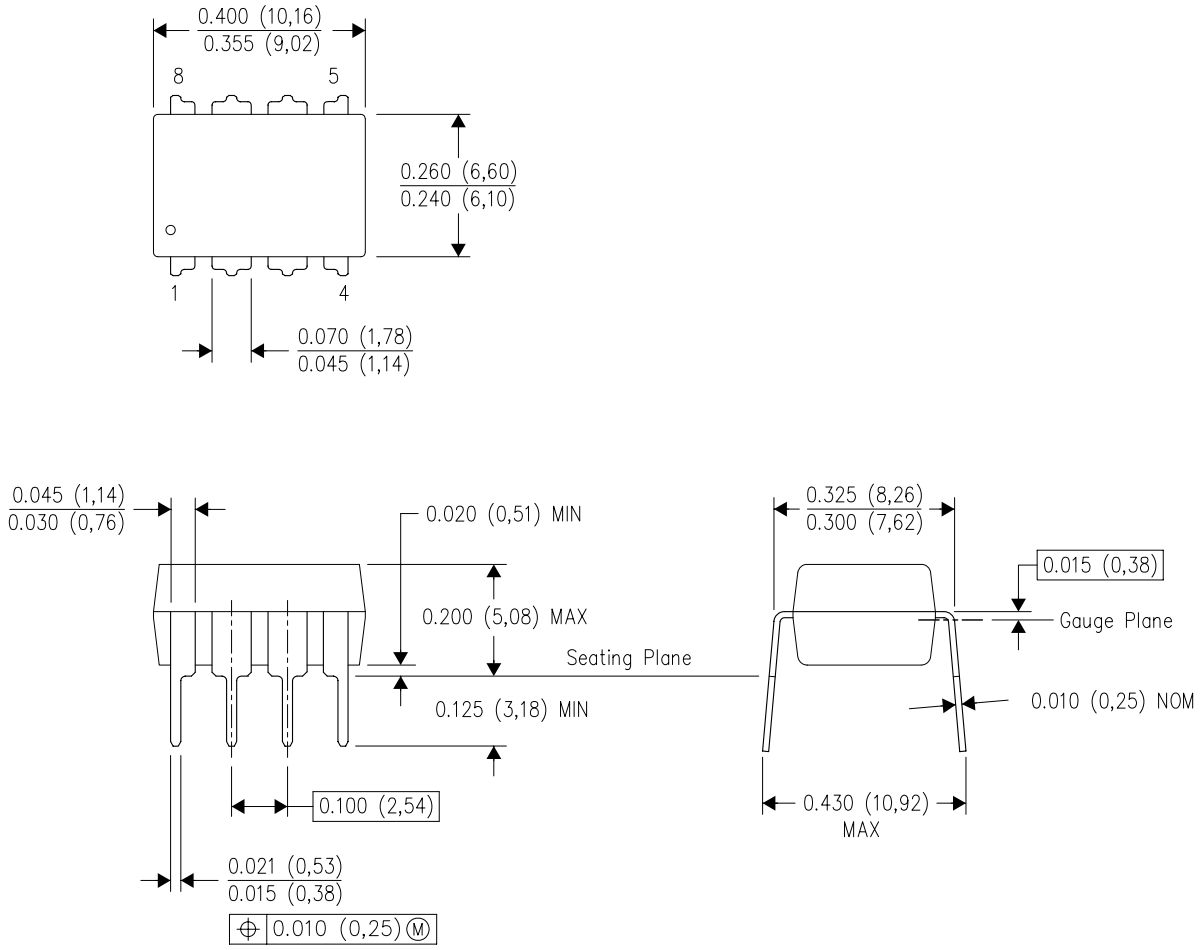
MCER001A – JANUARY 1995 – REVISED JANUARY 1997

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

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

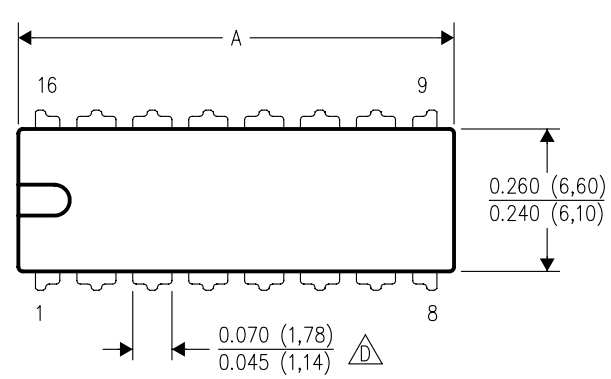


NOTES:
A. All linear dimensions are in inches (millimeters).
B. This drawing is subject to change without notice.
C. Falls within JEDEC MS–001 variation BA.

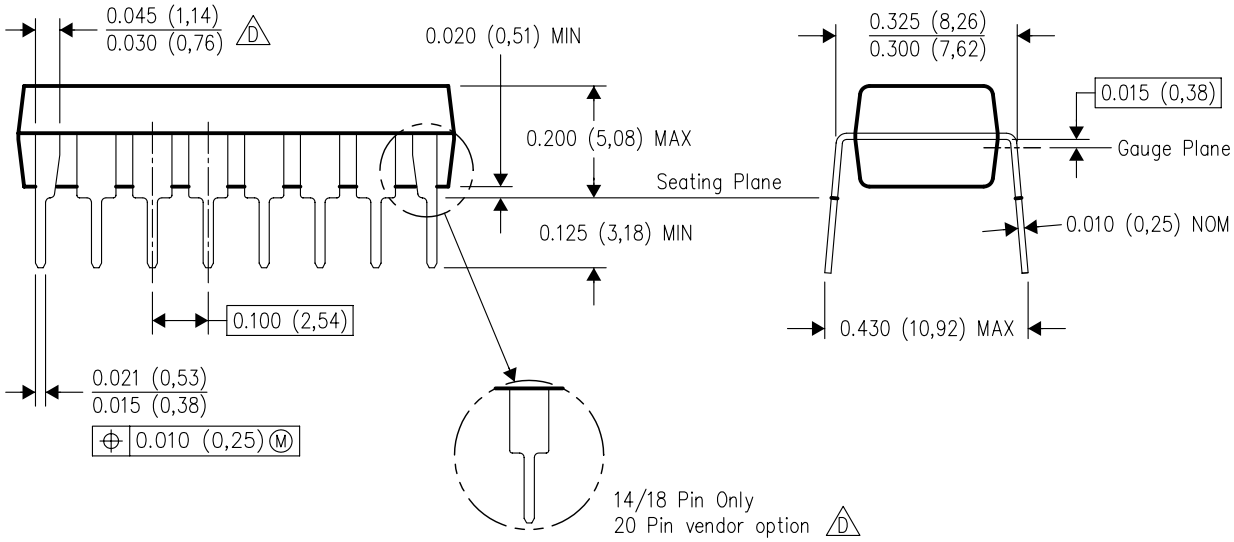
N (R–PDIP–T**)

PLASTIC DUAL–IN–LINE PACKAGE

16 PINS SHOWN



DIM \ PINS **	14	16	18	20
A MAX	0.775 (19,69)	0.775 (19,69)	0.920 (23,37)	1.060 (26,92)
A MIN	0.745 (18,92)	0.745 (18,92)	0.850 (21,59)	0.940 (23,88)
MS–001 VARIATION (C)	AA	BB	AC	AD



4040049/E 12/2002

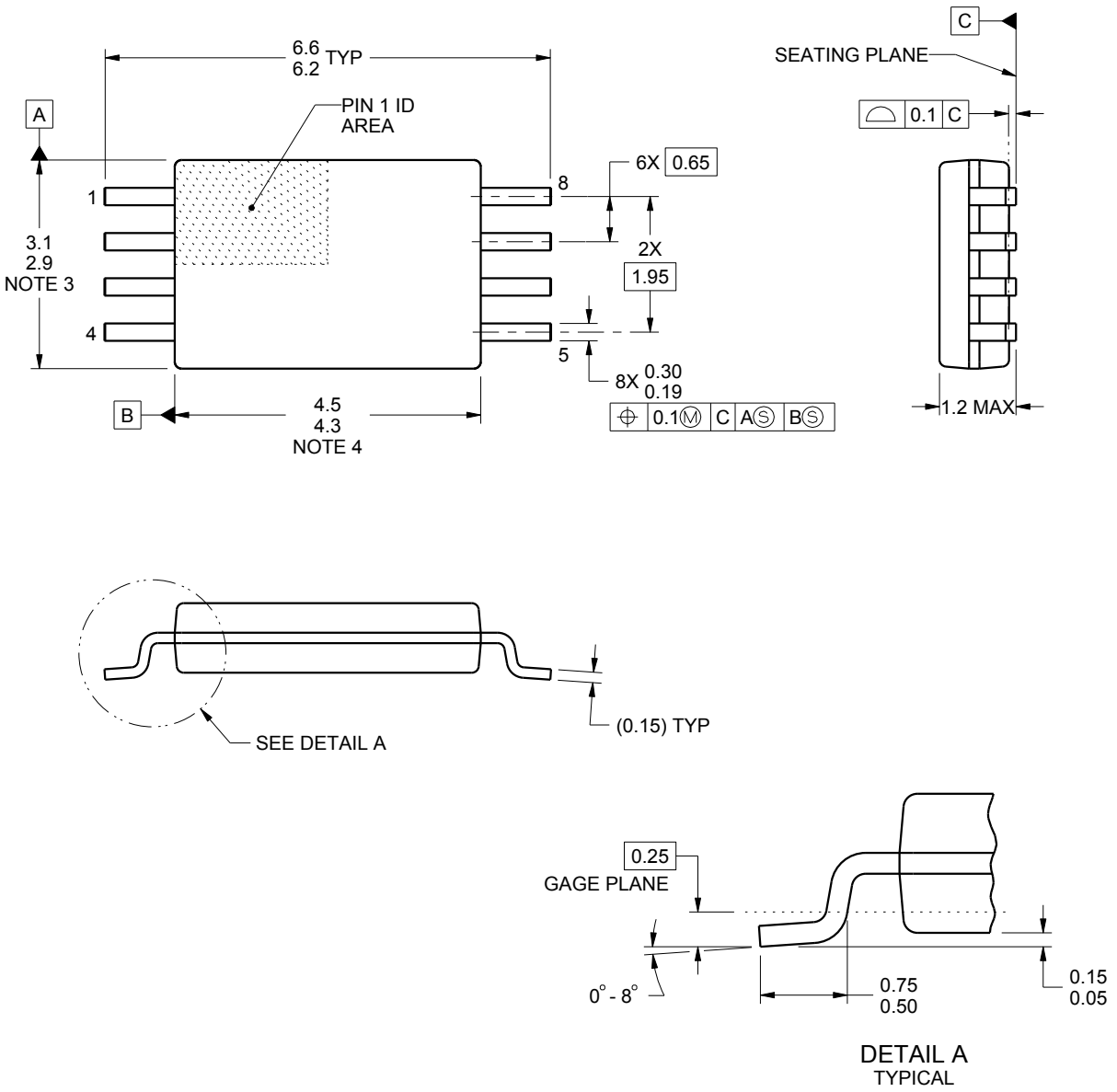
NOTES:
A. All linear dimensions are in inches (millimeters).
B. This drawing is subject to change without notice.
C. Falls within JEDEC MS–001, except 18 and 20 pin minimum body length (Dim A).
D. The 20 pin end lead shoulder width is a vendor option, either half or full width.

PACKAGE OUTLINE

PW0008A

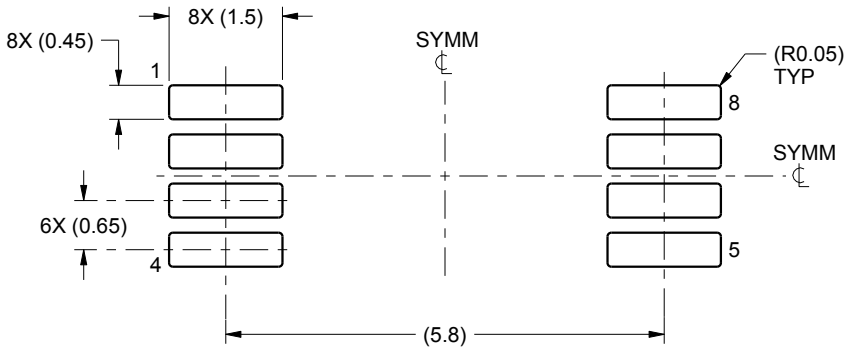
TSSOP - 1.2 mm max height

SMALL OUTLINE PACKAGE

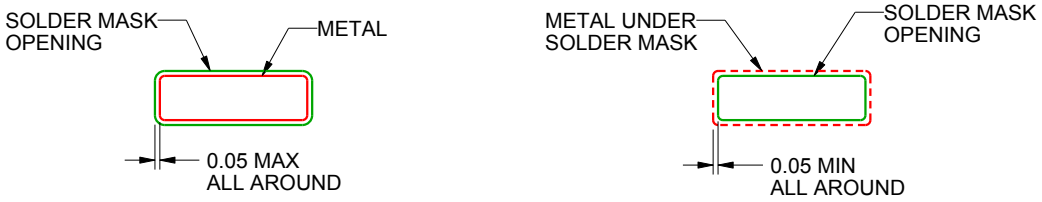


NOTES:

1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. This dimension does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.15 mm per side.
4. This dimension does not include interlead flash. Interlead flash shall not exceed 0.25 mm per side.
5. Reference JEDEC registration MO-153, variation AA.



LAND PATTERN EXAMPLE
SCALE:10X

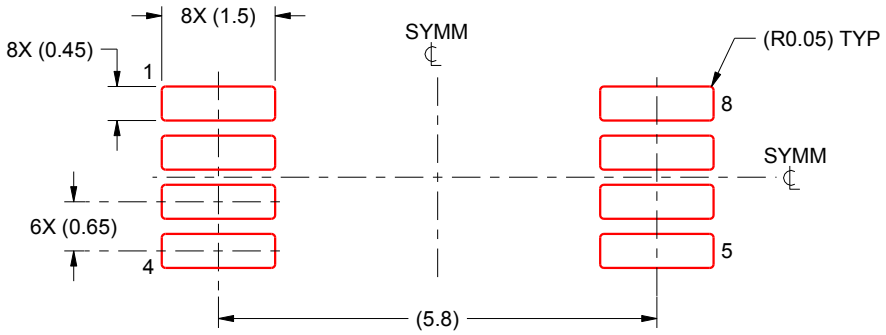


SOLDER MASK DETAILS
NOT TO SCALE

4221848/A 02/2015

NOTES: (continued)

6. Publication IPC-7351 may have alternate designs.
7. Solder mask tolerances between and around signal pads can vary based on board fabrication site.



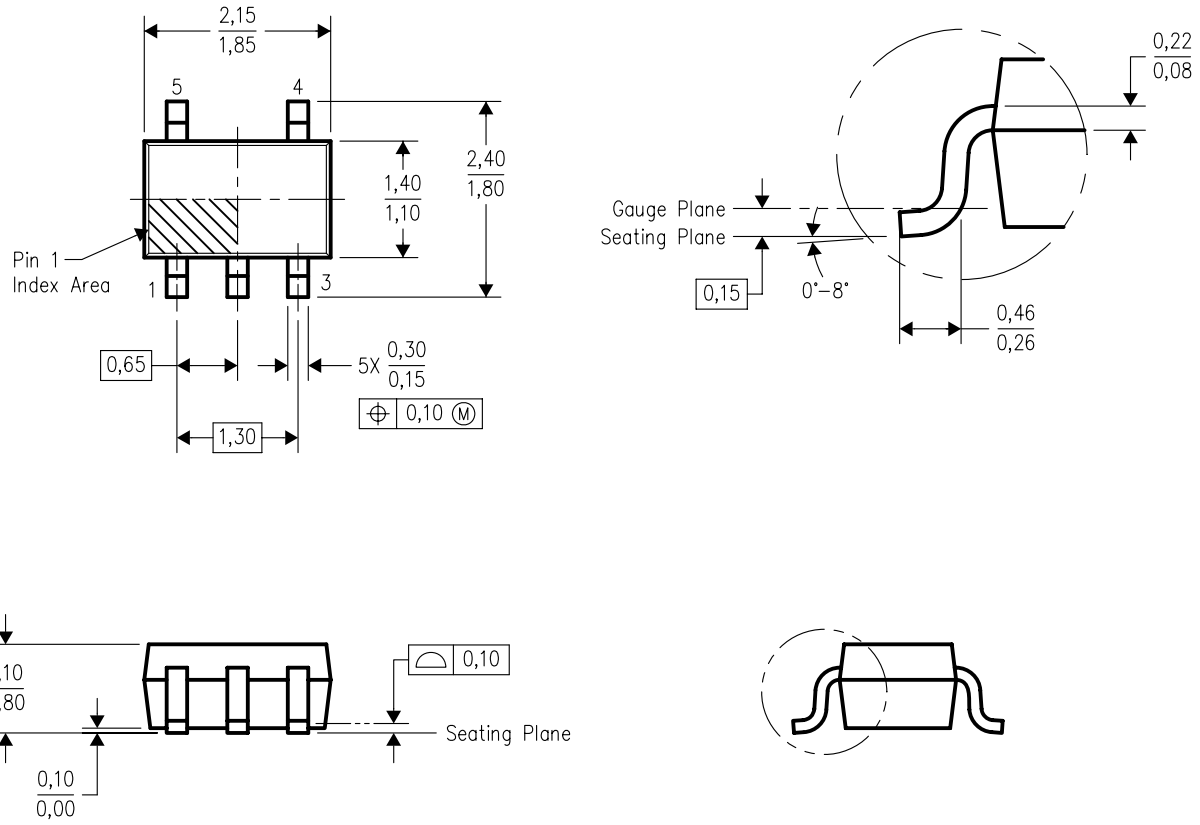
SOLDER PASTE EXAMPLE
BASED ON 0.125 mm THICK STENCIL
SCALE:10X

4221848/A 02/2015

NOTES: (continued)

8. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.
9. Board assembly site may have different recommendations for stencil design.

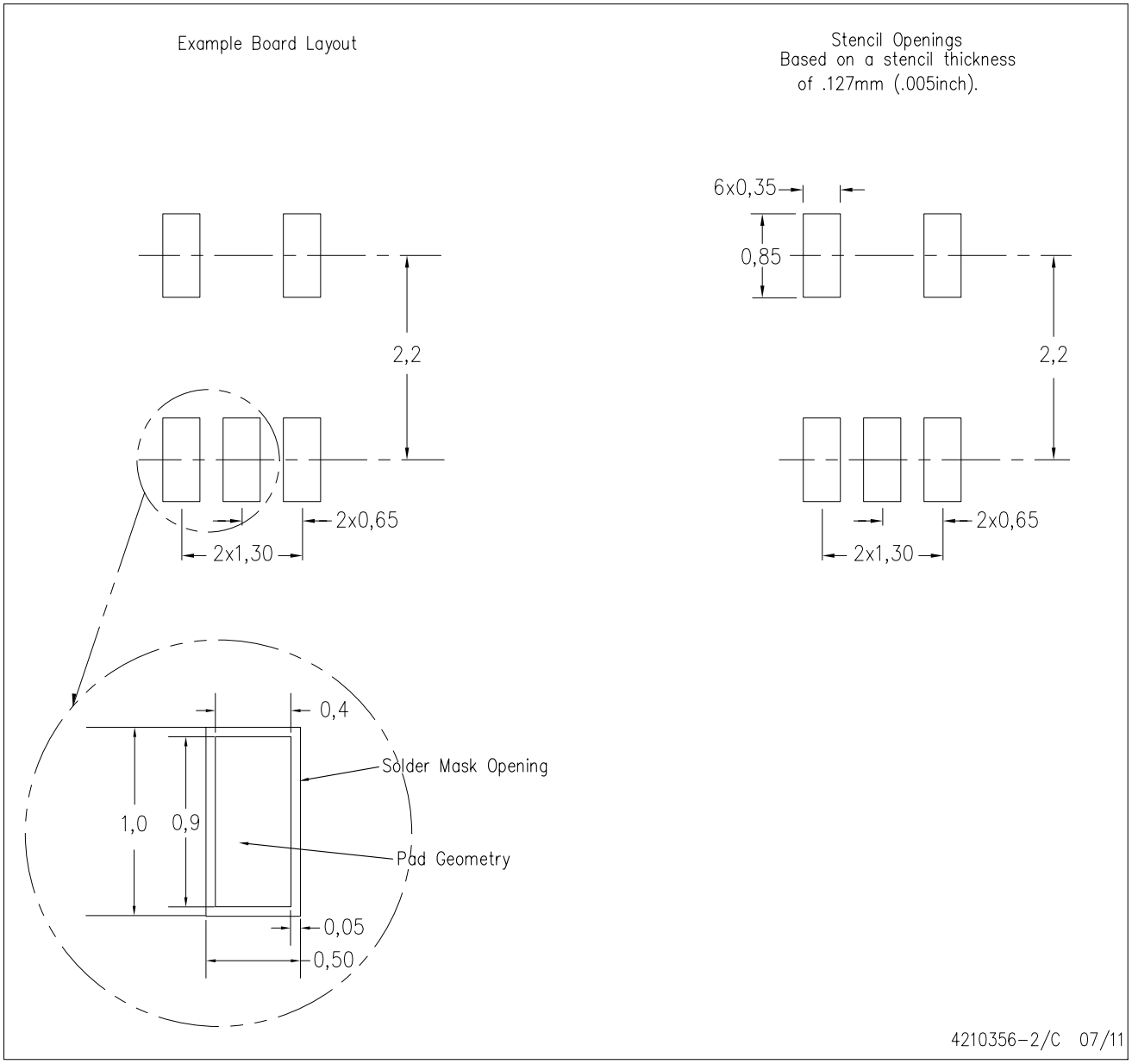
DCK (R–PDSO–G5) PLASTIC SMALL–OUTLINE PACKAGE



4093553–3/G 01/2007

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. Mold flash and protrusion shall not exceed 0.15 per side.
D. Falls within JEDEC MO–203 variation AA.

DCK (R–PDSO–G5) PLASTIC SMALL OUTLINE



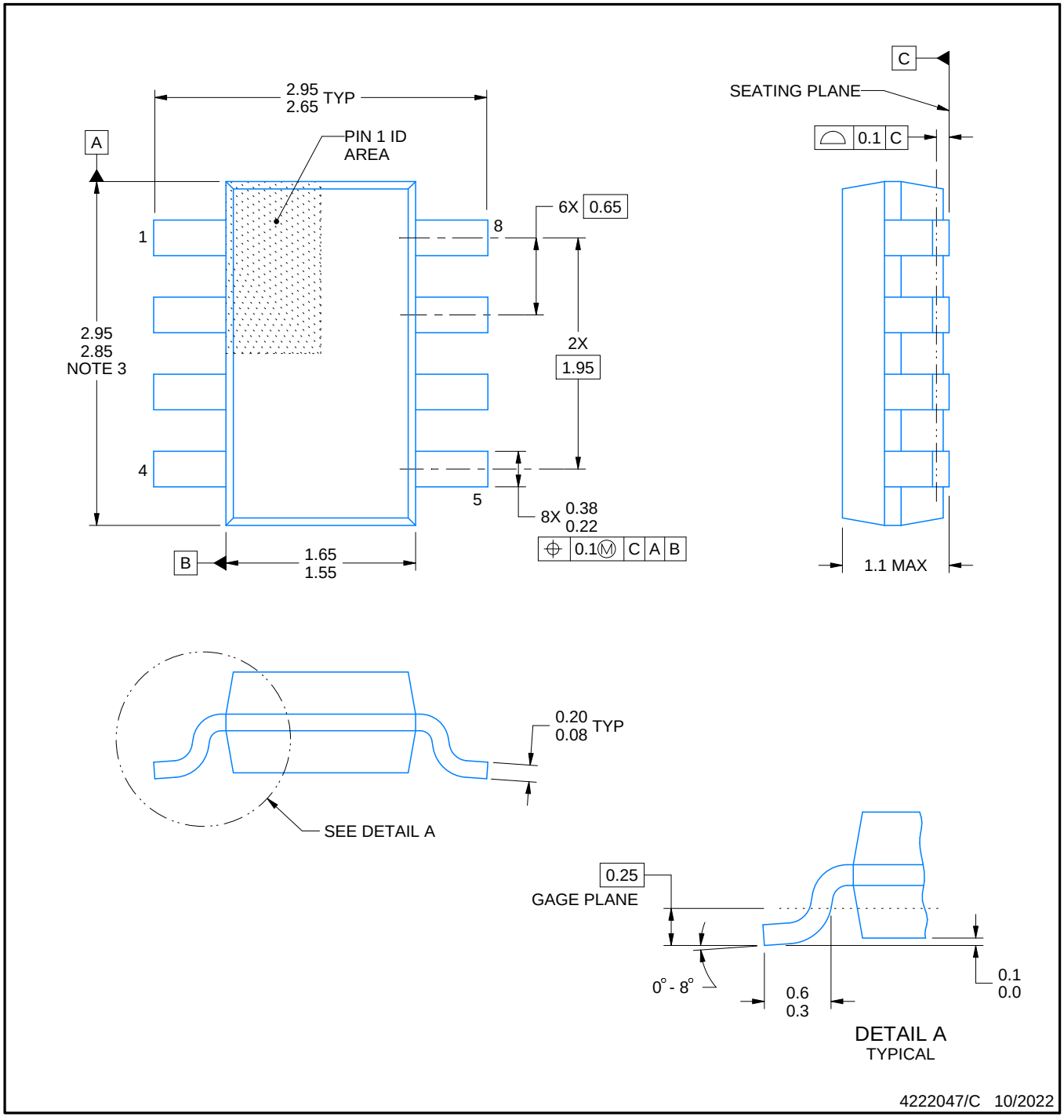
NOTES:
A. All linear dimensions are in millimeters.
B. This drawing is subject to change without notice.
C. Customers should place a note on the circuit board fabrication drawing not to alter the center solder mask defined pad.
D. Publication IPC–7351 is recommended for alternate designs.
E. Laser cutting apertures with trapezoidal walls and also rounding corners will offer better paste release. Customers should contact their board assembly site for stencil design recommendations. Example stencil design based on a 50% volumetric metal load solder paste. Refer to IPC–7525 for other stencil recommendations.

PACKAGE OUTLINE

DDF0008A

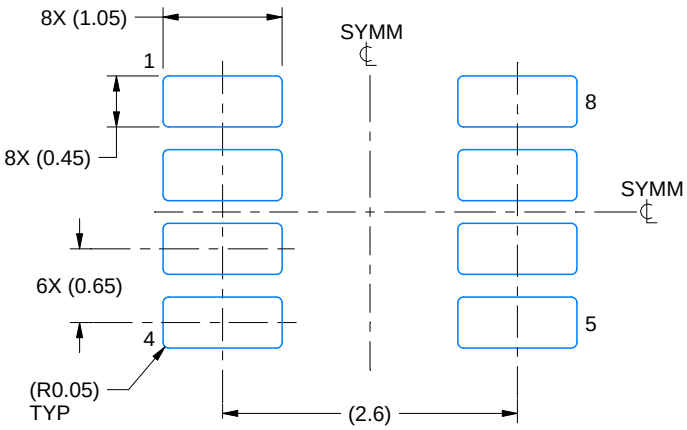
SOT-23 - 1.1 mm max height

PLASTIC SMALL OUTLINE



NOTES:

1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. This dimension does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.15 mm per side.



LAND PATTERN EXAMPLE
SCALE:15X

NON SOLDER MASK
DEFINED

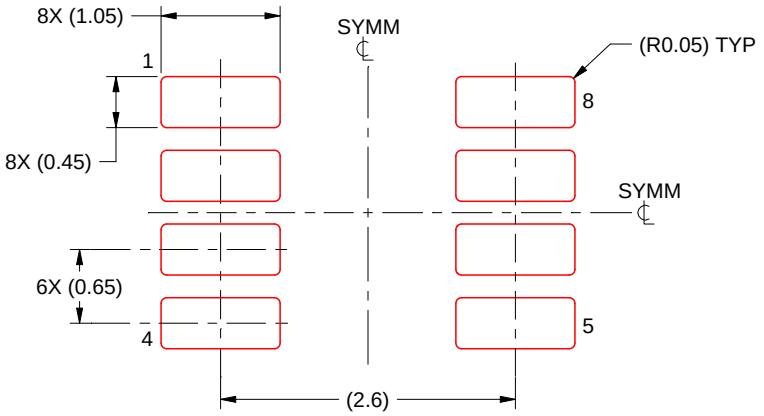
SOLDER MASK
DEFINED

SOLDER MASK DETAILS

4222047/C 10/2022

NOTES: (continued)

4. Publication IPC-7351 may have alternate designs.
5. Solder mask tolerances between and around signal pads can vary based on board fabrication site.



SOLDER PASTE EXAMPLE
BASED ON 0.125 mm THICK STENCIL
SCALE:15X

4222047/C 10/2022

NOTES: (continued)

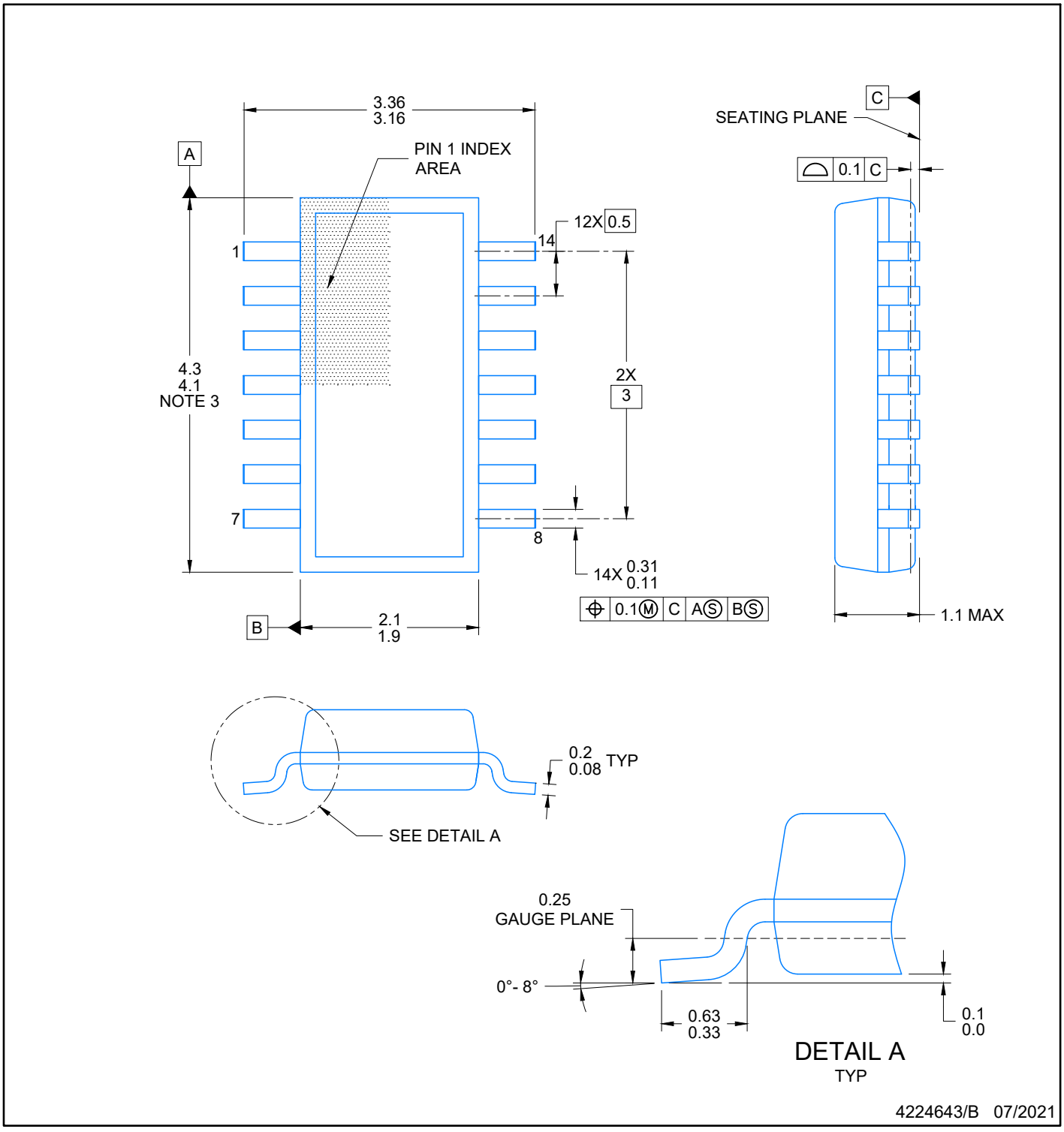
6. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.
7. Board assembly site may have different recommendations for stencil design.

PACKAGE OUTLINE

DYY0014A

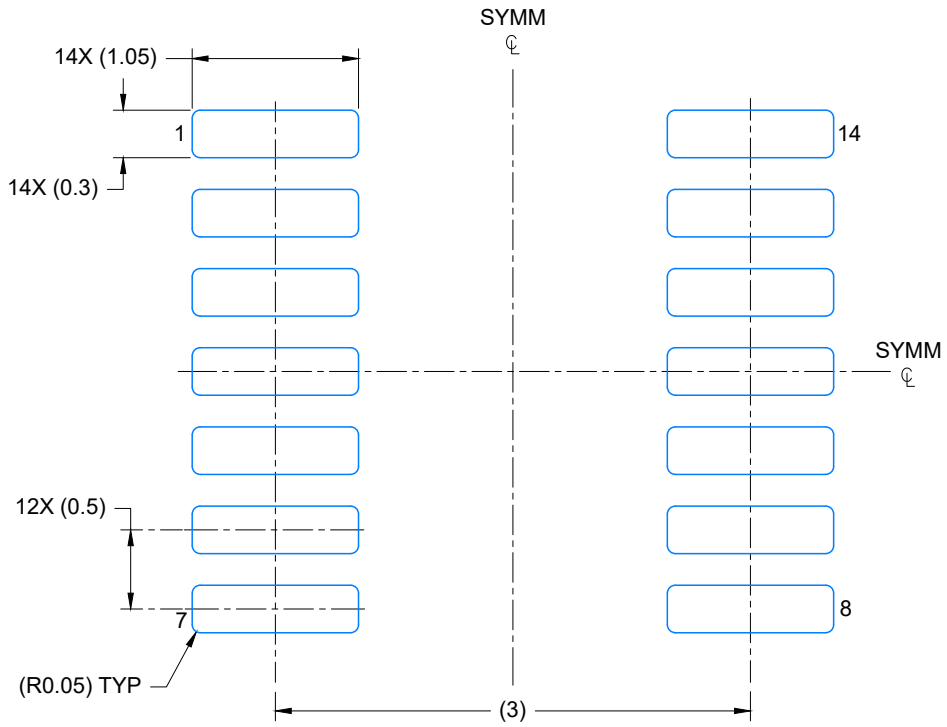
SOT-23-THIN - 1.1 mm max height

PLASTIC SMALL OUTLINE

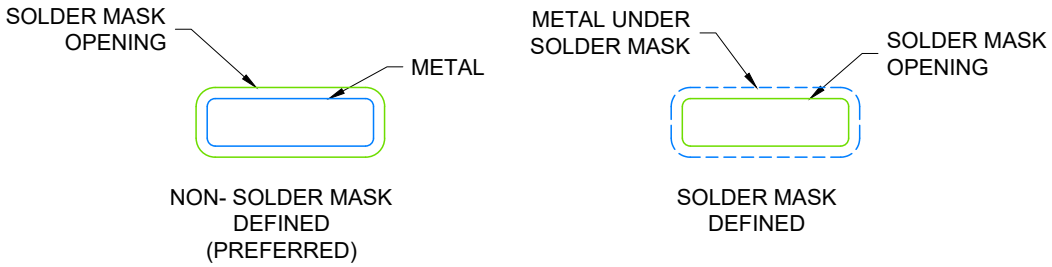


NOTES:

1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. This dimension does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.15 per side.
4. This dimension does not include interlead flash. Interlead flash shall not exceed 0.50 per side.
5. Reference JEDEC Registration MO-345, Variation AB



LAND PATTERN EXAMPLE
EXPOSED METAL SHOWN
SCALE: 20X

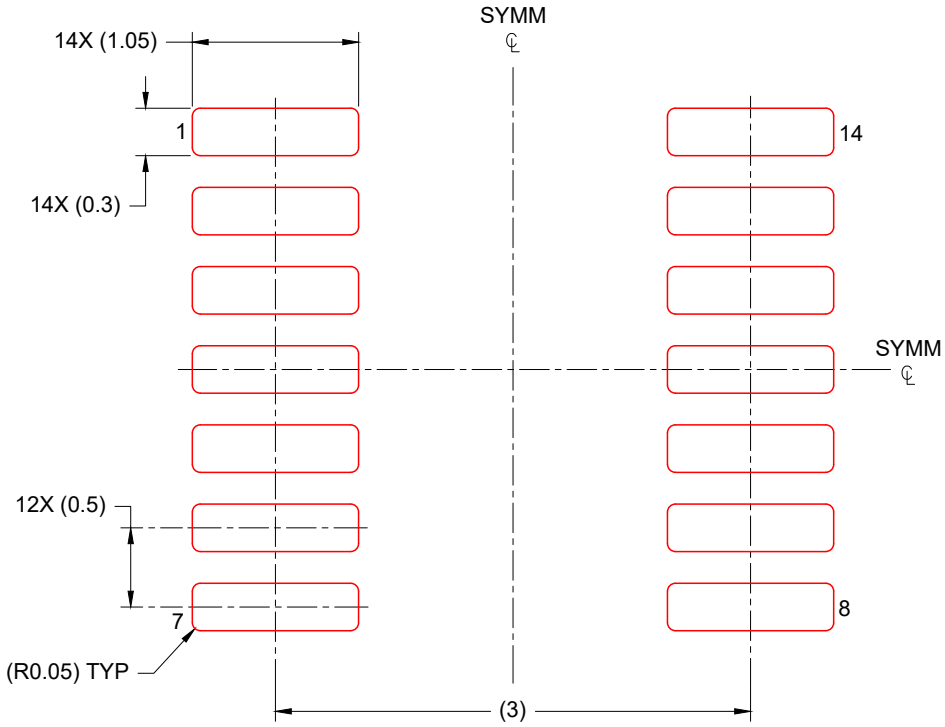


SOLDER MASK DETAILS

4224643/B 07/2021

NOTES: (continued)

6. Publication IPC-7351 may have alternate designs.
7. Solder mask tolerances between and around signal pads can vary based on board fabrication site.



SOLDER PASTE EXAMPLE
BASED ON 0.125 mm THICK STENCIL
SCALE: 20X

4224643/B 07/2021

NOTES: (continued)

8. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.
9. Board assembly site may have different recommendations for stencil design.

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