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Thème

Conception et Réalisation d'un Oxymètre de pouls connecté à base d'une carte LINKIT ONE

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Spo2 : Saturation pulsée de l'hémoglobine en oxygène.

SaO_2 : Saturation artérielle en oxygène.

O_2 : oxygène.

CO_2 : dioxyde de carbone.

Hb : Hémoglobine réduit.

HbO_2 : Hémoglobine Oxygéné.

AC : composante alternatif.

DC : composante Continu.

Fe^{2+} : fer ferreux.

nm : unité de longueur d'onde (nanomètre).

Hz : unité de fréquence (hertz)

F_c : fréquence de coupure

Introduction Générale

Introduction générale

L'oxymétre de pouls connecté est un outil primordial au sein des blocs opératoires et salles de réanimation. Ce système permet au chirurgien de suivre en temps réel l'évolution du taux d'oxygène dans le sang, ce qui lui permet de prendre la bonne décision au bon moment au cours d'une opération chirurgicale. C'est alors un outil vital dans le domaine hospitalier et en particulier dans le service de réanimation et les blocs opératoires. L'oxymétre de pouls connecté est utilisé pour la détection des différentes anomalies dans le système cardio-respiratoire lors du transport de l'oxygène ainsi que la détection précoce des hypoxies.

La conception d'appareils permettant une mesure fiable, continue du contenu sanguin en oxygène a donc constitué depuis de nombreuses années un enjeu important. L'oxymétrie de pouls a permis d'apporter quelques solutions. C'est une méthode non invasive de mesure de la saturation en oxygène à partir d'un signal lumineux transmis au travers des tissus et qui prend en compte le caractère pulsatile du flux sanguin. Des progrès technologiques comme les diodes émettrices de lumière (LED), les phot détecteurs miniaturisés et les microprocesseurs et microcontrôleurs ont permis d'aboutir au cours des années 80 à des oxymétries de pouls de petite taille, peu coûteux et faciles à utiliser.

Notre travail consiste à réaliser un système qui permet de mesurer le rythme cardiaque ainsi que le taux de saturation en oxygène SpO_2 dans le sang. Il est organisé comme suit :

Dans le premier chapitre, nous exposons la notion de base sur le système cardio-vasculaire et les généralités sur l'Oxymétre, dans le deuxième chapitre la conception et les différant bloc du système ainsi que la carte d'acquisition. Dans le dernier chapitre on présentera la partie réalisation du système.

Chapitre I

Introduction

Le corps humain établieplusieursfonction et en même temps il est exposé à plusieurs maladies, et parmi ces fonction la respiration qui est obligatoire pour que l'être humain survie.

D'une part, pour la réalisation de cette fonction on a besoin de deux opération essentielle qui sont l'inspiration et l'expiration, ces derniers sont effectués grâce à la combinaison d'un système cardio-respiratoire (poumons, le cœur) et le système cardio-vasculaire (le cœur et le sang) basé sur la circulation du sang chargé des gaz respiratoires.

D'autre part, le disfonctionnement de ce système provoque quelques maladies parmi elles l'hypoxémie.

Pour la surveillance du patient on a proposé un système qui sert à calculer le taux d'oxygénation et le rythme cardiaque dans le corps humain, et cela se fait avec un appareil médical qui est l'Oxymétre de pouls. Cet appareil a de nombreuses applications en pneumologie, anesthésie et surtout en médecine d'urgence.

I. Généralité sur le système cardio-vasculaire

I .1- Définition du système

Le système cardiovasculaire s'échange des aliments, des déchets et des gaz dans les cellules du corps. Il se compose de cœur et d'un réseau complexe de vaisseaux sanguins [1,2].

I.1.1- Le Cœur

Le cœur estun organe principal de l'appareil circulatoire, il joue un rôle d'une pompe ou le sang inspiré vers le cœur et produise vers les organes [3].

Les artères transportent le sang du cœur et se ramifiepour former des capillaires et trois vaisseaux de diamètres d'un seul globule rouge (artères, veines, capillaires).Les aliments dans le sang et les déchets des cellules s'échangent à traversdes parois capillaires. Le sang dans les capillaires est collecté des veines qui renvoient le sang vers lecœur [1 ,6].

Le système cardio-vasculaire se divise en deux circulations sanguines :

- Circulation pulmonaire : Le cœur renvoie un sang pauvre en oxygène (O_2) vers les capillaires des paumons et se décharge du gaz carbonique (CO_2) et se recharge en oxygène avant de revenir au cœur.
- Circulation générale : le sang quitte le cœur et transporte l'oxygène vers les tissus du corps [1].**La figure I.1** suivante représente la circulation sanguine.

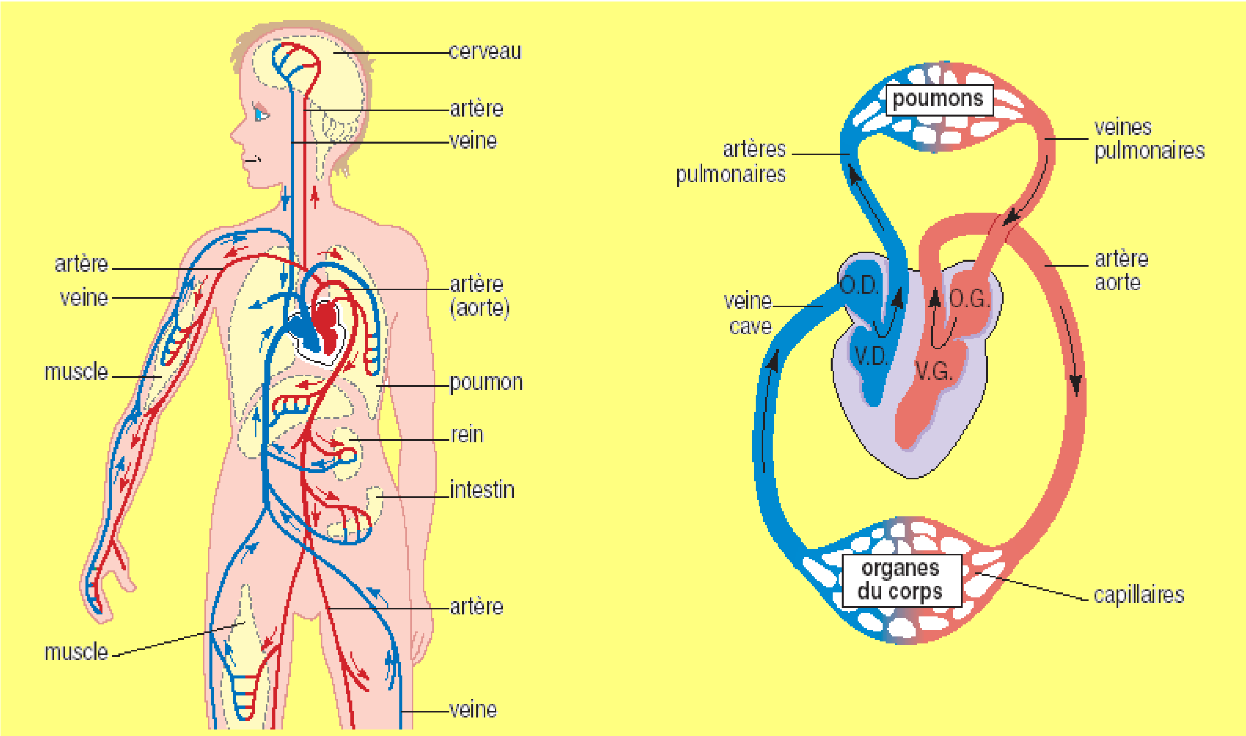

Figure I.1Illustration de la circulation sanguine [7].

I.2 –Définition du système respiratoire

Le système respiratoire regroupe les organes qui permettent d'inspirer et d'expirer l'air dans le but de fournir de l'oxygène (O_2) à l'organisme et d'éliminer le dioxyde de carbone (CO_2)[3,5].

L'appareille respiratoire est formé :

- **Les voies Aériennes** : qui contiennent le nez, les fausses nasales, les branches, latrachée, pharynx, larynx.
- **Les poumons**
- **Les alvéoles pulmonaires**

Lorsqu'un individu inspire l'air, celui-ci passe par la trachée, rentre dans les bronches, passe par les bronchioles et se rend jusqu'aux alvéoles. C'est là que les échanges gazeux se font. Les alvéoles relient le système respiratoire aux capillaires du système circulatoire. Le sang qui circule dans les capillaires libère du CO_2 et extrait l'O_2 de l'air [2, 3, 10,11].

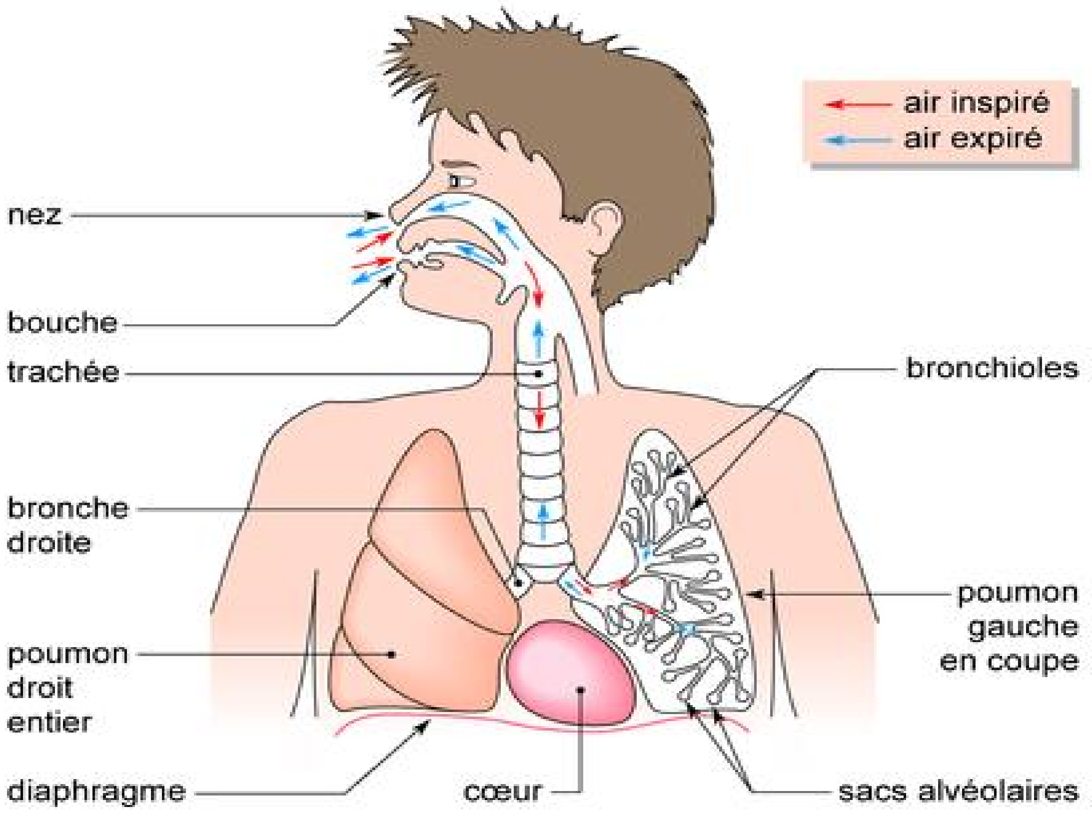

Figure I.2 la structure de l'appareil respiratoire [11].

I.3- Hémoglobine

I.3.1- Structurede l'hémoglobine

Le Hb est un héteproteine (protéine dont l'hydrolyse ne libère que des acides animés mais également d'autre composée non protidique) composée de quatre sous unité quasiment identique, chaque sous unité est composée :

- D'une protéine, la globine**,** l'Hb est composée au totale de deux globines Alpha et deux globines Beta.

- D’un groupement prothétique, Hème qui contient un atome de fer ferreux (Fe^{2+}) capable de fixer une molécule de dioxygène.

Grace à ses unités quasiment identiques, la molécule d’Hb peut fixer quatre molécules d’oxygène au total sur les atomes de hèmes.

Dans ce cas, on parlera d’hémoglobine saturé ou Oxyhémoglobine. L’oxygène se lie plus précisément sur le fer de l’Hb selon une réaction rapide, réversible, non linéaire et auto catalytique[12,13].

$$Hb+4O_2=Hb(O_2)_4. \qquad (I.1)$$

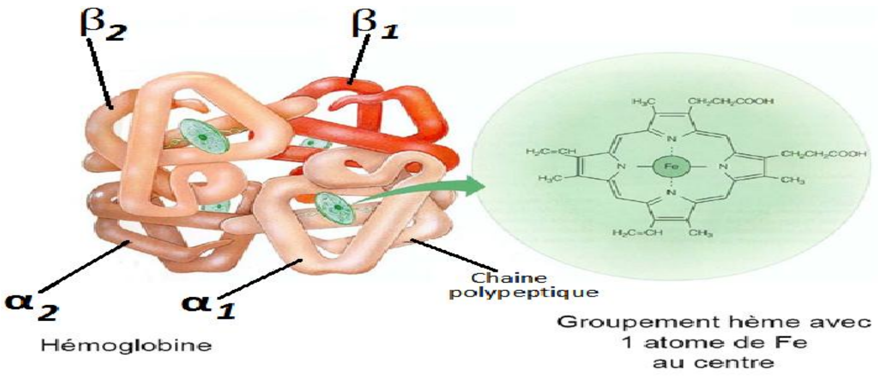

Figure I.3 : structure d’hémoglobine [13].

Le principe de fixation des molécules d’O_2sur l’Hb est particulier : il est basé sur le mode coopératif.En effet, l’Hb ne peut fixer qu'une seule molécule à la fois, car un seul atome de fer est réellement accessible à O_2[14,15].

I.4- les modes de transport des gaz

Le transport des gaz s’effectue en deux modes :

I.4.1 -Mode de transport de l’oxygène

- L'oxygène est transporté:
  - dans le plasma: sous forme dissoute (2%).
  - dans les hématies: sous forme dissoute et essentiellement lié à l'Hb(98%).

I.4.2 -Mode de transport de CO_2

- Le CO_2 est transporté sous trois formes dans le sang :
  - CO_2 dissous (7%).
  - à l'état de bicarbonates (essentiellement à 70%).
  - sous forme de Carbhémoglobine (23%) [12 ,13].

II- L'Oxymétre de pouls

II.1-Définition

L'oxymétrie de pouls, également appelé le Saturométre ou sphygmo–oxymétre. C'est un dispositif médicale permet de mesurer le taux d'Oxygène et le rythme cardiaque au niveau des capillaires sanguins. La SpO_2est très proche à la SaO_2.

II.2 -Historique

L'oxymétre de pouls est un outil de diagnostic utilisé dans le monde entier en médecine pour surveiller l'oxygénation du taux sanguin d'un patient. Son histoire remonte aux années 1800. Ils incluent des noms comme Lambert, Bière, Bunson et Kirchhoff en 1860. Stoke et Hoppe-Seyler, Nicolai en 1932 et plus tard Krammer et Carl Mathes.

Après le travail de terrain des premiers scientifiques; Millikan, bois et Shaw développé les principes de l'oxymétre de pouls en 1940 à 1964. En 1972, TakuoAoyagi, un bio-ingénieur japonais, a inventé l'oxymétre de pouls après la mesure de la saturation en oxygène par l'envoi de lumière à travers les tissus. En 1978, William New, MD, Ph.D., a amélioré le principe après avoir réalisé que la lumière infrarouge et rouge mesure le sang.

L'oxymétre de pouls a fait un impact significatif sur le domaine médical et a propulsé l'avancement des soins aux patients en particulier dans les domaines de l'anesthésie et de soins critiques. Dans un article de John Severinhaus, MD, intitulé «TakusAoyagi: Découverte d'oxymétrie de pouls» Publié en anesthésie et l'analgésie, le 23 Avril 2007. Il conclut que l'introduction de l'oxymétrie de pouls a coïncidé avec une réduction de 90 pour cent en anesthésie liée deaths.Finally, les patients oxygénation du sang pourrait être contrôlée et mesurée par un outil de diagnostic le résultat est de continuer à améliorer la qualité et l'efficacité des soins aux patients [16].

II.3- principe de fonctionnement

Le principe de fonctionnement est basé sur :

- L'émission de deux lumières (rouge et infrarouge).
- L'absorption par le flux pulsatile du sang (Hb, HbO_2) [16,17].

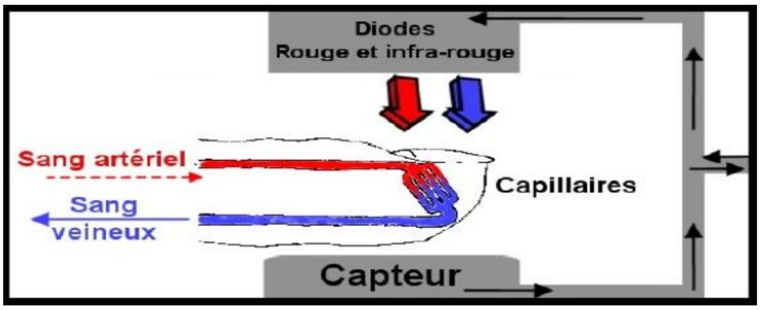

Figure I.4 : Principe d'émission /réception [17].

Hb et HbO_2 sont des spectres d'absorption lumineuse différente suivante une lumineuse rouge (660 nm) et infrarouge (940nm) [17].

Le SpO_2 obtenue à partir d'absorption lumineuse a la formule suivante :

SpO_2=R=AC (66O) DC (660) /AC (940) DC (940) (I.2) [18, 20].

II.4- La loi physiquede l'Oxymétre de pouls :

Le conceptde l'Oxymétre de pouls est basé surla loi de Beer-Lambert (également dénommée loi de Beer ou loi de Bouguer) qui stipule quela concentration d'unsolutédans un solvantinconnupeut être déterminée par l'absorption de la lumière [18].Beer et Lambert ont proposé d'observer l'atténuation d'un faisceau de la lumière afin de prédire la concentration d'un composé [19]. Cette loi exprime la relation de proportionnalité existant entre l'absorbance A et les trois paramètres qui sont :

- **L'absorptivité** (ε en $Lmmol^{-1}cm^{-1}$) de l'analyte absorbant la lumière.
- **l'épaisseur**de la cellule de mesure (l).

- **la concentration** (c enmmol L^{-1}) de l'analyte.

La forme mathématique sous laquelle est habituellement présentée cette loi.

A= ε l c

- **A** : l'absorbance ou densité optique à une longueur d'onde λ (sans unité).
- **ε** : le coefficient d'extinction molaire, exprimée en L·mol−1·cm−1.
- **ℓ :** la longueur du trajet optique dans la solution traversée, elle correspond à l'épaisseur de la cuvette utilisée (en cm).
- **C :** la concentration molaire de la solution (en mol.L−1).

Lorsqu'une radiation monochromatique traverse un milieu, une partie de son énergie peut être absorbée. La loi de Beer-Lambert donne l'intensité de lumière qui traverse le substrat diminue exponentiellement[19],et la figure ci-dessus représente l'allure de l'intensité avec laquelle une transmission dans une substance**.**

$I = I_0 \cdot \exp(-\varepsilon cl)$ (I.4)

$I = I_0 * e^{-\varepsilon cl}$(I.5)

Chaque substance a un coefficient extinction (absorptivité) spécifique pour l'absorption de la lumière à une longueur d'onde spécifique [20].

De cette relation on déduit la transmittance :

$T = \frac{I_0}{I}$I/Io est la transmittance (sans unité).(I.6)

Et l'absorbance :

$A = -logT = -log\frac{I_0}{I} = \varepsilon cl$ (I.7)

L'absorbance est parfois considérée comme la densité optique d'un milieu [21].

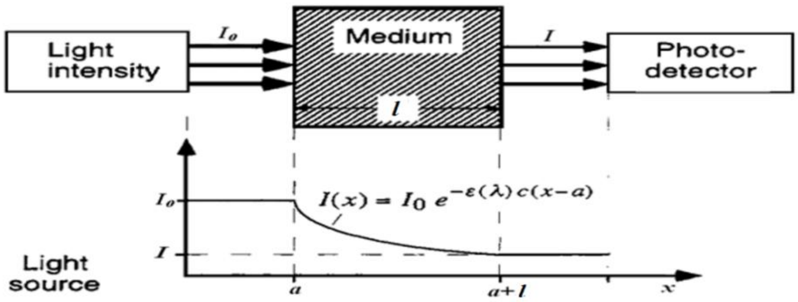

Figure I.5:la loi de Beer-Lambert [21].

L'intensité lumineuse diminue exponentiellement avec la distance dans le milieu absorbant.

II.4.1 Spectre d'absorption de l'hémoglobine:

L'analyse du spectre assiste de déterminer la plage de détection de la quantité de l'hémoglobine pour une longueur d'onde approprié. La composition chimique des différentes espèces d'hémoglobine modifie leurs propriétés d'absorption, comme le montre la Figure II. 3. L'absorbance de la lumière dans la région rouge du spectre est beaucoup plus élevée pour l'hémoglobine réduite que pour l'oxyhémoglobine. Les coefficients d'extinction des deux espèces d'hémoglobine sont égaux au point isosbestic (à 805nm) [20]. Les coefficients d'extinction pour COHb et MetHb ne sont pas zéro dans la plage rouge et infrarouge et leur présence sera, par conséquent, contribuer à l'absorption [22]. L'hémoglobine réduite est plus transparente à la lumière infrarouge que l'oxyhémoglobine. Le coefficient d'extinction de la carboxyhémoglobine est environ le même que celui d'oxyhémoglobine à la longueur d'onde de 660 nm cependant la carboxyhémoglobine est presque transparente dans la région infrarouge [24**].**

La Méthémoglobine absorbe plus de lumière rouge et son coefficient d'extinction est plus élevé que celui d'oxyhémoglobine dans la région infrarouge.

A ce stade, l'hémoglobine se présente sous forme désoxygénée dont l'indice colorimétrique varie par rapport à l'oxyhémoglobine.

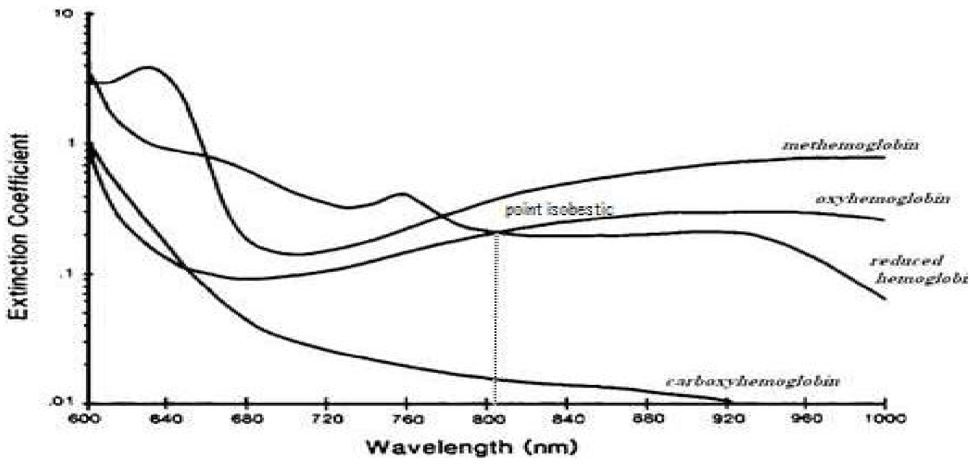

Figure1.6 : Coefficients extinction des quatre espèces les plus communes d'hémoglobine oxyhémoglobine, l'hémoglobine réduite, la carboxyhémoglobine, et méthémoglobine à des longueurs d'onde d'intérêt d'étude [24].

II.5 les facteurs qui limitent d'utilisation

La mesure de la SpO_2 connait quelques limites, liées soit à la technologie utilisée, soit au patient et à sa condition clinique.

- **Bruit de fond trop important :** le signal peut être perturbé par un bruit de fond généré par exemple par les mouvements du patient et cela risque d'entrainer des alarmes intempestives.
- **Shunt optique :** lorsque la photodiode (récepteur) reçoit de la lumière qui n'est pas passée par les tissus, la SpO_2 affichée est de 85%(cette valeur correspond au rapport rouge /infrarouge=1). Attention, lors de la mesure de la SpO_2 prés de sources lumineuses (scialytiques, forte lumière solaire).

- **Modification de l'absorption :** certains facteurs sont susceptibles de modifier l'absorption du signal. Ainsi la pigmentation cutanée est susceptible de modifier la mesure pour deux raisons distinctes à savoir que la pigmentation peut modifier l'absorption et que les algorithmes ont été établis chez des sujet non pigmentes.

- La présence de certains vernis à ongle influence la mesure.

- **L’anémie** sévère semble modifier l’absorption, même si en l’absence d’hypoxémie, la mesure de la SpO_2 reste fiable. Par contre, l’hyper bilirubinémie ne semble pas pose de problème de mesure avec les Oxymétres classiques.

- **Intoxication aumonoxyde de carbone(CO) :** La carboxyhémoglobine (possède un spectre d’absorption égal l’HBO_2) est confondue avec l’oxyhémoglobine. La valeur de la SpO_2 est alors faussement normale (surestimation) alors qu’il existe une diminution importante du transport en oxygène, en rapport avec la concentration en monoxyde de carbone.

- **Encas de méthémoglobinémie :** la SpO_2 surestime la SaO_2 de manière proportionnelle au contenu en méthémoglobine initiale puis se stabilise à 85% car la méthémoglobine a un rapport d’absorption rouge /infrarouge égale à 1[19,24].

Conclusion

Dans ce chapitre nous avons présenté le fonctionnement de système cardiovasculaire et cardio- respiratoire qui s’intéresse à l’inspiration O_2 et l’expiration de CO_2, et le milieu des échanges gazeux qui procède la saturation du sang en oxygène transporté par l’hémoglobine. Ensuite le principe de fonctionnement de l’oxymétre de pouls qui repose sur l’émission de deux lumières (rouge et infrarouge), et de la mesure de leur absorption par le flux pulsatile du sang.

Dans ce qui suit, nous allons proposer une conception d’un oxymétre de pouls.

Chapitre II

Introduction

Après un aperçu sur le fonctionnement du système cardio-vasculaire dans le premier chapitre, et cité les méthodes de calcul du taux oxygénation et le rythme cardiaque dans le corps, nous avons choisi l'Oxymétre de pouls vu la facilité de mis en œuvre, et l'auto diagnostique qu'il offre à l'utilisateur.

Ce chapitre est consacré à description des différents blocs composant du système électronique que nous allons réaliser.

II.1 Rappel sur le fonctionnement de l'Oxymétre de pouls

Le principe de fonctionnement de l'Oxymétre de pouls est basé sur les caractéristiques d'absorption de la lumière par l'hémoglobine et la nature pulsatile de la circulation du sang au niveau des artères dans le but de déterminer l'état de l'oxygénation dans l'organisme. Cet appareil est caractérisé par l'émission de deux lumières (rouge et infrarouge) et par la mesure de leur absorption par le flux pulsatile du sang.

En effet, l'hémoglobine oxygénée, absorbe plus de lumière infrarouge tout en laissant passer plus de lumière rouge. Tandis que l'hémoglobine désoxygénée (ou faible en oxygène) absorbe une quantité plus grande de lumière rouge tout en laissant passer plus de lumière infrarouge. En calculant la différence d'absorption de ces deux lumières, l'Oxymétre de pouls peut, ainsi, mesurer le niveau d'oxygénation.

Cet appareil équipé d'un photo-détecteur qui reçoit la lumière passant à travers le site demesure et le restitue au moniteur qui l'analyse et calcule le rapport lumière rouge / lumière infrarouge avant de mettre en évidence la valeur de la saturation artérielle en oxygène (SpO_2).

II.2Description générale du système réalisé

Le système que nous allons réaliser est constituer de trois étapes principales (acquisition, conditionnement du signal, et affichage des résultats), comme illustre dans la figure suivante :

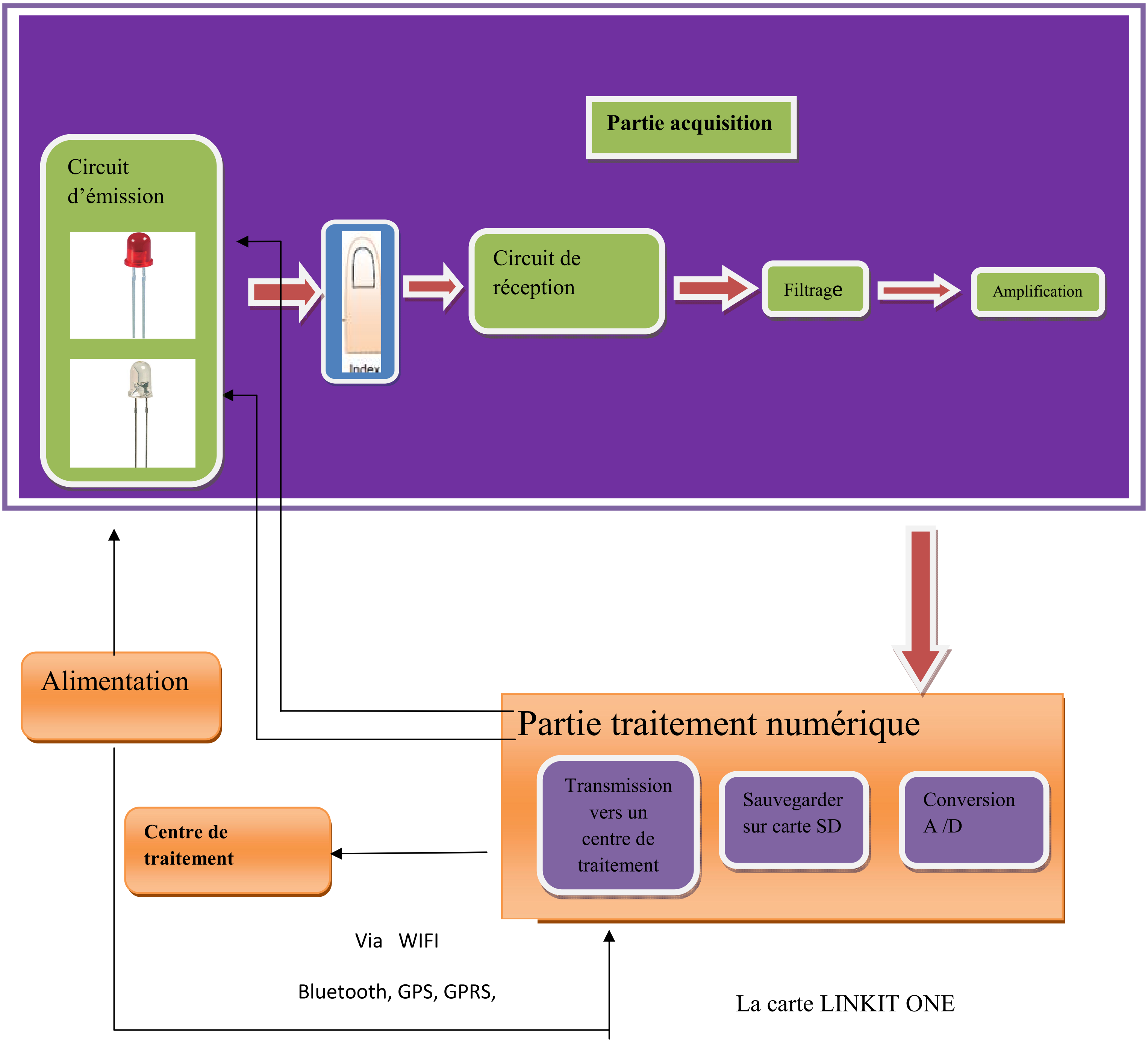

Figure II.1 : Schéma synoptique de l'appareil.

La réalisation de notre système est composée de deux parties, une partie analogique et une partie numérique.

La partie analogique est composée d'un capteur lumineux. Ce capteur se décompose en un émetteur qui est une LED infrarouge et une LED rouge, et un récepteur qui est une photodiode.

En effet une carte électronique est un ensemble de composants tel que des résistances, condensateurs ou circuits intégrés réunis sur une plaque d'une manière à former un circuit destiné à un usage précis, dans ce chapitre nous étudierons tout d'abord la conception par ordinateur du circuit électronique à l'aide d'un logiciel PROTEUS. On crée d'abords le schéma électrique en utilisant les bibliothèques de composants incluses dans le logiciel. Puis on utilise les outils de simulation fonctionnelle et électrique pour tester le comportement du circuit grâce aux modes de simulations, ensuite nous allons développer le typon du circuit puis la préparation du circuit imprimé et la mise en place et la soudure des composants.

La partie numérique est composé d'une carte à microcontrôleur de type LINKIT ONE, qui après l'acquisition des données les transmettra à un ordinateur via le wifi

II.3 Description détaillée du système

II.3.1 partie analogique

Le circuit analogique sert à amplifier le signal de sortie du capteur de telle sorte que l'on puisse utiliser la carte LINKIT ONE pour traiter le signal et obtenir des informations utiles.

II.3.1.1 Capteur

Dans notre réalisation nous allons exploiter un capteur optique composé d'une source lumineuse constituée d'une LED infrarouge disposée au dessus du doigt (émetteur)et d'un récepteur (photodiode) qui détecte les variations d'intensité lumineuse.

- **Principe de fonctionnement du capteur**

Le capteur dans son ensemble est composé d'un émetteur d'une lumière infrarouge et d'un récepteur sensible a cette lumière, son principe est de détecté les variations d'intensité lumineuse.

Les deux LEDs (rouge, Infrarouge) et la photodiode sont situés de part et d’autre de l’extrémité d’un doigt le déplacement du sang dans le doit modifie son opacité, la variation de lumière introduite une petite variation de tension autour du point de repos statique de la photodiode.

II.3.2 Conditionnement du capteur

II.3.2.1 LED infrarouge

La LED infrarouge est un composant semi-conducteur à un seul sens de branchement. Elle émette une longueur d’onde invisible à l’œil humain .on a choisi une LED infrarouge de type Gallium Arsenic (GaAs)(c’est un semi-conducteur utilise notamment pour réaliser des composants tels que les diodes électroluminescentes dans l’infrarouge) . C’est la LED de référence VSMB3940X01-GSOS [25].

Figure II.2 : LED infrarouge[25].

II.3.2.2 LED rouge

La LED rouge standard présente une tension de seuil de 1,6V à 2V, et de type ka35288SUCRC [26].

Figure II.3 : LED rouge [26].

II.3.2.3 La photodiode

Une photodiode est un dispositif à semi-conducteurqui convertit la lumière en courant. Le courant est généré lorsque les photons sont absorbés par la photodiode. Une petite quantité de courant est également produite en l'absence de lumière est présent. Les photodiodes peuvent contenir des filtres optiques, intégrés dans les lentilles, et peuvent avoir de grandes ou petites surfaces. Photodiodes ont généralement un temps de réponse plus lent que leur zone superficielle augmente [28]. Mais dans notre travail on a utilisé une photodiode de type VBP104SR qui est d'une sensibilité importante, le tableau suivant présente les caractéristiques suivants :

ABSOLUTE MAXIMUM RATINGS (T_{amb} = 25 °C, unless otherwise specified)				
PARAMETER	TEST CONDITION	SYMBOL	VALUE	UNIT
Reverse voltage		V_R	60	V
Power dissipation	$T_{amb} \leq 25$ °C	P_V	215	mW
Junction temperature		T_j	100	°C
Operating temperature range		T_{amb}	- 40 to + 100	°C
Storage temperature range		T_{stg}	- 40 to + 100	°C
Soldering temperature	Acc. reflow solder profile fig. 8	T_{sd}	260	°C
Thermal resistance junction/ambient		R_{thJA}	350	K/W

Tableau II.1 : Tableau de caractéristiques de VBP104SR [29].

Le courant maximum produit par la photodiode varie en fonction de la lumière transmise, elle pourra atteindre 80uA maximum s'il reçoit 4mW/cm^2 d'intensité lumineuse.

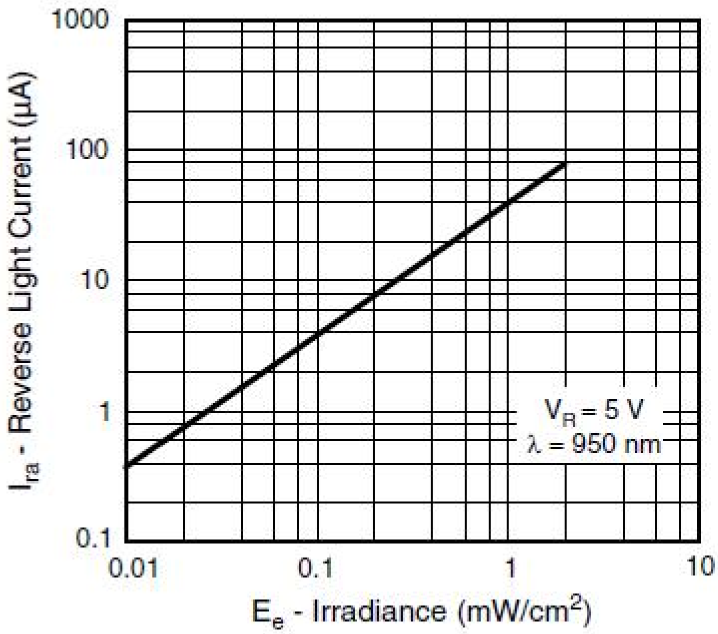

Figure II.4: courant de la collecte en fonction de la lumière [29].

Le VBP104 SR offre une plage de longueur d'onde entre 350 et 1150nm, ce qui permet son utilisation.

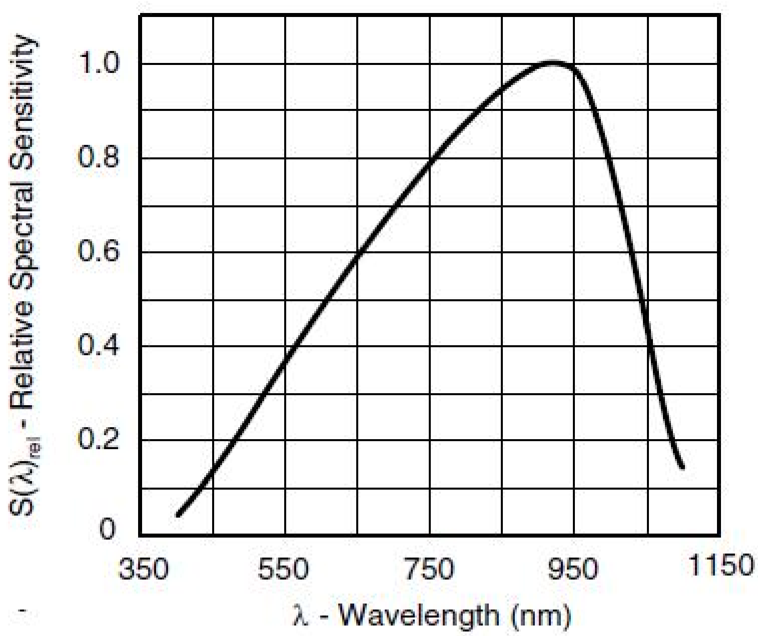

Figure II.5: Le spectre de sensibilité en fonction de la longueur d'onde [29]

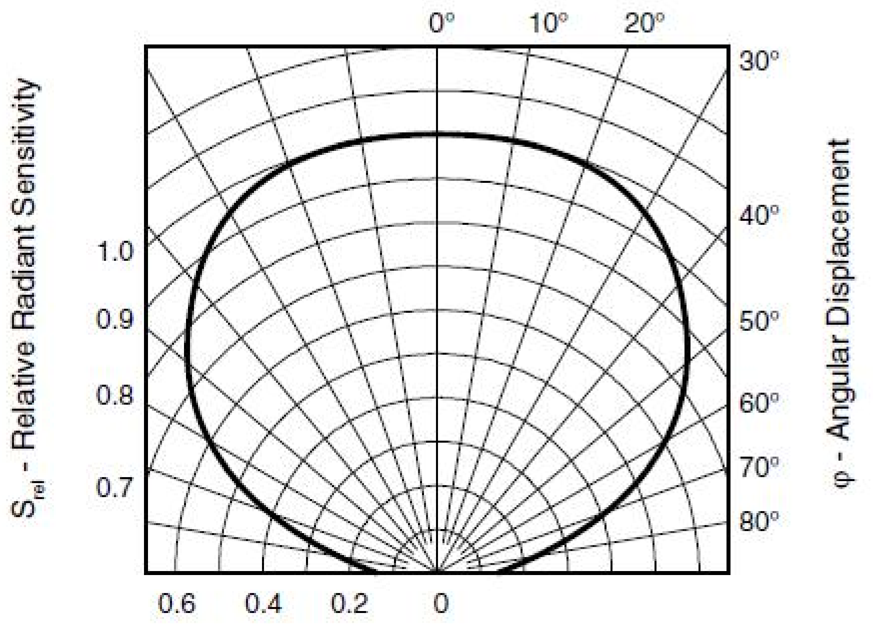

Figure II.6 : Le diagramme de rayonnement [29].

II.4.circuit électronique du système

La figure suivante montre le circuit analogique composé du capteur VBP104SR et son circuit de conditionnement.

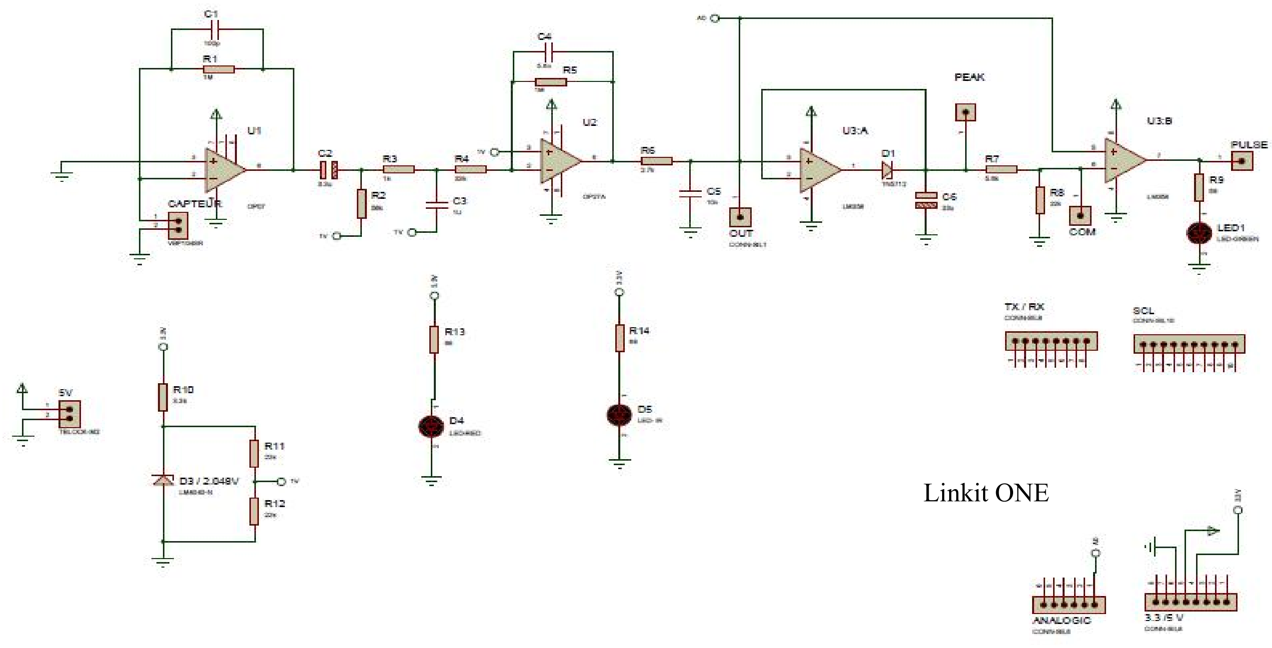

Figure II.7 : Le circuit analogique du système.

II.4.1.Les différentes blocs du système

II.4.1.1 Bloc trans-impédance

Ce bloc à base du système amplificateur opérationnel OPO7, est utilisé comme un amplificateur à trans-impédance. On convertit le courant généré par la photodiode en une tension. Cette étape assure un gain élevé et permet l'utilisation du capteur sur presque toutes les parties du corps.

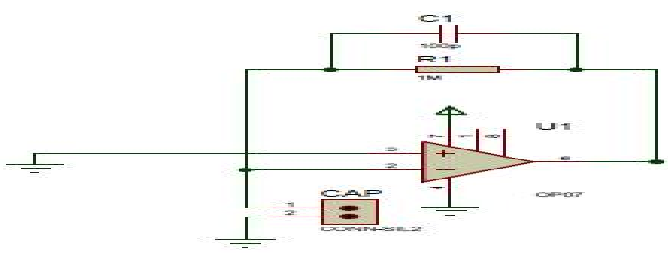

Figure II.8 : Bloc de trans- impédance.

II.4.1.2 Filtrage du signal

Pour obtenir un signal exploitable, il faut utiliser un circuit de filtrage qui pourra être choisis selon les composantes utilisé et la structure sur laquelle il est construit .selon ces conditions ils se divisent on deux familles :

Filtres passifs : ils sont réalisés autour de composants passifs (Resistances, condensateurs, selfs ……..) le gain utilisé est égale à la tension de sortie.

Filtre actifs : Ils sont conçus autour d'un amplificateur opérationnel.

Dans notre circuit on utilise un filtragepasse bande et passe bascomme lemontre les figures(II.9 et II.11).

II.4.1.2.1Filtre passe bande

Le filtres passe bande n'est pas connecté à GND, mais à 1 V référence, pour augmenter le décalage du signal mesuré pour un traitement ultérieur.

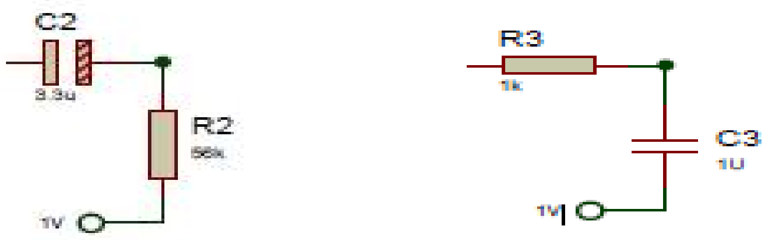

Figure II.9 : Filtre passe bande.

Calcule de fréquence de coupureFc1 et Fc2

$F_{C1} = 1/2*3,14*R_2*C_2$ II.1

$F_{c1}=1/2*3,14*56*10^3*3,3*10^{-6}$

$\mathbf{F_{C1} = 0,86Hz}$

$F_{C2} = 1/2*3,14*R_3*C_3$ II.2

$F_{c2}=1/2*3,14*1*10^3*1*10^{-6}$

$\mathbf{F_{C2} = 159Hz}$

Ce filtre laisse passer une bande de fréquence comprise [0,86Hz-159Hz].

Calcul du gain :

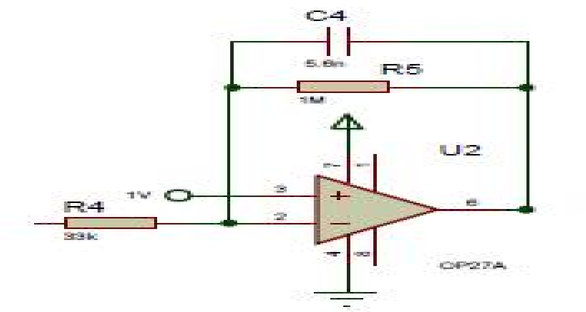

Figure II.10: Amplificateur inverseur.

G = R5/R4 II.3

G=30

II.3.2.1.2Filtre passe bas

On a utilisé un filtre passe bas qui sert à laisser passer les basses fréquences et atténue les hauts fréquences. Le filtre passe bas utiliser est donné par le schéma suivant :

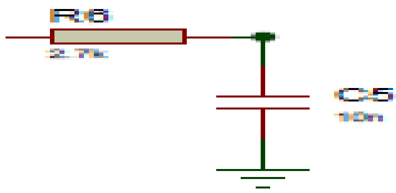

Figure II.11 : Filtre passe bas.

Calcul de la fréquence de coupure :

Fc=1/2*3,14*R6*C5 III.4

Fc= 1 /2*3,14*2,7K*10n

Fc=5,9Hz

Le signal filtré issue de deuxième filtre est injecté dans un autre bloc qui à pour but de comparer la différence de potentiel électrique présente à son entrée avec une référence. Ce bloc est un comparateur de type LM358.

II.4.1.3 Etude du comparateur

Le LM358 est un double circuit intégré amplificateur opérationnel de faible puissance à l'origine introduit par National Semi-conducteur. Il est utilisé dans les circuits de détection. Le LM358 indique un circuit intégré à 8 broches, comprenant deux amplificateurs opérationnels à faible puissance. Il est conçu pour une utilisation générale que des amplifications, filtres [30].

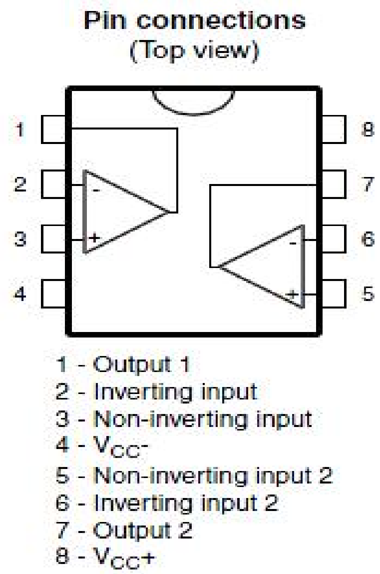

Figure II.12 : Description de LM358 [30].

Le LM358 possède une tension d'alimentation totale VCC de 32Vmaximum, la série LM358 peut être directement alimentéeà partir de la tension d'alimentation standard + 5V de puissance.

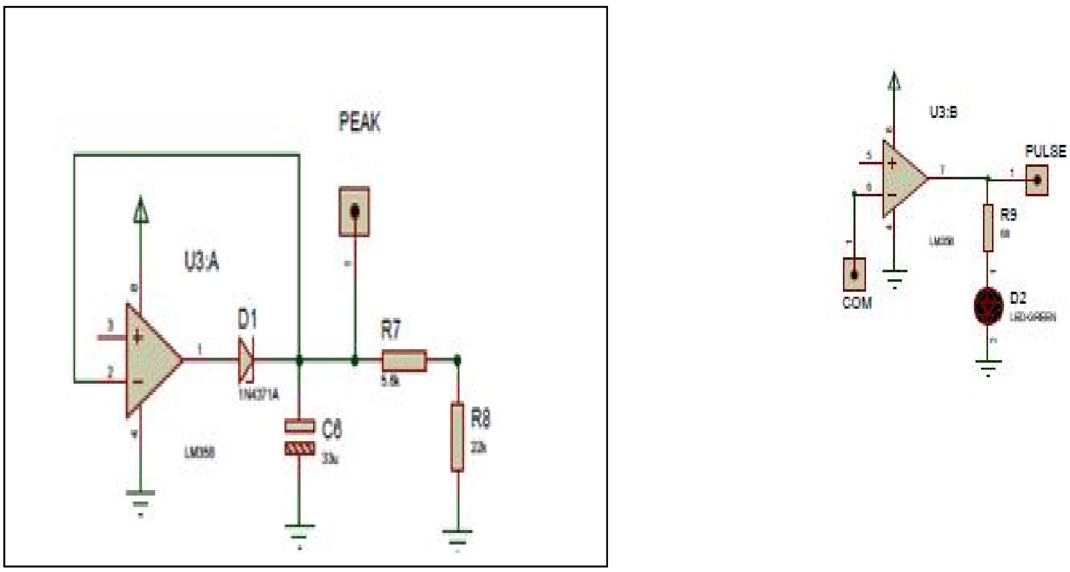

Figure II.13 : La détection de Peak et pulse.

L'entrée négative du comparateur U3.B est reliée au signal modifié à l'aide du circuit détecteur de crête. Les composantsU3.A, D1 et C6 sont utilisés pour détecter et maintenir la tension maximale du signal d'entrée. R7 et R8 sont déchargent le condensateur C6. Ce circuit est utilisé pour la tension de référence, ce qui permet la détection des impulsions, même faibles provoqués par les changements brusques de position du capteur sur le corps.

III.4.1.4 Circuit de tension de référence 1v

La tension de référence est créée en utilisant le LM4040-N et par le diviseur de tension (R15, R16).

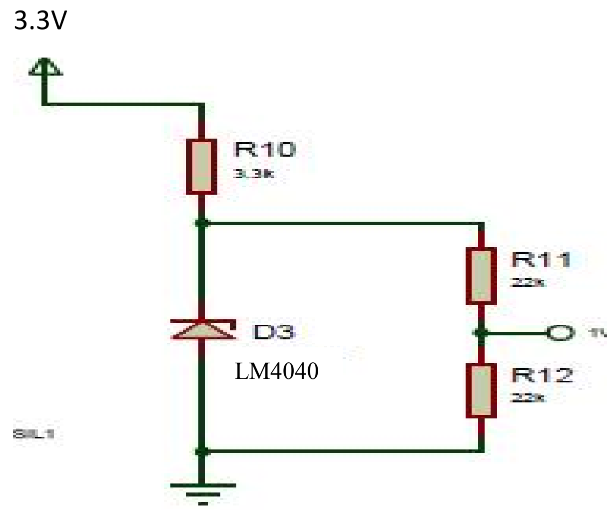

Figure II.14 : Circuit de tension de référence.

II.5 Partie numérique

II.5.1 La Carte LINKLT ONE

La carte Seeed studio LINKIT ONE compatible Arduino est équipée des fonctions GSM, GPRS, Wifi, Bluetooth BR/EDR/BLE, GPS et Audio. Elle dispose d'un port micro-SD pour le stockage et d'un port pour carte SIM [31].

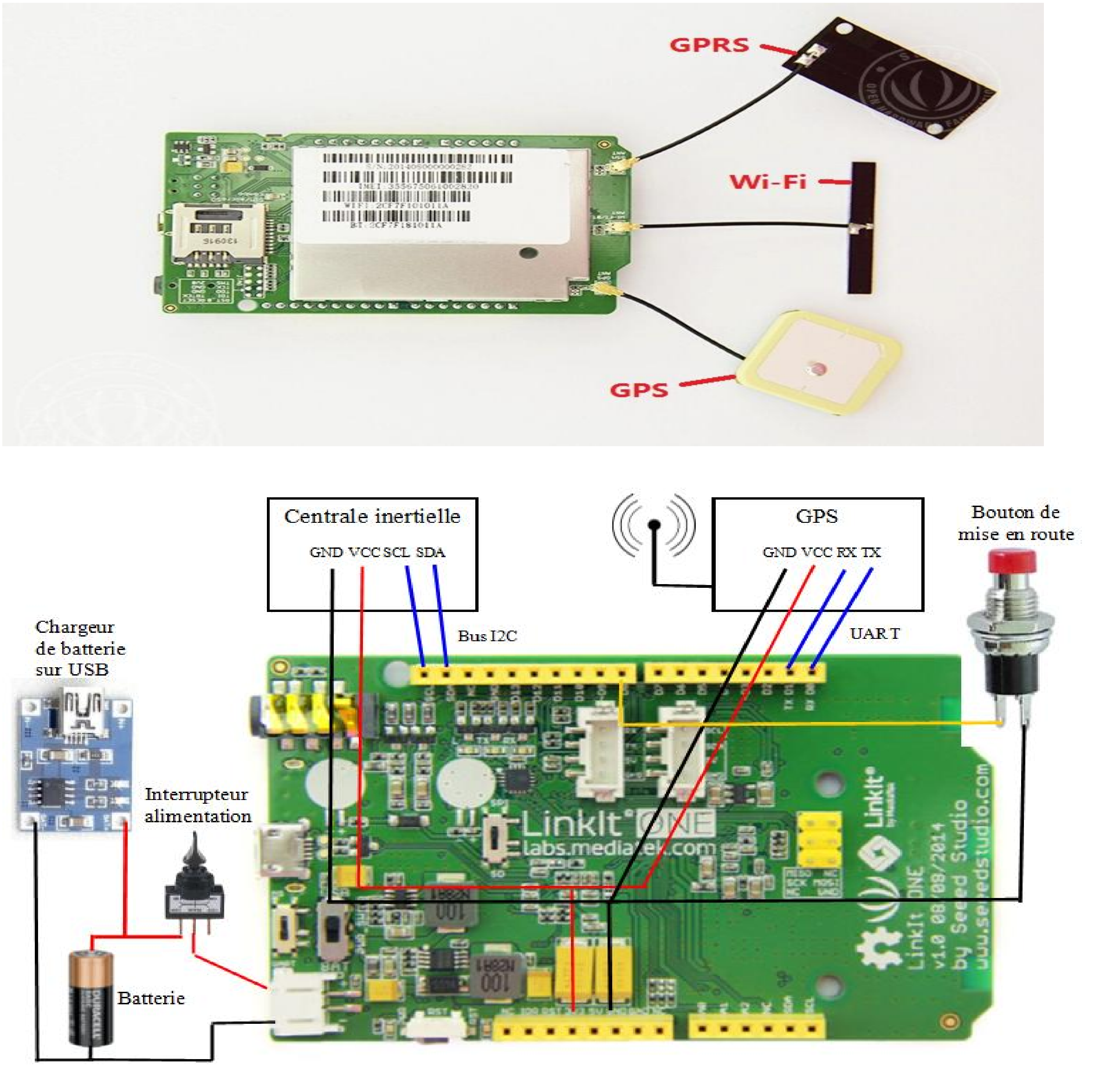

Figure II.15 : Description de la carte LINKIT ONE [31].

Elle est basée sur un MT2502A ARM7 EJ-S cadencé à 260 MHz. Les connecteurs latéraux compatibles Arduino permettent d'utiliser la plupart des shields disponibles et deux connecteurs Grove sont disponibles pour le raccordement de capteurs.

Elle est livrée avec un accu Li-ion 1000 mAh et les 3 antennes de réception (GPS, GSM et Wifi/Bluetooth). Cette carte a été spécialement développée pour des applications d'internet des objets et des vêtements connectés.

Cette carte peut se programmer avec le logiciel Arduino. Le contrôleur contient un boot loader qui permet de modifier le programme sans passer par un programmateur.

Remarque:

Les entrées/sorties digitales fonctionnent sous 3,3 V et les entrées analogiques sous 5 V, il est recommandé de bien vérifier la compatibilité des différents modules.

II.5.1.1 Caractéristique principales de la Carte

LINKIT ONE conseil de développement fournit une configuration pin-out similaire à l'Arduino UNO, comme représenté sur la figure II.16

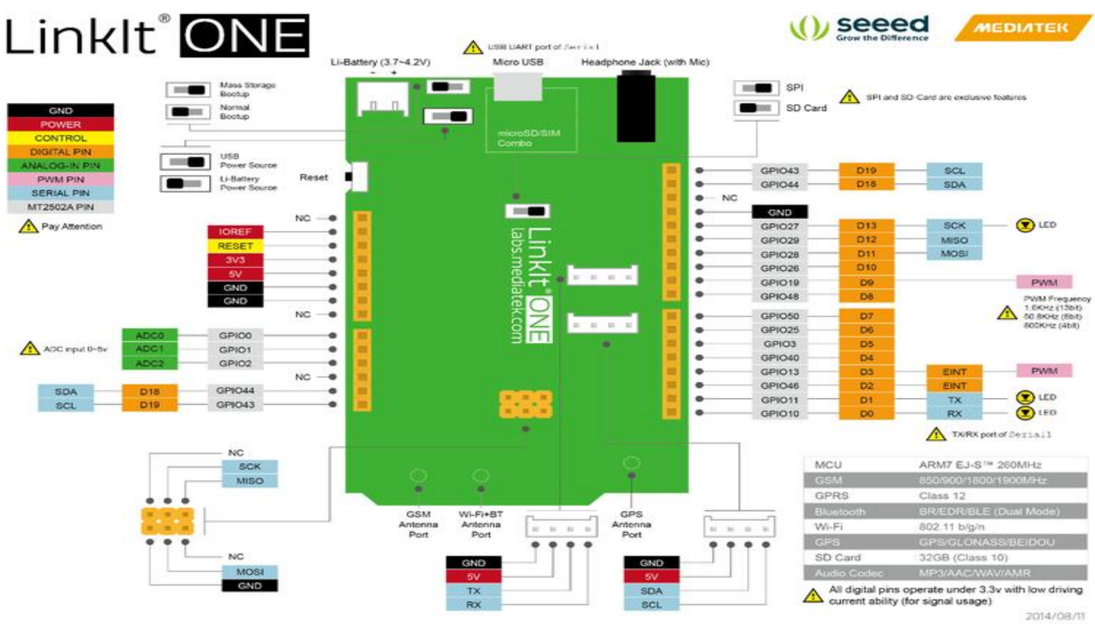

Figure II.16 : Diagramme de la carte.

II.5.1.2 Configuration de commutateur

Il y a 3 commutateurs à glissière sur LINKIT ONE qui sont utilisés pour configurer le / mode de fonctionnement de la fonction :

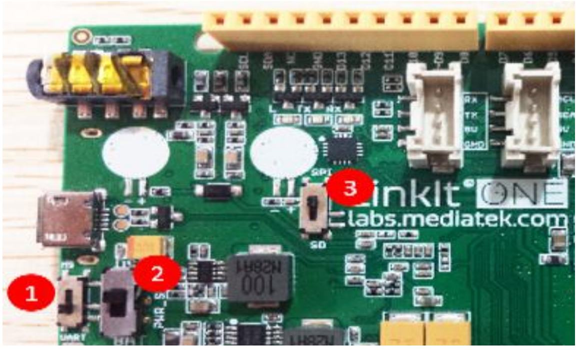

Figure II.17 : illustration de commutateur.

Commutateur n °	Fonctionnalité	Position 1 - Fonctionnalité	Position 2 - Fonctionnalité
1	Mode Programme	MS: Dans cette position, lorsqu'il est connecté à un PC, LINKIT Une carte se affichée en tant que lecteur 10Mo USB. Le programme ne sera pas exécuté dans ce mode. Tout fichier qui est copié sur ce disque peut être lu via le code.	UART: Cette position est utilisée pour définir la carte en mode programme. Le logiciel peut être téléchargé dans ce mode.
2	Puissance	BAT: Conseil alimenté par batterie Li-ion. Pour charger la batterie, réglez le commutateur sur cette position et connecter la carte au PC.	USB: Carte alimentée par le port USB. Réglez le commutateur sur cette position quand il n'y a pas de batterie connecté à programmer la carte.
3	SD/SPI	SPI: Cette position permet l'accès des broches externes SPI (D10 - D13)	SD: Cette position permet le code pour accéder à la carte SD. Ce mode désactive également l'accès des broches SPI (D10-D13).

Tableau II .2 : configuration de commutateur [31].

II.5.1.3 Insertion carte SIM et de la carte SD

LINKIT ONE accepte la taille standard de carte SIM et la carte Micro SD. Comme montre la figure ci-dessous :

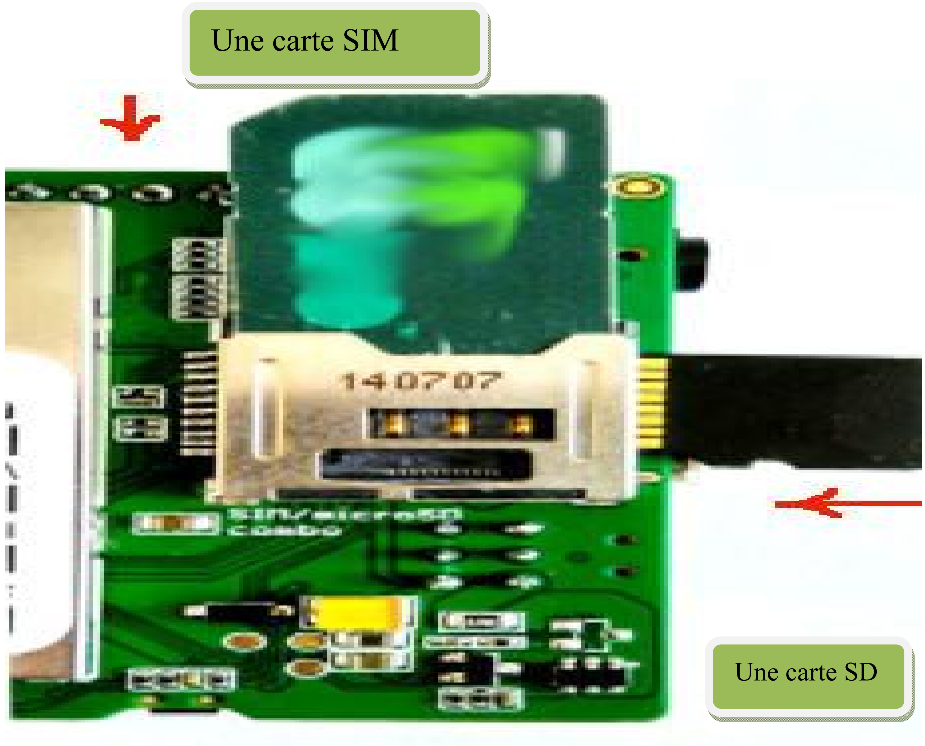

Figure II.18 : insertion la carte SIM et SD.

Le tableau représente la spécification des détails de la carte de développement LINKITONE

Catégorie	Fonction	spéciation
Microcontrôleur	Chipset	t MT2502A (Aster)
	Noyau	ARM7 EJ-STM
	Vitesse d'horloge	2600MHZ
PCB taille	Dimension	3,3*2,1 pouces
Mémoire	Flash	16MB
	RAM	4MB
Power	Jack Battery	3.7 ~ 4.2V
	Courant DC Per I O Pin	0,3 ~ 3mA /
Numérique IO Pins	Pin Count 16	D0 ~ D13, SDA, SCL
	Tension	3.3v
Entrée analogique Pins	Pin Count 3	ADC0, ADC1, CAN2

	Tension	0 ~ 5V
	Tension	3,3v
	Résolution Max	13Bit personnalisable
	Max Fréquence @ Résolution	1.6kHz@13bit 50.8kHz@8bit 800kHz @ 4bit personnalisable
Interruptions externes	Pin Count	2 D2 et D3
I2C (Maître uniquement)	Set Count	1 SDA, SCL
	Vitesse	100Kbps, 400 Kbps, 3.4Mbps
SPI (Maître uniquement)	Set Count	1 D11 (MOSI), D12 (MISO), D13 (SCK)
	Vitesse	104Kbps ~ 26Mbps
UART (Serial1)	Set count	1 D0 (RX), D1 (TX)
	Tension	3,3v
UART sur USB (série)	Set count	1
Communications	GSM/GPRS	850/900/1800/1900 MHz
	GPRS	Classe 12
	Bluetooth	BR / EDR / BLE (Dual Mode)
	Wifi	802.11 b / g / n
Positionnement	GPS	GPS / GLONASS / BEIDOU
Utilisateur de stockage	Flash	10MB
	Carte SD	jusqu'à 32 Go (Classe 10)

Tableau II.3 :Caractéristiques principale de la carte [31].

II.5.2 Organigramme :

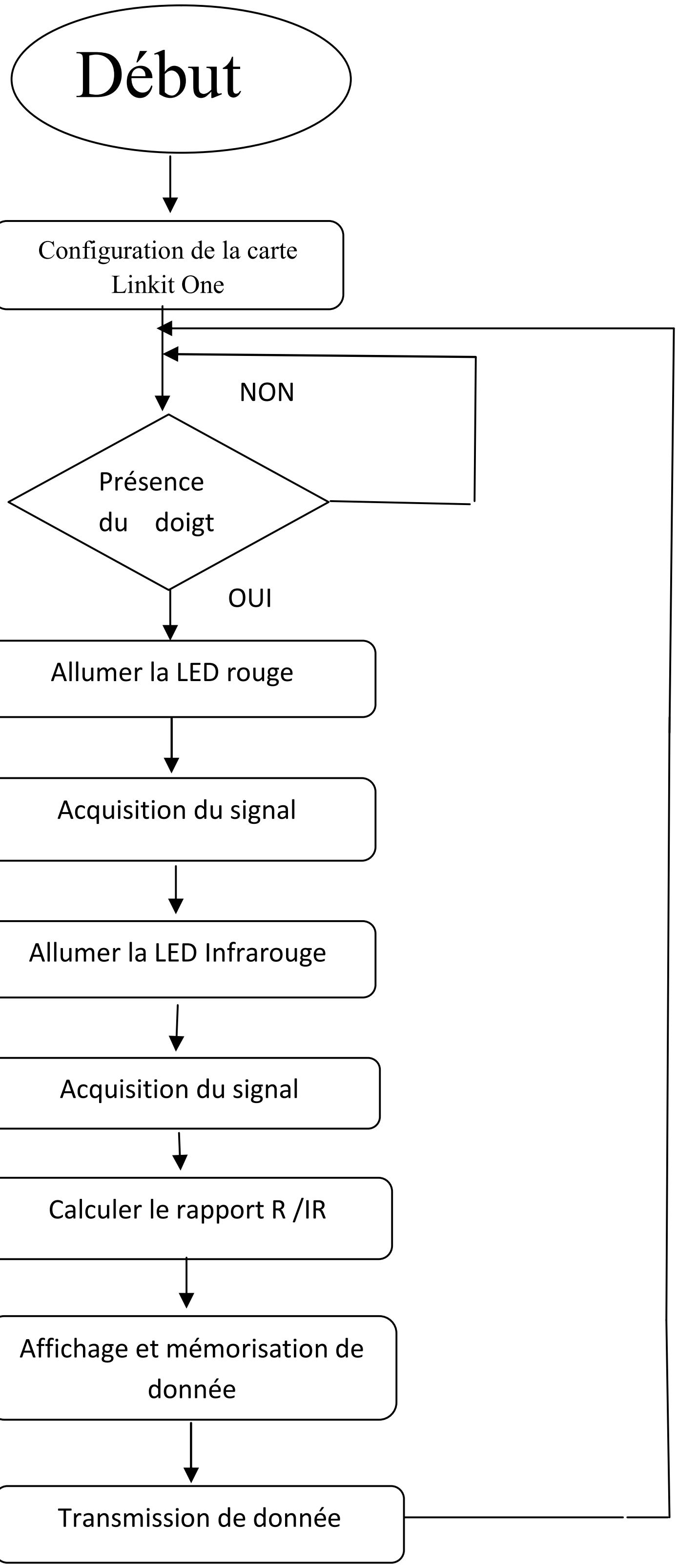

Figure II.19 : Organigramme de programmation.

Chapitre III

Introduction

Dans ce chapitre, une étude pratique détaillée du dispositif qu'on a réalisé est présentée. Cette étude pratique est composée d'un ensemble de tests surles différents blocs constituant le dispositif.

III.1 Principe de fonctionnement

Les LEDs lumineuses (LED rouge, Infrarouge) sont reliées chacune d'elle à une sortie de la carte LINKIT ONE, cette dernière génère un signal carrée de base fréquence compris entre (10 - 40Hz), de ce fait une lumière de couleur rouge et un faisceau Infrarouge sont transmit vers la photodiode la figure ci- dessous illustre.

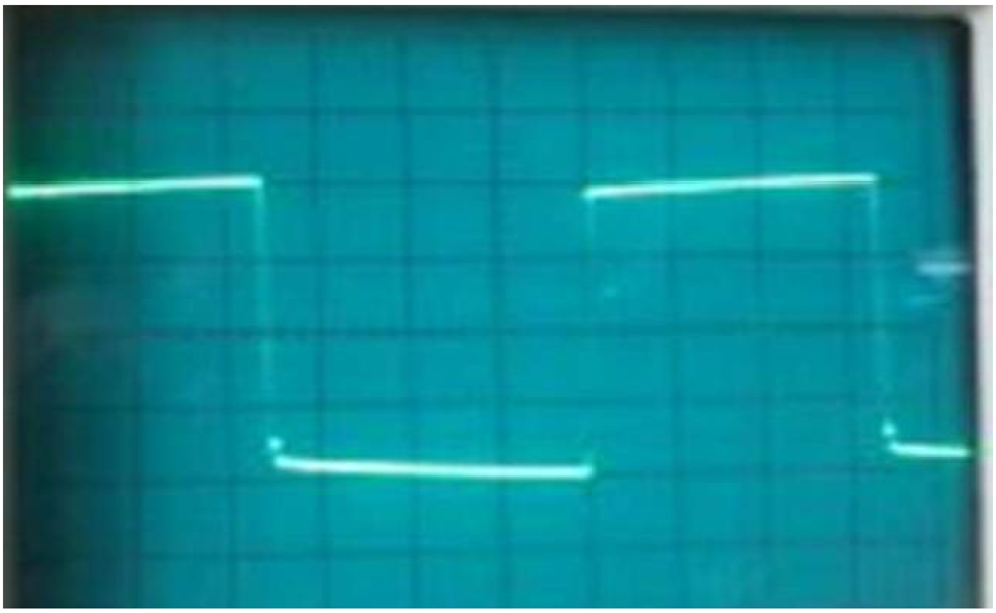

Figure III.1 : le signal de commande à l'entrée.

L'ampli opérationnel U1 est montéen trans-impédance, et à la sortie de cet adaptateur impédance, on recueille un signal proportionnel à la quantité d'oxygénation du sang avec un gain unitaire.

Le signal issue de U1 est filtré par un passe haut afin d'éliminer les fréquences élevées puis un second filtre de type passe bas poursupprimer les basses fréquences, puis le signal est dirigée vers un amplificateur de tension dont le gain de cet amplificateur est déterminée à l'aide du condensateur C4.

III.2 Matériels utilisés

Nous avonseffectué nos essais dans le labo maquette du département, les appareils qu'on a utilisés sont :

a- Oscilloscope : Pourvisualiser nos signaux on a utilisé l'oscilloscope.

b- L'alimentation : Ona utilisé un générateur qui délivre 5V.

c-Multimètre : Tester les composants qu'on a utilisé.

III.3 Système réalisésur lab d'essai

La figure ci-dessous montre le système qu'on a réalisé monté sur lab d'essai.

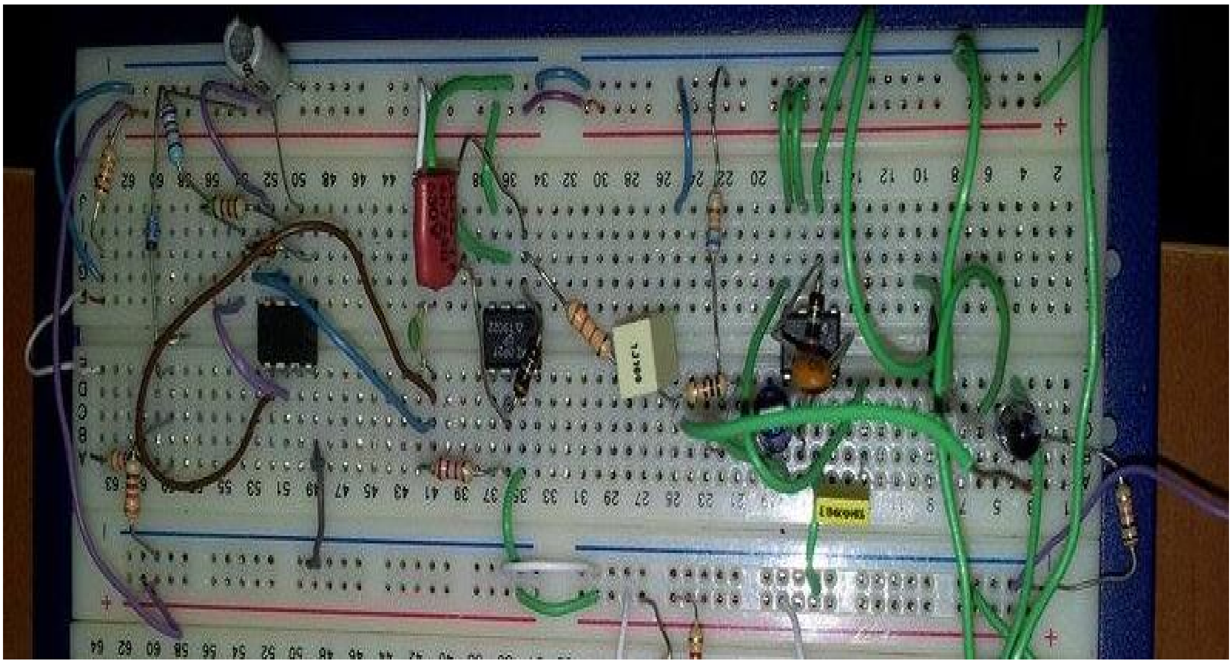

Figure III.2:Photo du dispositif lors de son développement sur labd'essai.

III.3 Circuit imprimé

Les deux figures suivantesprésentent respectivement le typon du circuit, et une vue 3D du schémad'implantation des composants de la carte électronique.

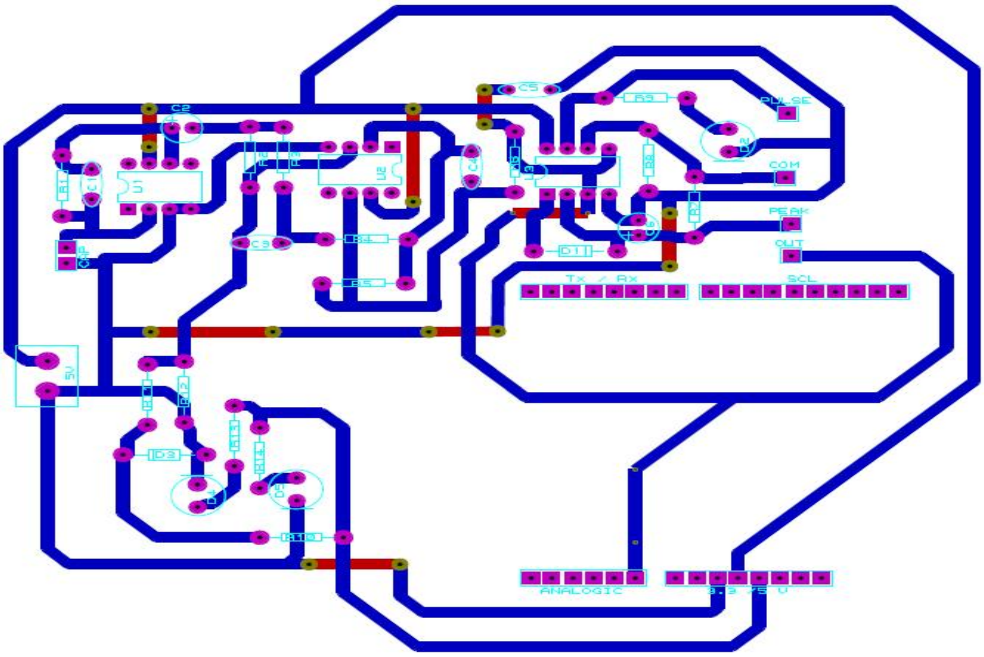

Figure III.3: le circuit imprimé du dispositif.

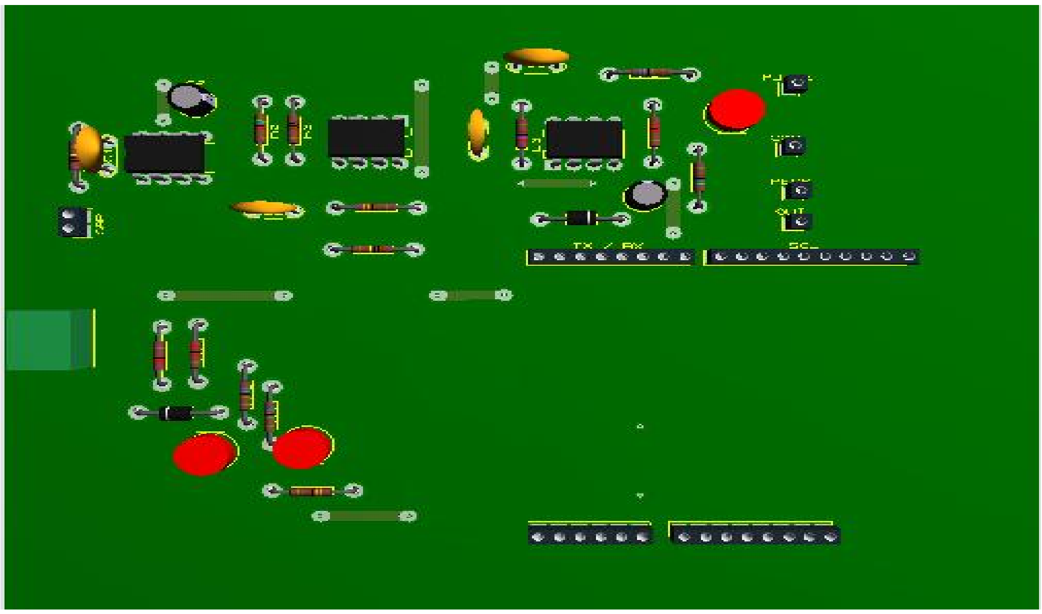

Figure III. 4 : Vu 3D du schéma d'implantation des composants de la carte électronique.

III.4 La liste des composants utilisés pour le système

Les composants	La qualité	La valeur	La quantité
Resistances	**R1, R5**	**1M**	**2**
	R2	**56K**	**1**
	R3	**1K**	**1**
	R4	**33K**	**1**
	R6	**2,7K**	**1**
	R7	**5,6K**	**1**
	R8, R10, R11, R12	**22K**	**4**
	R9, R13, R14	**68R**	**3**
Photodiode	**VBP104SR**		**1**
Diode Schottky	**1N5712**	**1V**	**1**
Diode Zener	**IN4731A**	**2,04V**	**1**
Amplificateur	**LM358**	**Max 23V**	**1**
	Op07		**1**
	OP27	**15V**	**1**
Les LEDs	**LED Rouge**	**1,6v**	**1**
	LED infra-rouge	**1,6V**	**1**
Capacités	**C1**	**1OOp**	**1**
	C2	**3,3u**	**1**
	C3	**1u**	**1**
	C4	**5,6n**	**1**
	C5	**10n**	**1**
	C6	**2,7u**	**1**

Tableau III.1 : la liste des composants.

III.5.Les résultats obtenus sur l'oscilloscope

III.5.1Bloc de trans-impédance

Après des essais, le signal obtenu à la sortie du capteurest visualisé à l'oscilloscope comme le montrela figure suivante :

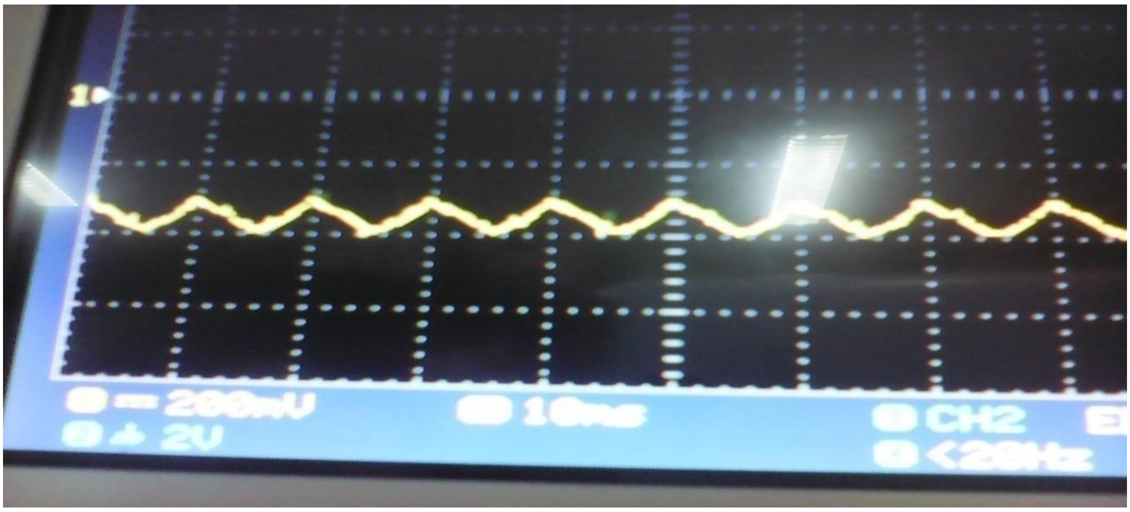

Figure III.5 : le signal à la sortie ducapteur.

III.5.2. le signal de sortie du système

Le signal de sortie est visualisé sur l'oscilloscope, on a vu que ce signal est bruitée.

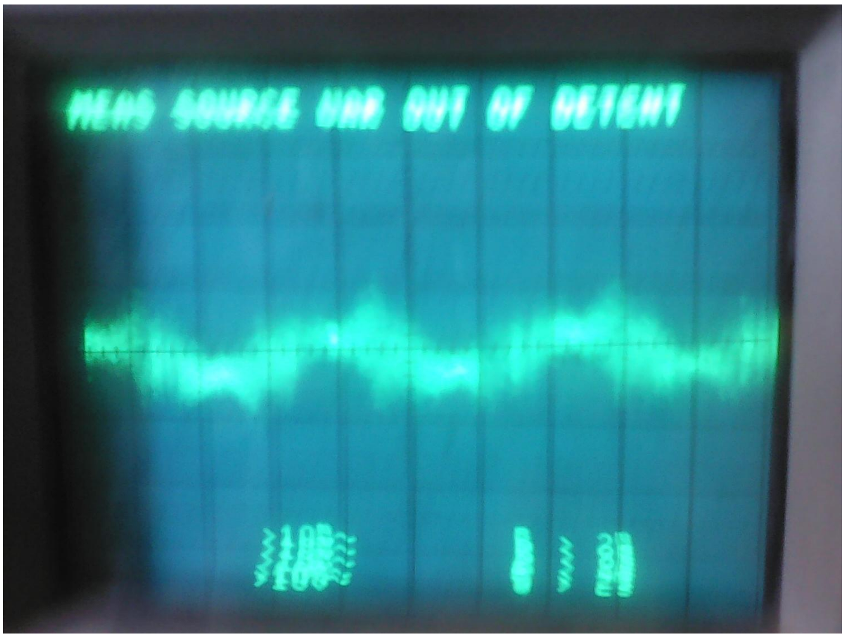

Figure III.6: signal final bruitée.

Le signal de sortie du système qui devrait être obtenu se présente comme illustré sur la **figure III.7** [32].

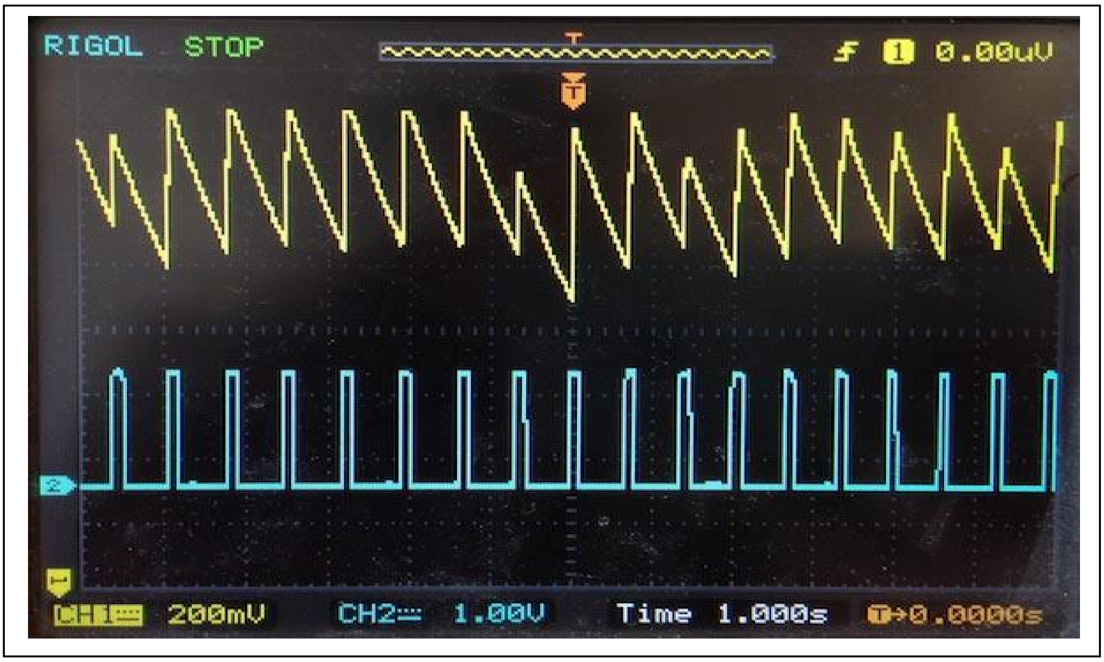

Figure III.7 : La sortie dépendant du temps tension nœuds COMP (CH1) et Pulse(CH2).

(Signal final non bruitée)[32].

III.6 Carte réalisé

Cette photo montre la carte qu'on a réalisé, elle est constituée de trois blocs nécessaires ;

- ✓ Capteur.
- ✓ La carte électronique réalisable.
- ✓ La carte LINKIT ONE.

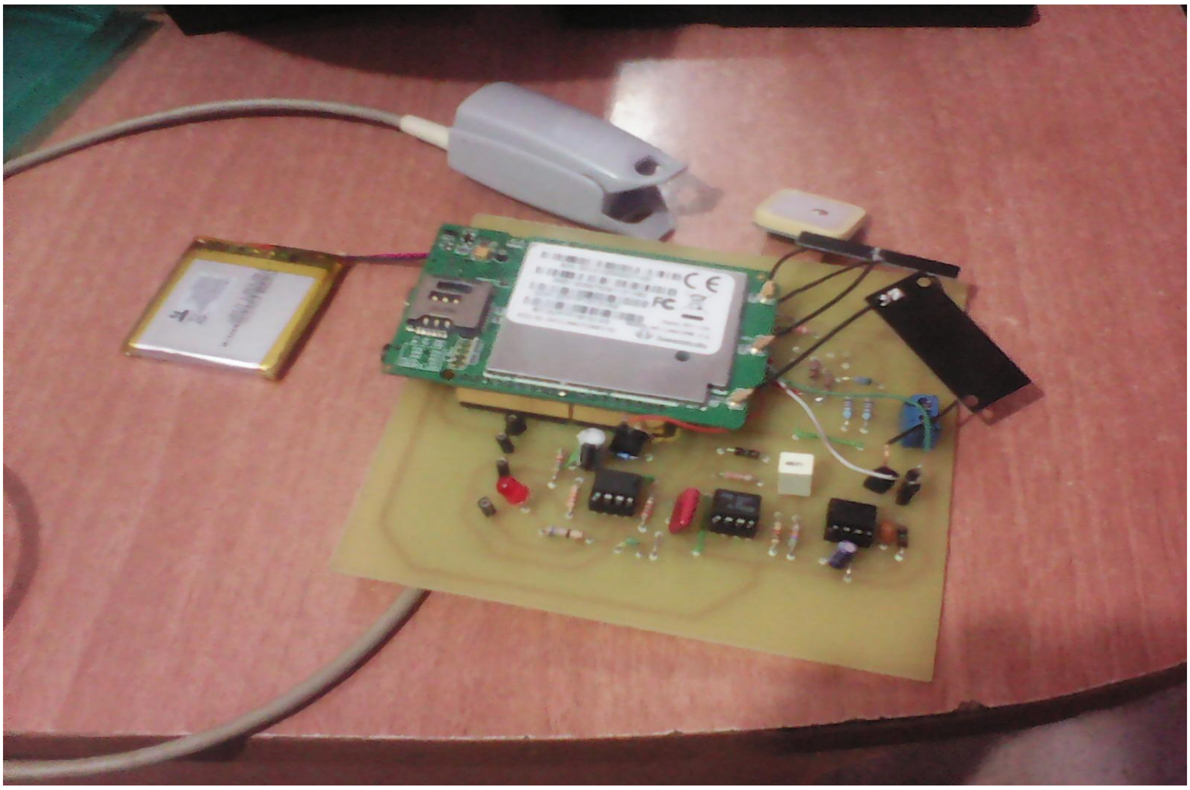

Figure III.8 la carte réalisable.

Conclusion Générale

Conclusion générale

Dans notre projet de fin d'études, nous avons réalisé un Oxymètre de pouls qui permet de mesurer la saturation périphérique en oxygène (SpO_2) ainsi que le rythme cardiaque. Le circuit de mise en forme réalisé consiste en deux parties élémentaires. Une première partie analogique et une autre numérique.

La partie analogique constitue d'une sonde optique, de circuits analogiques de mise en forme ; en particulier un circuit amplificateur branché avec le photo détecteur afin d'obtenir le signal. La photo détectrice utilisée est une photodiode permettant d'améliorer la qualité du signal que l'on recueillir à travers elle. Un circuit de filtrage est aussi réalisé afin de réduire les bruits qui pouvant affecter le signal recueilli. On utilise la carte Linkit one pour le traitement des données et la transmission via le wifi.

Ce travail nous a permis d'approfondir nos connaissances dans le domaine d'acquisition de signaux et le développement des cartes électroniques. Il pourrait être amélioré en utilisant des composantsplus performants.

Ce travail reste ouvert sur plusieurs perspectives :

- Développement de la partie transmission de données via Bluetooth, WIFI, GPS, GPRS,
- fonctionnement en lignes- et hors lignes pour faire un Oxymètre de pouls connecté

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Annexes

LMx58-N Low-Power, Dual-Operational Amplifiers

1 Features

- Available in 8-Bump DSBGA Chip-Sized Package, (See AN-1112, SNVA009)
- Internally Frequency Compensated for Unity Gain
- Large DC Voltage Gain: 100 dB
- Wide Bandwidth (Unity Gain): 1 MHz (Temperature Compensated)
- Wide Power Supply Range:
  – Single Supply: 3V to 32V
  – Or Dual Supplies: ±1.5V to ±16V
- Very Low Supply Current Drain (500 μA)—Essentially Independent of Supply Voltage
- Low Input Offset Voltage: 2 mV
- Input Common-Mode Voltage Range Includes Ground
- Differential Input Voltage Range Equal to the Power Supply Voltage
- Large Output Voltage Swing
- Unique Characteristics:
  – In the Linear Mode the Input Common-Mode Voltage Range Includes Ground and the Output Voltage Can Also Swing to Ground, even though Operated from Only a Single Power Supply Voltage.
  – The Unity Gain Cross Frequency is Temperature Compensated.
  – The Input Bias Current is also Temperature Compensated.
- Advantages:
  – Two Internally Compensated Op Amps
  – Eliminates Need for Dual Supplies
  – Allows Direct Sensing Near GND and V_{OUT} Also Goes to GND
  – Compatible with All Forms of Logic
  – Power Drain Suitable for Battery Operation

2 Applications

- Active Filters
- General Signal Conditioning and Amplification
- 4- to 20-mA Current Loop Transmitters

3 Description

The LM158 series consists of two independent, high gain, internally frequency compensated operational amplifiers which were designed specifically to operate from a single power supply over a wide range of voltages. Operation from split power supplies is also possible and the low power supply current drain is independent of the magnitude of the power supply voltage.

Application areas include transducer amplifiers, dc gain blocks and all the conventional op-amp circuits which now can be more easily implemented in single power supply systems. For example, the LM158 series can be directly operated off of the standard 3.3-V power supply voltage which is used in digital systems and will easily provide the required interface electronics without requiring the additional ±15V power supplies.

The LM358 and LM2904 are available in a chip sized package (8-Bump DSBGA) using TI's DSBGA package technology.

Device Information(1)

PART NUMBER	PACKAGE	BODY SIZE (NOM)
LM158-N	TO-CAN (8)	9.08 mm x 9.09 mm
	CDIP (8)	10.16 mm x 6.502 mm
LM258-N	TO-CAN (8)	9.08 mm x 9.09 mm
LM2904-N	DSBGA (8)	1.31 mm x 1.31 mm
	SOIC (8)	4.90 mm x 3.91 mm
	PDIP (8)	9.81 mm x 6.35 mm
LM358-N	TO-CAN (8)	9.08 mm x 9.09 mm
	DSBGA (8)	1.31 mm x 1.31 mm
	SOIC (8)	4.90 mm x 3.91 mm
	PDIP (8)	9.81 mm x 6.35 mm

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

Voltage Controlled Oscillator (VCO)

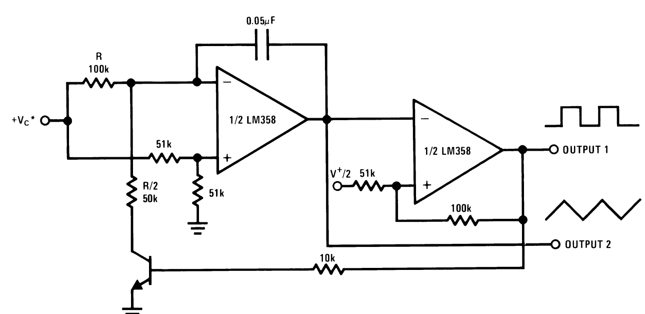


Table of Contents

4 Revision History

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

Changes from Revision H (March 2013) to Revision I — **Page**

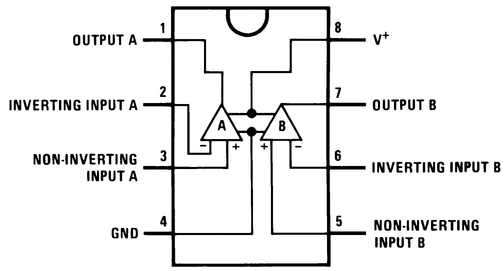
- Added *Pin Configuration and Functions* section, *ESD Ratings* table, *Feature Description* section, *Device Functional Modes*, *Application and Implementation* section, *Power Supply Recommendations* section, *Layout* section, *Device and Documentation Support* section, and *Mechanical, Packaging, and Orderable Information* section 1

Changes from Revision G (March 2013) to Revision H — **Page**

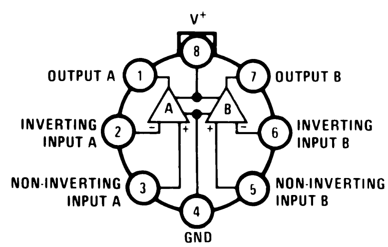
- Changed layout of National Data Sheet to TI format 25

5 Pin Configuration and Functions

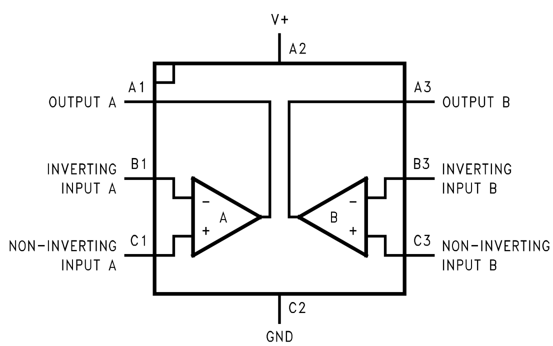
D, P, and NAB Package
8-Pin SOIC, PDIP, and CDIP
Top View



LMC Package
8-Pin TO-99
Top View



YPB Package
8-Pin DSBGA
Top View



Pin Functions

PIN			TYPE	DESCRIPTION
D/P/LMC NO.	DSBGA NO.	NAME		
1	A1	OUTA	O	Output , Channel A
2	B1	-INA	I	Inverting Input, Channel A
3	C1	+INA	I	Non-Inverting Input, Channel A
4	C2	GND / V-	P	Ground for Single supply configurations. negative supply for dual supply configurations
5	C3	+INB	I	Output, Channel B
6	B3	-INB	I	Inverting Input, Channel B
7	A3	OUTB	O	Non-Inverting Input, Channel B
8	A2	V+	P	Positive Supply

6 Specifications

6.1 Absolute Maximum Ratings

See [1][2][3].

			LM158, LM258, LM358, LM158A, LM258A, LM358A		LM2904		UNIT
			MIN	MAX	MIN	MAX	
Supply Voltage, V^+				32		26	V
Differential Input Voltage				32		26	V
Input Voltage			−0.3	32	−0.3	26	V
Power Dissipation[4]	PDIP (P)			830		830	mW
	TO-99 (LMC)			550			mW
	SOIC (D)			530		530	mW
	DSBGA (YPB)			435			mW
Output Short-Circuit to GND (One Amplifier)[5]	$V^+ \leq 15$ V and $T_A = 25°C$			Continuous		Continuous	
Input Current ($V_{IN} < −0.3V$)[6]				50		50	mA
Temperature			−55	125			°C
	PDIP Package (P): Soldering (10 seconds)			260		260	°C
	SOIC Package (D)	Vapor Phase (60 seconds)		215		215	°C
		Infrared (15 seconds)		220		220	°C
Lead Temperature	PDIP (P): (Soldering, 10 seconds)			260		260	°C
	TO-99 (LMC): (Soldering, 10 seconds)			300		300	°C
Storage temperature, T_{stg}			−65	150	−65	150	°C

(1) *Absolute Maximum Ratings* indicate limits beyond which damage to the device may occur. *Recommended Operating Conditions* indicate conditions for which the device is intended to be functional, but specific performance is not ensured. For ensured specifications and the test conditions, see the Electrical Characteristics.
(2) Refer to RETS158AX for LM158A military specifications and to RETS158X for LM158 military specifications.
(3) If Military/Aerospace specified devices are required, please contact the TI Sales Office/Distributors for availability and specifications.
(4) For operating at high temperatures, the LM358/LM358A, LM2904 must be derated based on a 125°C maximum junction temperature and a thermal resistance of 120°C/W for PDIP, 182°C/W for TO-99, 189°C/W for SOIC package, and 230°C/W for DSBGA, which applies for the device soldered in a printed circuit board, operating in a still air ambient. The LM258/LM258A and LM158/LM158A can be derated based on a +150°C maximum junction temperature. The dissipation is the total of both amplifiers—use external resistors, where possible, to allow the amplifier to saturate or to reduce the power which is dissipated in the integrated circuit.
(5) Short circuits from the output to V^+ can cause excessive heating and eventual destruction. When considering short circuits to ground, the maximum output current is approximately 40 mA independent of the magnitude of V^+. At values of supply voltage in excess of +15 V, continuous short-circuits can exceed the power dissipation ratings and cause eventual destruction. Destructive dissipation can result from simultaneous shorts on all amplifiers.
(6) This input current will only exist when the voltage at any of the input leads is driven negative. It is due to the collector-base junction of the input PNP transistors becoming forward biased and thereby acting as input diode clamps. In addition to this diode action, there is also lateral NPN parasitic transistor action on the IC chip. This transistor action can cause the output voltages of the op amps to go to the V^+voltage level (or to ground for a large overdrive) for the time duration that an input is driven negative. This is not destructive and normal output states will re-establish when the input voltage, which was negative, again returns to a value greater than −0.3 V (at 25°C).

6.2 ESD Ratings

			VALUE	UNIT
$V_{(ESD)}$	Electrostatic discharge	Human-body model (HBM), per ANSI/ESDA/JEDEC JS-001[1]	±250	V

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

6.3 Recommended Operating Conditions

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

	MIN	MAX	UNIT
Supply Voltage (V+ - V-):LM158. LM258, LM358	3 (±1.5)	32 (±16)	V
Supply Voltage (V+ - V-):LM2904	3 (±1.5)	26 (±13)	V
Operating Temperature: LM158	-55	125	°C
Operating Temperature: LM258	-25	85	°C
Operating Temperature: LM358	0	70	°C
Operating Temperature: LM2904	-40	85	°C

6.4 Thermal Information

THERMAL METRIC(1)		LM158-N, LM258-N, LM358-N	LM158-N	LM2904-N, LM358-N			UNIT
		LMC	NAB	YPB	D	P	
		8 PINS					
$R_{\theta JA}$	Junction-to-ambient thermal resistance	155	132	230	189	120	°C/W

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

6.5 Electrical Characteristics: LM158A, LM358A, LM158, LM258

V^+ = +5.0 V, See(1), unless otherwise stated

PARAMETER	TEST CONDITIONS	LM158A			LM358A			LM158, LM258			UNIT
		MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
Input Offset Voltage	See(2), T_A = 25°C		1	2		2	3		2	5	mV
Input Bias Current	$I_{IN(+)}$ or $I_{IN(-)}$, T_A = 25°C,		20	50		45	100		45	150	nA
	V_{CM} = 0 V,(3)										
Input Offset Current	$I_{IN(+)} - I_{IN(-)}$, V_{CM} = 0V, T_A = 25°C		2	10		5	30		3	30	nA
Input Common-Mode	V^+ = 30 V,(4)	0		V^+−1.5	0		V^+−1.5	0		V^+−1.5	V
Voltage Range	(LM2904, V^+ = 26V), T_A = 25°C										
Supply Current	Over Full Temperature Range										
	R_L = ∞ on All Op Amps										
	V^+ = 30V (LM2904 V^+ = 26V)		1	2		1	2		1	2	mA
	V^+ = 5V		0.5	1.2		0.5	1.2		0.5	1.2	mA
Large Signal Voltage Gain	V^+ = 15 V, T_A = 25°C, R_L ≥ 2 kΩ, (For V_O = 1 V to 11 V)	50	100		25	100		50	100		V/mV
Common-Mode	T_A = 25°C,	70	85		65	85		70	85		dB
Rejection Ratio	V_{CM} = 0 V to V^+−1.5 V										
Power Supply	V^+ = 5 V to 30 V	65	100		65	100		65	100		dB
Rejection Ratio	(LM2904, V^+ = 5 V to 26 V), T_A = 25°C										

(1) These specifications are limited to –55°C ≤ T_A ≤ +125°C for the LM158/LM158A. With the LM258/LM258A, all temperature specifications are limited to −25°C ≤ T_A ≤ 85°C, the LM358/LM358A temperature specifications are limited to 0°C ≤ T_A ≤ 70°C, and the LM2904 specifications are limited to –40°C ≤ T_A ≤ 85°C.
(2) V_O ≃ 1.4 V, R_S = 0 Ω with V^+ from 5 V to 30 V; and over the full input common-mode range (0 V to V^+ −1.5 V) at 25°C. For LM2904, V^+ from 5 V to 26 V.
(3) The direction of the input current is out of the IC due to the PNP input stage. This current is essentially constant, independent of the state of the output so no loading change exists on the input lines.
(4) The input common-mode voltage of either input signal voltage should not be allowed to go negative by more than 0.3 V (at 25°C). The upper end of the common-mode voltage range is V^+ −1.5 V (at 25°C), but either or both inputs can go to 32 V without damage (26 V for LM2904), independent of the magnitude of V^+.

Electrical Characteristics: LM158A, LM358A, LM158, LM258 (continued)

$V^+ = +5.0$ V, See(1), unless otherwise stated

PARAMETER		TEST CONDITIONS	LM158A			LM358A			LM158, LM258			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
Power Supply Rejection Ratio		$V^+ = 5$ V to 30 V (LM2904, $V^+ = 5$ V to 26 V), $T_A = 25°C$	65	100		65	100		65	100		dB
Amplifier-to-Amplifier Coupling		f = 1 kHz to 20 kHz, $T_A = 25°C$ (Input Referred), See(5)		−120			−120			−120		dB
Output Current	Source	$V_{IN}^+ = 1$ V, $V_{IN}^- = 0$ V, $V^+ = 15$ V, $V_O = 2$ V, $T_A = 25°C$	20	40		20	40		20	40		mA
	Sink	$V_{IN}^- = 1$ V, $V_{IN}^+ = 0$ V, $V^+ = 15$ V, $T_A = 25°C$, $V_O = 2$ V	10	20		10	20		10	20		mA
		$V_{IN}^- = 1$ V, $V_{IN}^+ = 0$ V, $T_A = 25°C$, $V_O = 200$ mV, $V^+ = 15$ V	12	50		12	50		12	50		µA
Short Circuit to Ground		$T_A = 25°C$, See(6), $V^+ = 15$ V		40	60		40	60		40	60	mA
Input Offset Voltage		See(2)			4			5			7	mV
Input Offset Voltage Drift		$R_S = 0Ω$		7	15		7	20		7		µV/°C
Input Offset Current		$I_{IN(+)} − I_{IN(−)}$			30			75			100	nA
Input Offset Current Drift		$R_S = 0Ω$		10	200		10	300		10		pA/°C
Input Bias Current		$I_{IN(+)}$ or $I_{IN(−)}$		40	100		40	200		40	300	nA
Input Common-Mode Voltage Range		$V^+ = 30$ V, See(4) (LM2904, $V^+ = 26$ V)	0		$V^+−2$	0		$V^+−2$	0		$V^+−2$	V
Large Signal Voltage Gain		$V^+ = +15$ V ($V_O = 1$ V to 11 V) $R_L \geq 2$ kΩ	25			15			25			V/mV
Output Voltage Swing	V_{OH}	$V^+ = +30$ V, $R_L = 2$ kΩ	26			26			26			V
		(LM2904, $V^+ = 26$ V), $R_L = 10$ kΩ	27	28		27	28		27	28		V
	V_{OL}	$V^+ = 5$V, $R_L = 10$ kΩ		5	20		5	20		5	20	mV
Output Current	Source	$V_{IN}^+ = +1$ V, $V_{IN}^- = 0$ V, $V^+ = 15$ V, $V_O = 2$ V	10	20		10	20		10	20		mA
	Sink	$V_{IN}^- = +1$ V, $V_{IN}^+ = 0$ V, $V^+ = 15$ V, $V_O = 2$ V	10	15		5	8		5	8		mA

(5) Due to proximity of external components, insure that coupling is not originating via stray capacitance between these external parts. This typically can be detected as this type of capacitance increases at higher frequencies.
(6) Short circuits from the output to V^+ can cause excessive heating and eventual destruction. When considering short circuits to ground, the maximum output current is approximately 40 mA independent of the magnitude of V^+. At values of supply voltage in excess of +15 V, continuous short-circuits can exceed the power dissipation ratings and cause eventual destruction. Destructive dissipation can result from simultaneous shorts on all amplifiers.

6.6 Electrical Characteristics: LM358, LM2904

V^+ = +5.0 V, See (1), unless otherwise stated

PARAMETER		TEST CONDITIONS	LM358			LM2904			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	
Input Offset Voltage		See (2) , T_A = 25°C		2	7		2	7	mV
Input Bias Current		$I_{IN(+)}$ or $I_{IN(−)}$, T_A = 25°C, V_{CM} = 0 V, See (3)		45	250		45	250	nA
Input Offset Current		$I_{IN(+)}$ − $I_{IN(−)}$, V_{CM} = 0 V, T_A = 25°C		5	50		5	50	nA
Input Common-Mode Voltage Range		V^+ = 30 V, See (4) (LM2904, V^+ = 26 V), T_A = 25°C	0		V^+−1.5	0		V^+−1.5	V
Supply Current		Over Full Temperature Range							
		R_L = ∞ on All Op Amps							
		V^+ = 30 V (LM2904 V^+ = 26 V)		1	2		1	2	mA
		V^+ = 5 V		0.5	1.2		0.5	1.2	mA
Large Signal Voltage		V^+ = 15V, T_A = 25°C,							
Gain		R_L ≥ 2 kΩ, (For V_O = 1 V to 11 V)	25	100		25	100		V/mV
Common-Mode Rejection Ratio		T_A = 25°C, V_{CM} = 0 V to V^+−1.5 V	65	85		50	70		dB
Power Supply Rejection Ratio		V^+ = 5 V to 30 V (LM2904, V^+ = 5 V to 26 V), T_A = 25°C	65	100		50	100		dB
Amplifier-to-Amplifier Coupling		f = 1 kHz to 20 kHz, T_A = 25°C (Input Referred), See (5)		−120			−120		dB
Output Current	Source	V_{IN}^+ = 1 V, V_{IN}^- = 0 V, V^+ = 15 V, V_O = 2 V, T_A = 25°C	20	40		20	40		mA
	Sink	V_{IN}^- = 1 V, V_{IN}^+ = 0 V V^+ = 15V, T_A = 25°C, V_O = 2 V	10	20		10	20		mA
		V_{IN}^- = 1 V, V_{IN}^+ = 0 V T_A = 25°C, V_O = 200 mV, V^+ = 15 V	12	50		12	50		μA
Short Circuit to Ground		T_A = 25°C, See (6), V^+ = 15 V		40	60		40	60	mA
Input Offset Voltage		See (2)			9			10	mV
Input Offset Voltage Drift		R_S = 0 Ω		7			7		μV/°C
Input Offset Current		$I_{IN(+)}$ − $I_{IN(−)}$			150		45	200	nA
Input Offset Current Drift		R_S = 0 Ω		10			10		pA/°C
Input Bias Current		$I_{IN(+)}$ or $I_{IN(−)}$		40	500		40	500	nA

(1) These specifications are limited to –55°C ≤ T_A ≤ +125°C for the LM158/LM158A. With the LM258/LM258A, all temperature specifications are limited to −25°C ≤ T_A ≤ 85°C, the LM358/LM358A temperature specifications are limited to 0°C ≤ T_A ≤ 70°C, and the LM2904 specifications are limited to –40°C ≤ T_A ≤ 85°C.
(2) V_O ≃ 1.4 V, R_S = 0 Ω with V^+ from 5 V to 30 V; and over the full input common-mode range (0 V to V^+ −1.5 V) at 25°C. For LM2904, V^+ from 5 V to 26 V.
(3) The direction of the input current is out of the IC due to the PNP input stage. This current is essentially constant, independent of the state of the output so no loading change exists on the input lines.
(4) The input common-mode voltage of either input signal voltage should not be allowed to go negative by more than 0.3 V (at 25°C). The upper end of the common-mode voltage range is V^+ −1.5 V (at 25°C), but either or both inputs can go to 32 V without damage (26 V for LM2904), independent of the magnitude of V^+.
(5) Due to proximity of external components, insure that coupling is not originating via stray capacitance between these external parts. This typically can be detected as this type of capacitance increases at higher frequencies.
(6) Short circuits from the output to V^+ can cause excessive heating and eventual destruction. When considering short circuits to ground, the maximum output current is approximately 40 mA independent of the magnitude of V^+. At values of supply voltage in excess of +15 V, continuous short-circuits can exceed the power dissipation ratings and cause eventual destruction. Destructive dissipation can result from simultaneous shorts on all amplifiers.

Electrical Characteristics: LM358, LM2904 (continued)

$V^+ = +5.0$ V, See(1), unless otherwise stated

PARAMETER		TEST CONDITIONS		LM358 MIN	LM358 TYP	LM358 MAX	LM2904 MIN	LM2904 TYP	LM2904 MAX	UNIT
Input Common-Mode Voltage Range		$V^+ = 30$ V, See(4) (LM2904, $V^+ = 26$ V)		0		V^+−2	0		V^+ −2	V
Large Signal Voltage Gain		$V^+ = +15$ V ($V_O = 1$ V to 11 V) $R_L \geq 2$ kΩ		15			15			V/mV
Output Voltage	V_{OH}	$V^+ = 30$ V	$R_L = 2$ kΩ	26			22			V
		(LM2904, $V^+ = 26$ V)	$R_L = 10$ kΩ	27	28		23	24		V
Swing	V_{OL}	$V^+ = 5$ V, $R_L = 10$ kΩ			5	20		5	100	mV
Output Current	Source	$V_{IN}^+ = 1$ V, $V_{IN}^- = 0$ V, $V^+ = 15$ V, $V_O = 2$ V		10	20		10	20		mA
	Sink	$V_{IN}^- = 1$ V, $V_{IN}^+ = 0$ V, $V^+ = 15$ V, $V_O = 2$ V		5	8		5	8		mA

6.7 Typical Characteristics

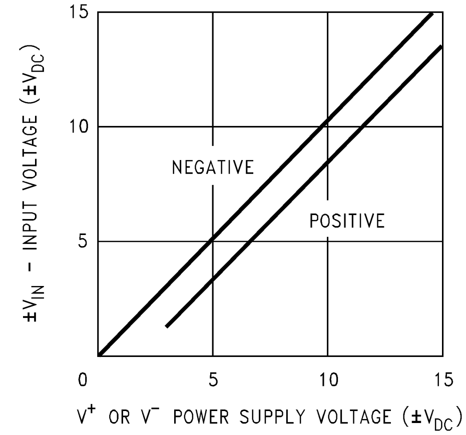


Figure 1. Input Voltage Range

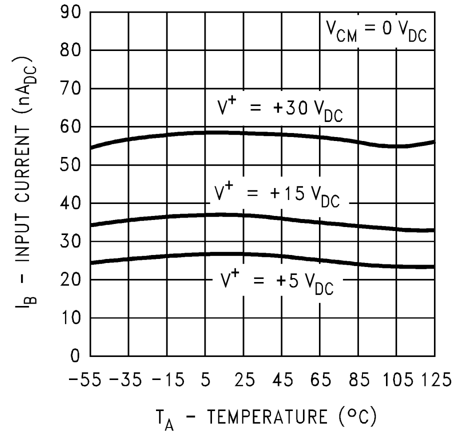


Figure 2. Input Current

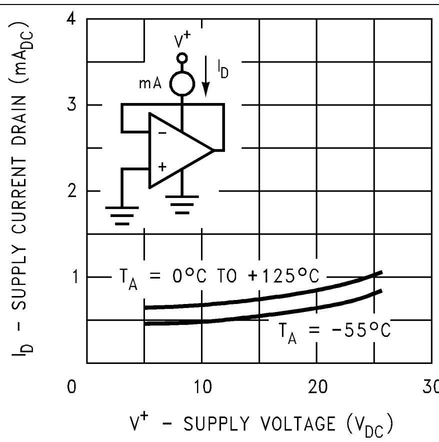


Figure 3. Supply Current

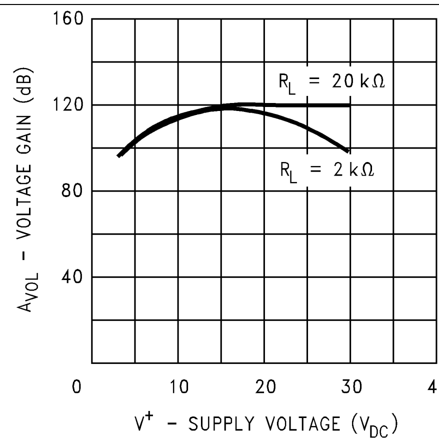


Figure 4. Voltage Gain

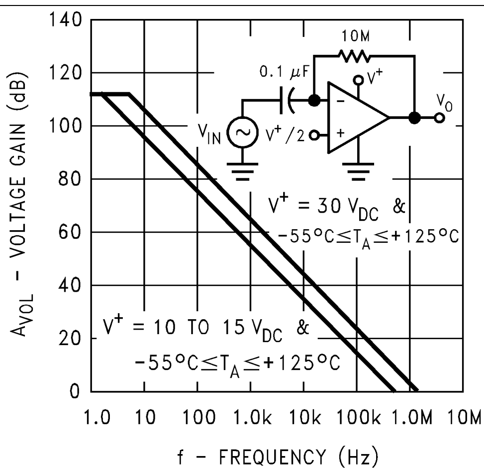


Figure 5. Open Loop Frequency Response

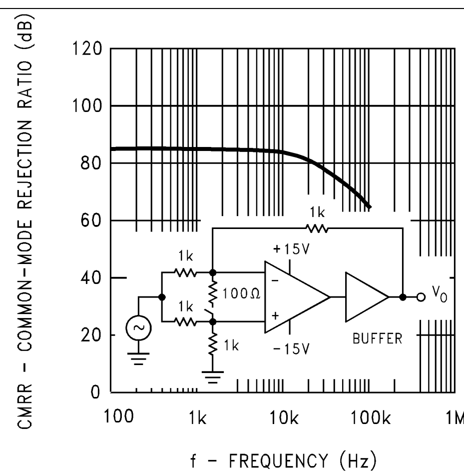


Figure 6. Common-Mode Rejection Ratio

Typical Characteristics (continued)

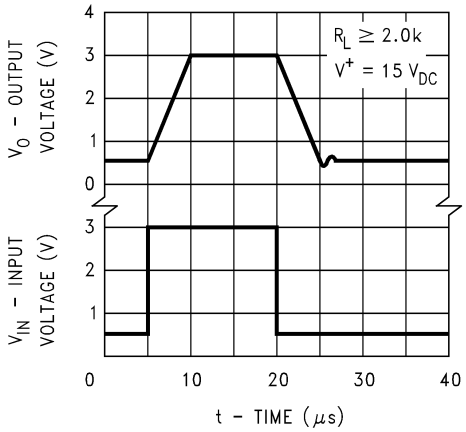


Figure 7. Voltage Follower Pulse Response

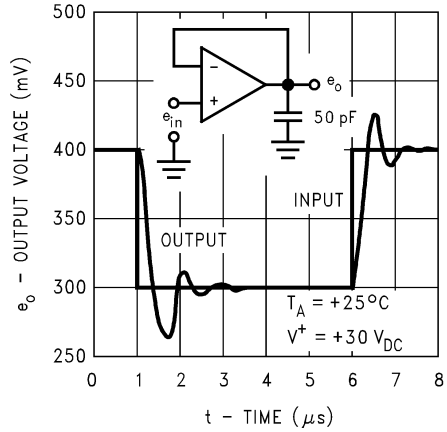


Figure 8. Voltage Follower Pulse Response (Small Signal)

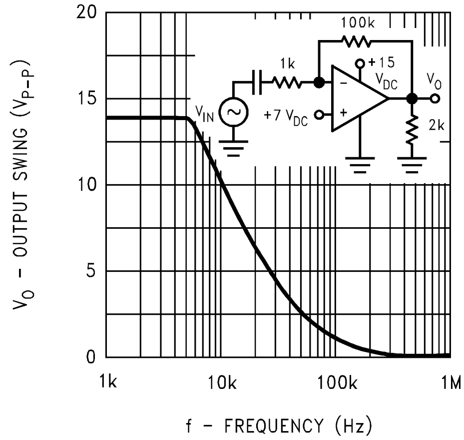


Figure 9. Large Signal Frequency Response

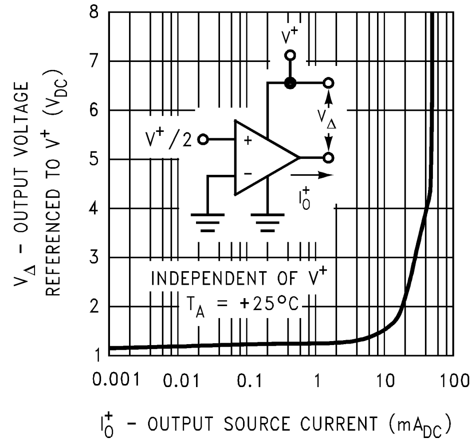


Figure 10. Output Characteristics Current Sourcing

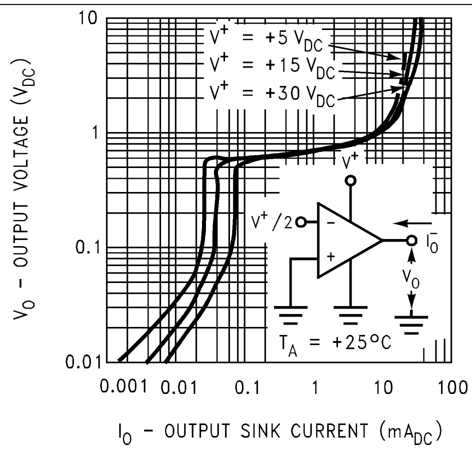


Figure 11. Output Characteristics Current Sinking

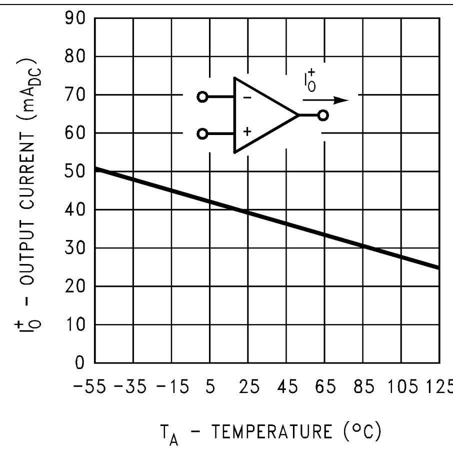


Figure 12. Current Limiting

Typical Characteristics (continued)

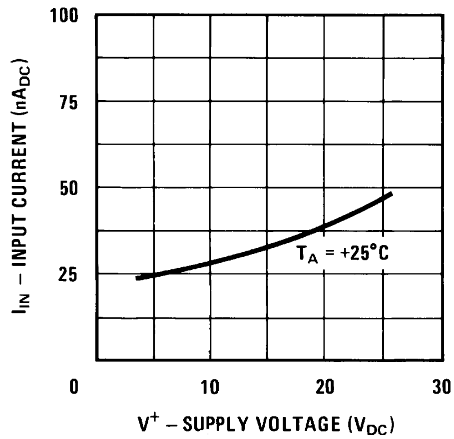


Figure 13. Input Current (LM2902 Only)

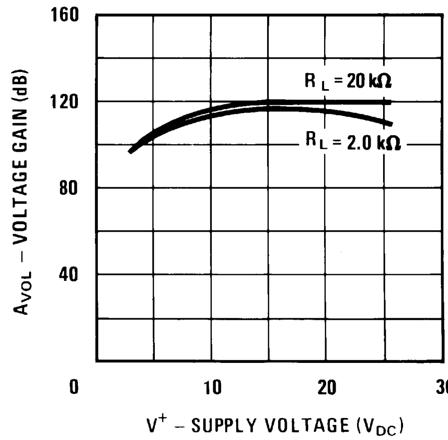


Figure 14. Voltage Gain (LM2902 Only)

7 Detailed Description

7.1 Overview

The LM158 series are operational amplifiers which can operate with only a single power supply voltage, have true-differential inputs, and remain in the linear mode with an input common-mode voltage of 0 V_{DC}. These amplifiers operate over a wide range of power supply voltage with little change in performance characteristics. At 25°C amplifier operation is possible down to a minimum supply voltage of 2.3 V_{DC}.

Large differential input voltages can be easily accommodated and, as input differential voltage protection diodes are not needed, no large input currents result from large differential input voltages. The differential input voltage may be larger than V^+ without damaging the device. Protection should be provided to prevent the input voltages from going negative more than −0.3 V_{DC} (at 25°C). An input clamp diode with a resistor to the IC input terminal can be used.

7.2 Functional Block Diagram

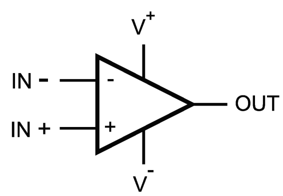


Figure 15. (Each Amplifier)

7.3 Feature Description

The amplifier's differential inputs consist of a non-inverting input (+IN) and an inverting input (–IN). The amplifer amplifies only the difference in voltage between the two inpus, which is called the differential input voltage. The output voltage of the op-amp Vout is given by Equation 1:

VOUT = AOL (IN+ - IN-)

where

- AOL is the open-loop gain of the amplifier, typically around 100dB (100,000x, or 10uV per Volt). (1)

To reduce the power supply current drain, the amplifiers have a class A output stage for small signal levels which converts to class B in a large signal mode. This allows the amplifiers to both source and sink large output currents. Therefore both NPN and PNP external current boost transistors can be used to extend the power capability of the basic amplifiers. The output voltage needs to raise approximately 1 diode drop above ground to bias the on-chip vertical PNP transistor for output current sinking applications.

For ac applications, where the load is capacitively coupled to the output of the amplifier, a resistor should be used, from the output of the amplifier to ground to increase the class A bias current and prevent crossover distortion. Where the load is directly coupled, as in dc applications, there is no crossover distortion.

Capacitive loads which are applied directly to the output of the amplifier reduce the loop stability margin. Values of 50 pF can be accommodated using the worst-case non-inverting unity gain connection. Large closed loop gains or resistive isolation should be used if larger load capacitance must be driven by the amplifier.

The bias network of the LM158 establishes a drain current which is independent of the magnitude of the power supply voltage over the range of 3 V_{DC} to 30 V_{DC}.

Output short circuits either to ground or to the positive power supply should be of short time duration. Units can be destroyed, not as a result of the short circuit current causing metal fusing, but rather due to the large increase in IC chip power dissipation which will cause eventual failure due to excessive junction temperatures. Putting direct short-circuits on more than one amplifier at a time will increase the total IC power dissipation to destructive levels, if not properly protected with external dissipation limiting resistors in series with the output leads of the amplifiers. The larger value of output source current which is available at 25°C provides a larger output current capability at elevated temperatures (see *Typical Characteristics*) than a standard IC op amp.

7.4 Device Functional Modes

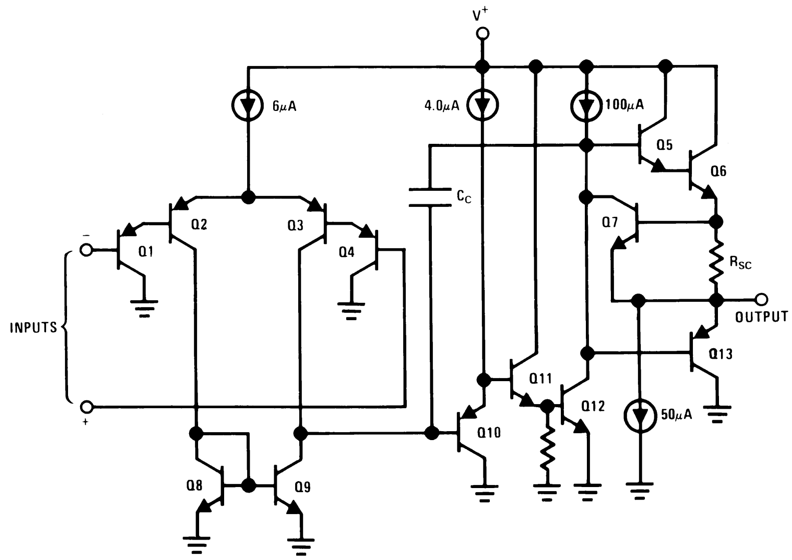


Figure 16. Schematic Diagram

The circuits presented in the *Typical Single-Supply Applications* emphasize operation on only a single power supply voltage. If complementary power supplies are available, all of the standard op-amp circuits can be used. In general, introducing a pseudo-ground (a bias voltage reference of $V^+/2$) will allow operation above and below this value in single power supply systems. Many application circuits are shown which take advantage of the wide input common-mode voltage range which includes ground. In most cases, input biasing is not required and input voltages which range to ground can easily be accommodated.

8 Application 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. Customers should validate and test their design implementation to confirm system functionality.

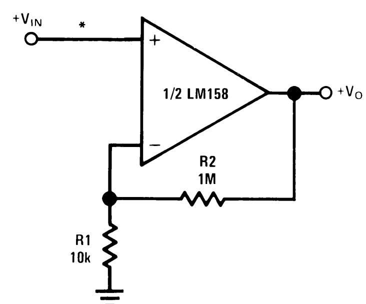
8.1 Application Information

The LM158 family bring performance, economy, and ease-of-use to a wide variety of op-amp applications.

8.2 Typical Applications

8.2.1 Noninverting DC Gain

Figure 17 shows a high input impedance non-inverting circuit. This circuit gives a closed-loop gain equal to the ratio of the sum of R1 and R2 to R1 and a closed-loop 3 dB bandwidth equal to the amplifier unity-gain frequency divided by the closed-loop gain. This design has the benefit of a very high input impedance, which is equal to the differential input impedance multiplied by loop gain. (Open loop gain/Closed loop gain.) In DC coupled applications, input impedance is not as important as input current and its voltage drop across the source resistance. Note that the amplifier output will go into saturation if the input is allowed to float. This may be important if the amplifier must be switched from source to source.



*R not needed due to temperature independent I_{IN}

Figure 17. Non-Inverting DC Gain (0-V Output)

8.2.1.1 Design Requirements

For this example application, the supply voltage is +5V, and 100x±5% of noninverting gain is necessary. Signal input impedance is approx 10kΩ.

8.2.1.2 Detailed Design Procedure

Using the equation for a non-inverting amplifier configuration ; G = 1+ R2/R1, set R1 to 10kΩ, and R2 to 99x the value of R1, which would be 990kΩ. Replacing the 990kΩ with a 1MΩ will result in a gain of 101, which is within the desired gain tolerance.

The gain-frequency characteristic of the amplifier and its feedback network must be such that oscillation does not occur. To meet this condition, the phase shift through amplifier and feedback network must never exceed 180° for any frequency where the gain of the amplifier and its feedback network is greater than unity. In practical applications, the phase shift should not approach 180° since this is the situation of conditional stability. Obviously the most critical case occurs when the attenuation of the feedback network is zero.

Typical Applications (continued)

8.2.1.3 Application Curve

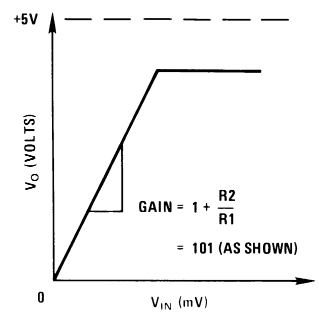
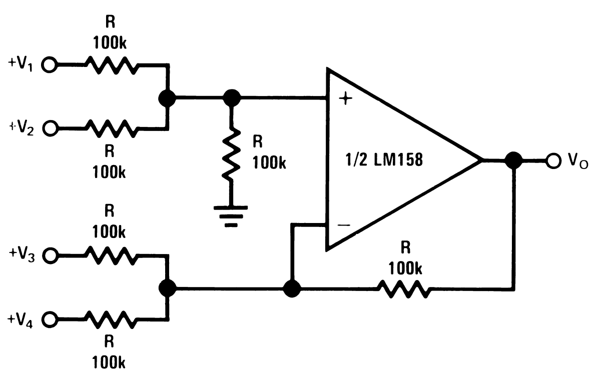


Figure 18. Transfer Curve for Non-Inverting Configuration

8.2.2 System Examples

8.2.2.1 Typical Single-Supply Applications

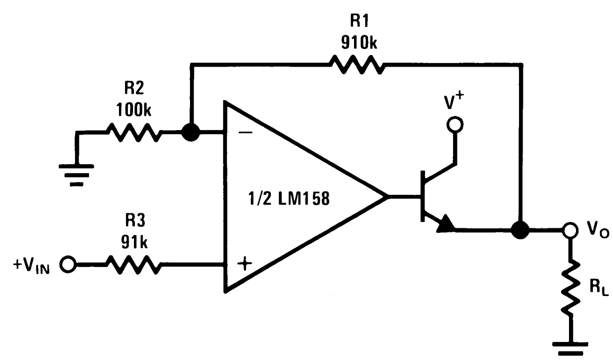
($V^+ = 5.0\ V_{DC}$)



Where: $V_O = V_1 + V_2 - V_3 - V_4$

$(V_1 + V_2) \geq (V_3 + V_4)$ to keep $V_O > 0\ V_{DC}$

Figure 19. DC Summing Amplifier ($V_{IN'S} \geq 0\ V_{DC}$ and $V_O \geq 0\ V_{DC}$)



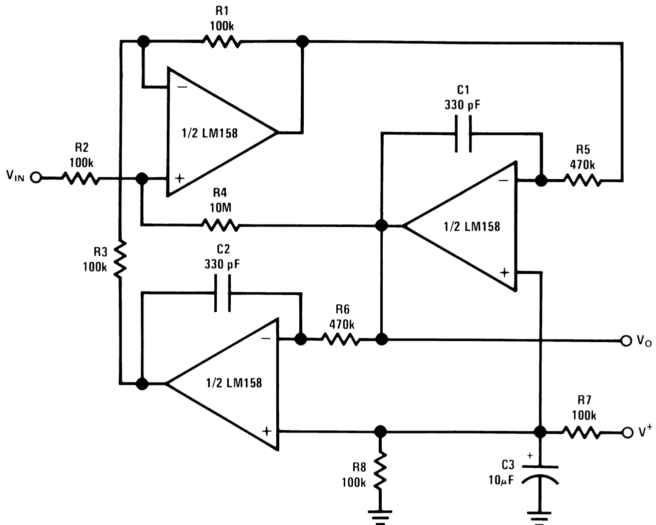
$V_O = 0\ V_{DC}$ for $V_{IN} = 0\ V_{DC}$

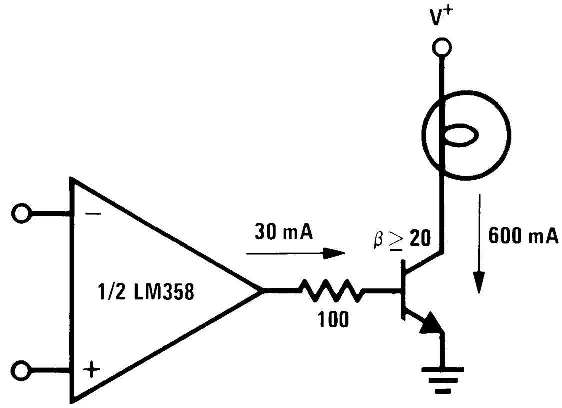
$A_V = 10$

Figure 20. Power Amplifier

Typical Applications (continued)

($V^{+} = 5.0\ V_{DC}$)





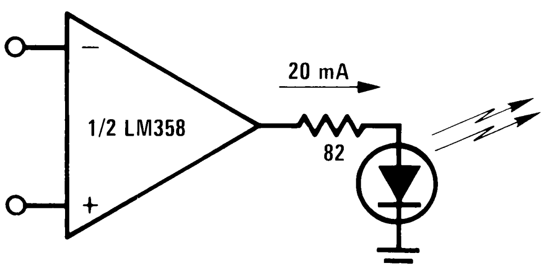
$f_o = 1\ kHz$

$Q = 50$

$A_v = 100\ (40\ dB)$

Figure 21. “BI-QUAD” RC Active Bandpass Filter

Figure 22. Lamp Driver



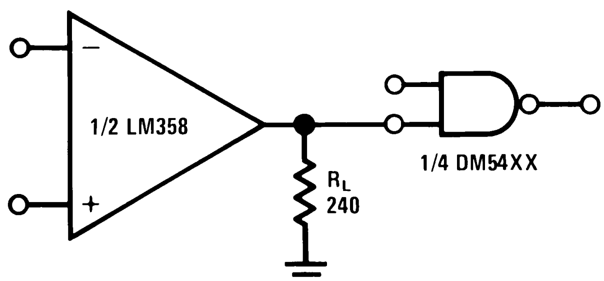
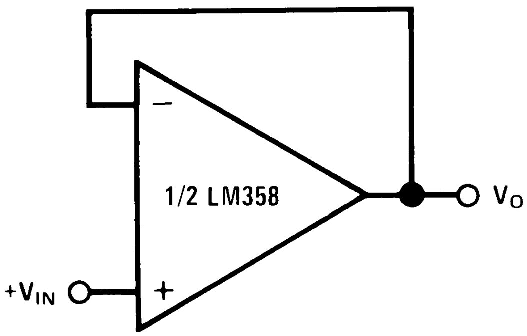


Figure 23. LED Driver

Figure 24. Driving TTL

Typical Applications (continued)

($V^+ = 5.0\ V_{DC}$)



$V_O = V_{IN}$

Figure 25. Voltage Follower

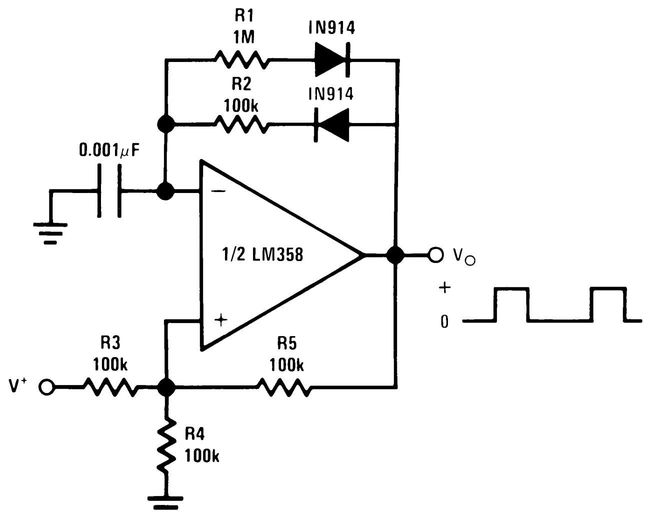


Figure 26. Pulse Generator

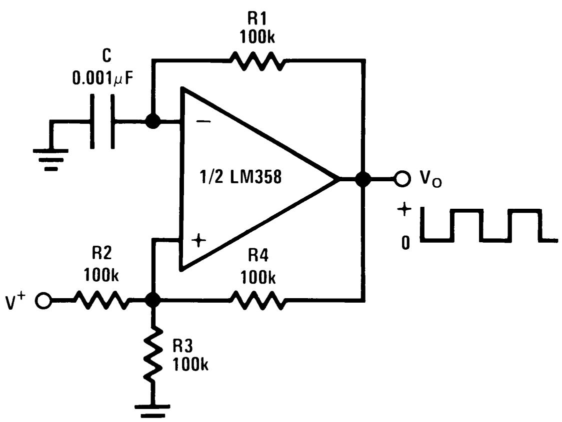


Figure 27. Squarewave Oscillator

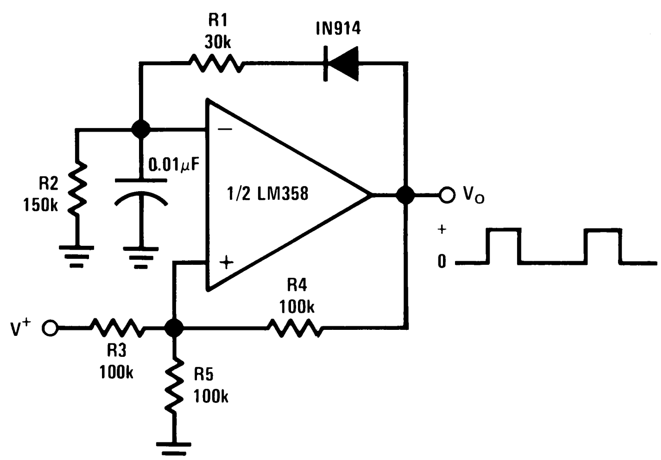
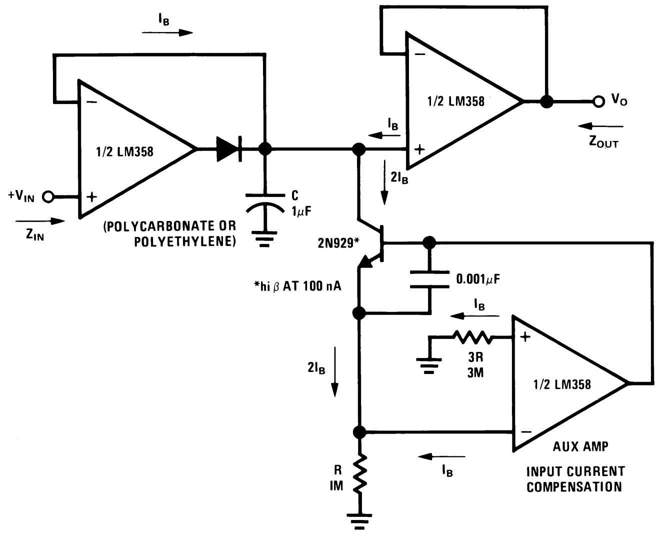


Figure 28. Pulse Generator

Typical Applications (continued)

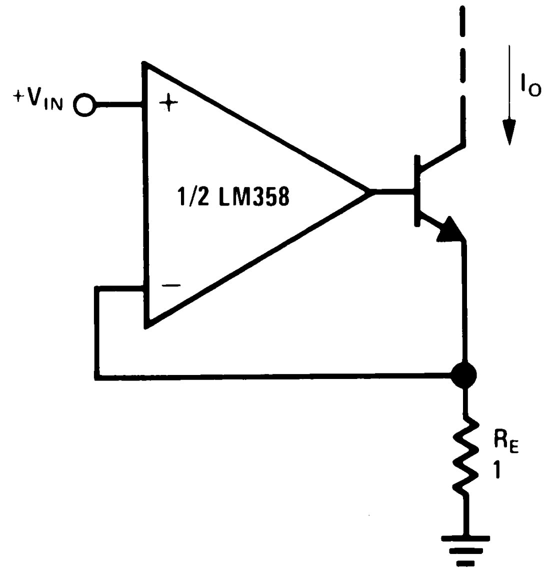
($V^+ = 5.0\ V_{DC}$)



HIGH Z_{IN}

LOW Z_{OUT}

Figure 29. Low Drift Peak Detector



I_O = 1 amp/volt V_{IN}

(Increase R_E for I_O small)

Figure 30. High Compliance Current Sink

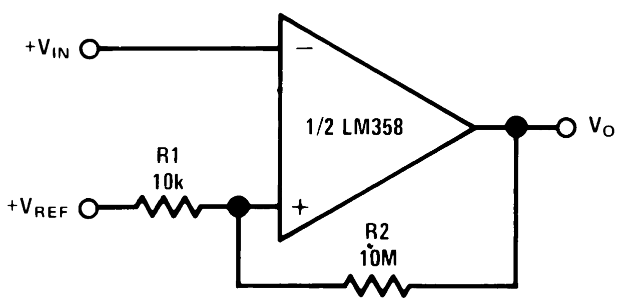
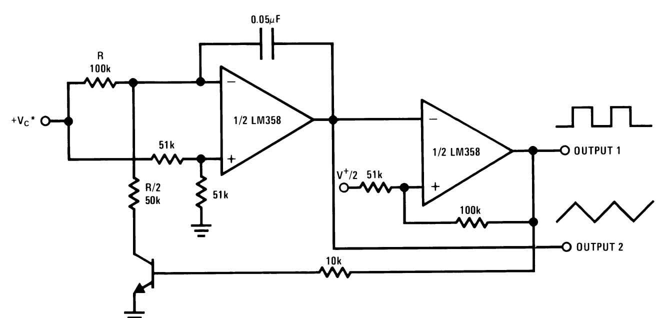


Figure 31. Comparator with Hysteresis



*WIDE CONTROL VOLTAGE RANGE: $0\ V_{DC} \leq V_C \leq 2\ (V^+ - 1.5V\ _{DC})$

Figure 32. Voltage Controlled Oscillator (VCO)

Typical Applications (continued)

($V^+ = 5.0\ V_{DC}$)

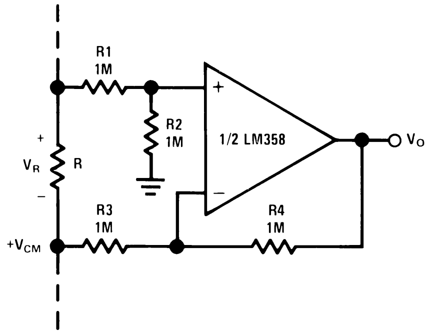
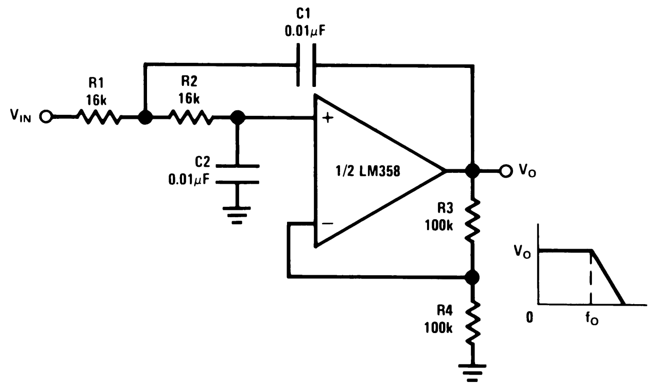


Figure 33. Ground Referencing a Differential Input Signal

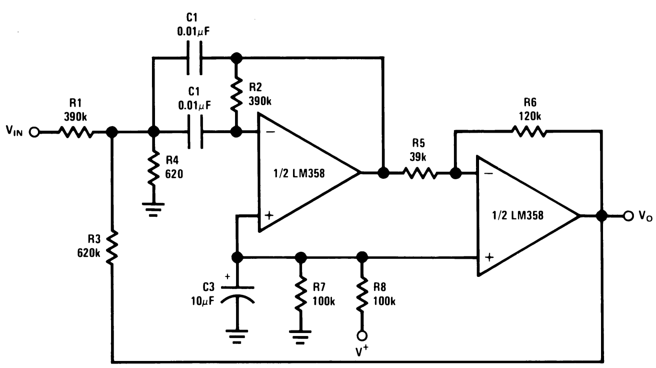


$f_o = 1$ kHz

$Q = 1$

$A_V = 2$

Figure 34. DC Coupled Low-Pass RC Active Filter



$f_o = 1$ kHz

$Q = 25$

Figure 35. Bandpass Active Filter

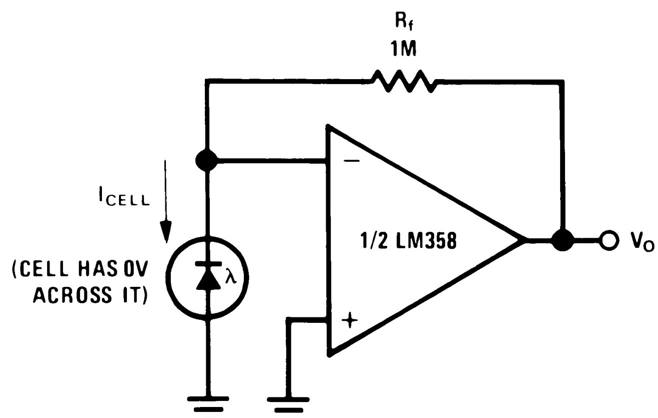


Figure 36. Photo Voltaic-Cell Amplifier

Typical Applications (continued)

($V^{+} = 5.0\ V_{DC}$)

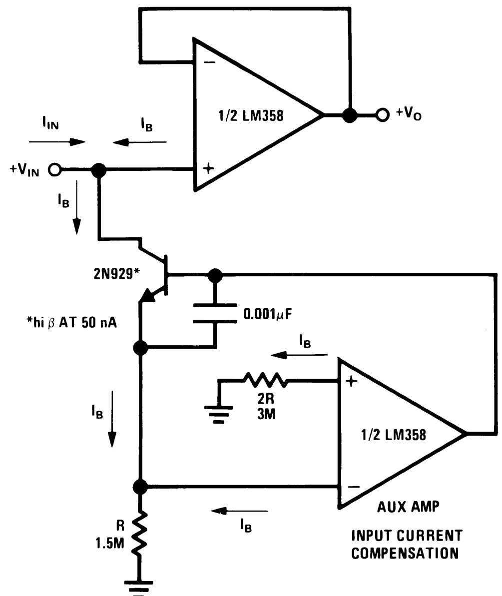
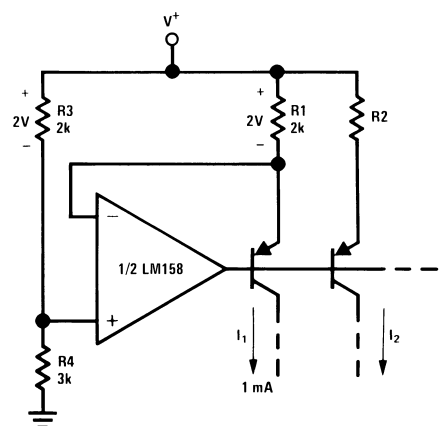


Figure 37. Using Symmetrical Amplifiers to Reduce Input Current (General Concept)

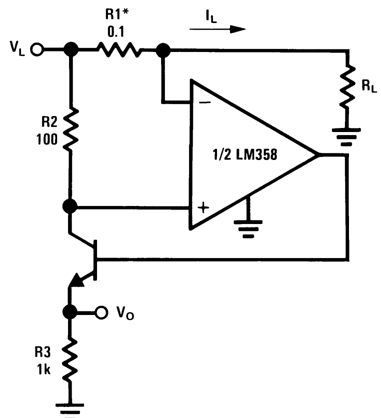


$$I_2 = \left(\frac{R1}{R2}\right) I_1$$

Figure 38. Fixed Current Sources

Typical Applications (continued)

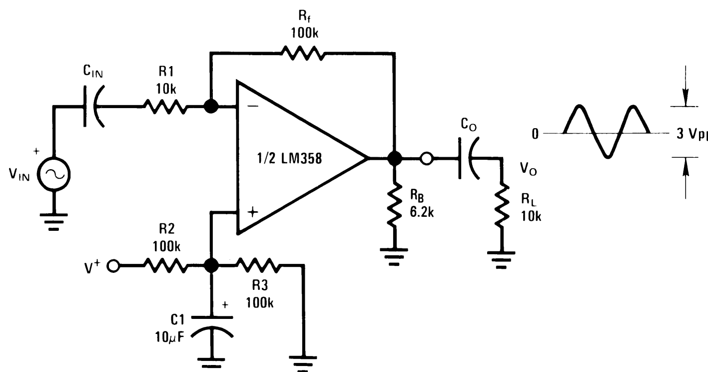
($V^+ = 5.0\ V_{DC}$)



$$V_O = \frac{1V\ (I_L)}{1A}$$

*(Increase R1 for I_L small)
$V_L \le V^+ - 2V$

Figure 39. Current Monitor

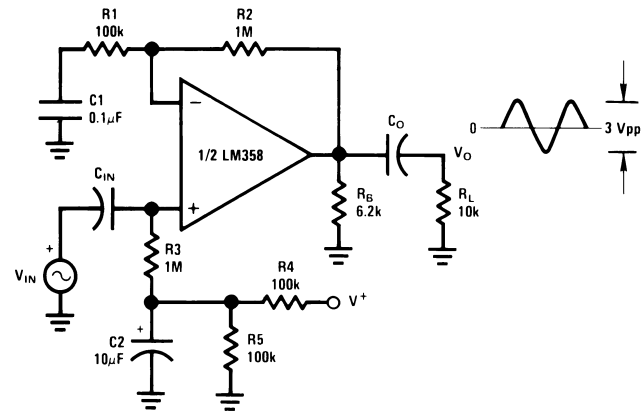


$$A_V = \frac{R_f}{R1} \quad \text{(As shown, } A_V = 10\text{)}$$

Figure 40. AC Coupled Inverting Amplifier

Typical Applications (continued)

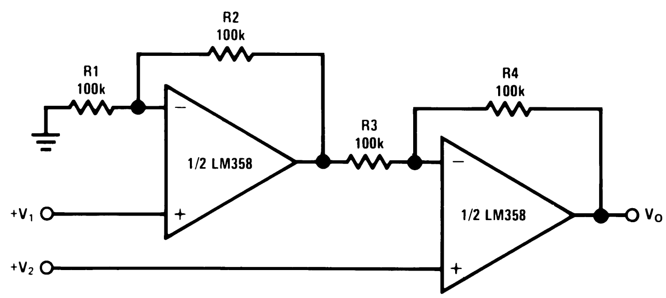
($V^+ = 5.0\ V_{DC}$)



$$A_V = 1 + \frac{R2}{R1}$$

$A_v = 11$ (As Shown)

Figure 41. AC Coupled Non-Inverting Amplifier

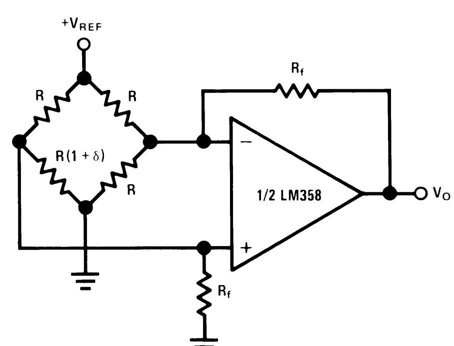


For $\frac{R1}{R2} = \frac{R4}{R3}$ (CMRR depends on this resistor ratio match)

$$V_O = 1 + \frac{R4}{R3} (V_2 - V_1)$$

As Shown: $V_O = 2 (V_2 - V_1)$

Figure 42. High Input Z, DC Differential Amplifier



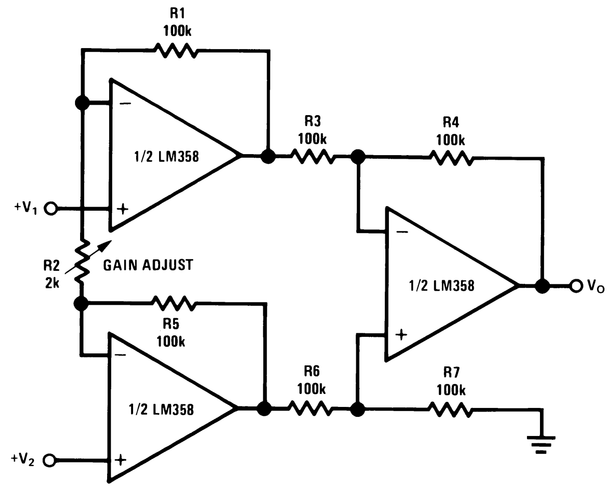
For $\delta << 1$ and $R_f >> R$

$$V_O \cong V_{REF} \left(\frac{\delta}{2}\right) \frac{R_f}{R}$$

Figure 43. Bridge Current Amplifier

Typical Applications (continued)

($V^+ = 5.0\ V_{DC}$)



If R1 = R5 & R3 = R4 = R6 = R7 (CMRR depends on match)

$$V_O = 1 + \frac{2R1}{R2} (V_2 - V_1)$$

As shown $V_O = 101 (V_2 - V_1)$

Figure 44. High Input Z Adjustable-Gain DC Instrumentation Amplifier

9 Power Supply Recommendations

For proper operation, the power supplies must be properly decoupled. For decoupling the supply pins it is suggested that 10 nF capacitors be placed as close as possible to the op-amp power supply pins. For single supply, place a capacitor between V+ and V−supply leads. For dual supplies, place one capacitor between V+ and ground, and one capacitor between V- and ground.

Precautions should be taken to insure that the power supply for the integrated circuit never becomes reversed in polarity or that the unit is not inadvertently installed backwards in a test socket as an unlimited current surge through the resulting forward diode within the IC could cause fusing of the internal conductors and result in a destroyed unit.

10 Layout

10.1 Layout Guidelines

For single-ended supply configurations, the V+ pin should be bypassed to ground with a low ESR capacitor. The optimum placement is closest to the V+ pin. Care should be taken to minimize the loop area formed by the bypass capacitor connection between V+ and ground. The ground pin should be connected to the PCB ground plane at the pin of the device. The feedback components should be placed as close to the device as possible to minimize stray parasitics.

For dual supply configurations, both the V+ pin and V- pin should be bypassed to ground with a low ESR capacitor. The optimum placement is closest to the corresponding supply pin. Care should be taken to minimize the loop area formed by the bypass capacitor connection between V+ or V- and ground. The feedback components should be placed as close to the device as possible to minimize stray parasitics.

For both configurations, as ground plane underneath the device is recommended.

10.2 Layout Example

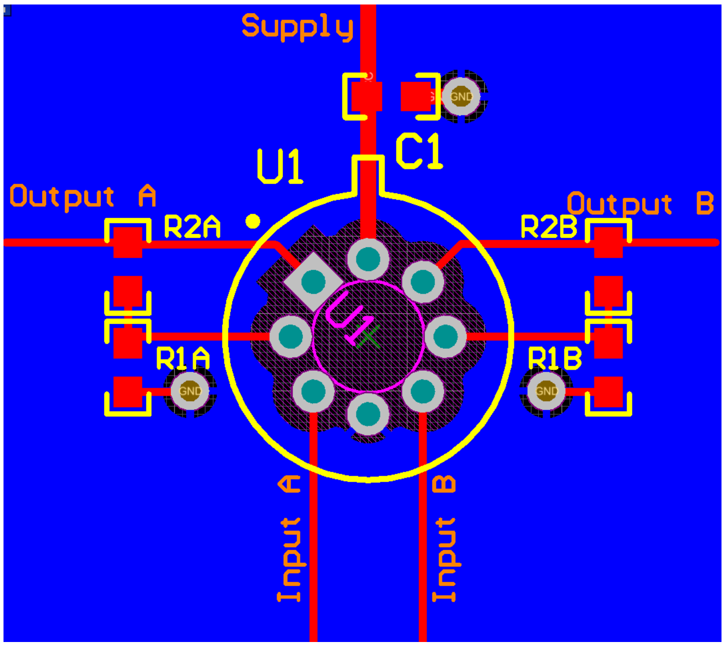


Figure 45. Layout Example

11 Device and Documentation Support

11.1 Related Links

The table below lists quick access links. Categories include technical documents, support and community resources, tools and software, and quick access to sample or buy.

Table 1. Related Links

PARTS	PRODUCT FOLDER	SAMPLE & BUY	TECHNICAL DOCUMENTS	TOOLS & SOFTWARE	SUPPORT & COMMUNITY
LM158-N	Click here	Click here	Click here	Click here	Click here
LM258-N	Click here	Click here	Click here	Click here	Click here
LM2904-N	Click here	Click here	Click here	Click here	Click here
LM358-N	Click here	Click here	Click here	Click here	Click here

11.2 Trademarks

All trademarks are the property of their respective owners.

11.3 Electrostatic Discharge Caution

These devices have limited built-in ESD protection. The leads should be shorted together or the device placed in conductive foam during storage or handling to prevent electrostatic damage to the MOS gates.

11.4 Glossary

SLYZ022 — *TI Glossary*.

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

12 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/Ball Finish (6)	MSL Peak Temp (3)	Op Temp (°C)	Device Marking (4/5)	Samples
LM158AH	ACTIVE	TO-99	LMC	8	500	TBD	Call TI	Call TI	-55 to 125	(LM158AH ~ LM158AH)	Samples
LM158AH/NOPB	ACTIVE	TO-99	LMC	8	500	Green (RoHS & no Sb/Br)	Call TI	Level-1-NA-UNLIM	-55 to 125	(LM158AH ~ LM158AH)	Samples
LM158H	ACTIVE	TO-99	LMC	8	500	TBD	Call TI	Call TI	-55 to 125	(LM158H ~ LM158H)	Samples
LM158H/NOPB	ACTIVE	TO-99	LMC	8	500	Green (RoHS & no Sb/Br)	Call TI	Level-1-NA-UNLIM	-55 to 125	(LM158H ~ LM158H)	Samples
LM158J	ACTIVE	CDIP	NAB	8	40	TBD	Call TI	Call TI	-55 to 125	LM158J	Samples
LM258H	ACTIVE	TO-99	LMC	8	500	TBD	Call TI	Call TI	-25 to 85	(LM258H ~ LM258H)	Samples
LM258H/NOPB	ACTIVE	TO-99	LMC	8	500	Green (RoHS & no Sb/Br)	Call TI	Level-1-NA-UNLIM	-25 to 85	(LM258H ~ LM258H)	Samples
LM2904ITP/NOPB	ACTIVE	DSBGA	YPB	8	250	Green (RoHS & no Sb/Br)	SNAGCU	Level-1-260C-UNLIM	-40 to 85	A 09	Samples
LM2904ITPX/NOPB	ACTIVE	DSBGA	YPB	8	3000	Green (RoHS & no Sb/Br)	SNAGCU	Level-1-260C-UNLIM	-40 to 85	A 09	Samples
LM2904M	NRND	SOIC	D	8	95	TBD	Call TI	Call TI	-40 to 85	LM 2904M	
LM2904M/NOPB	ACTIVE	SOIC	D	8	95	Green (RoHS & no Sb/Br)	CU SN	Level-1-260C-UNLIM	-40 to 85	LM 2904M	Samples
LM2904MX	NRND	SOIC	D	8	2500	TBD	Call TI	Call TI	-40 to 85	LM 2904M	
LM2904MX/NOPB	ACTIVE	SOIC	D	8	2500	Green (RoHS & no Sb/Br)	CU SN	Level-1-260C-UNLIM	-40 to 85	LM 2904M	Samples
LM2904N/NOPB	ACTIVE	PDIP	P	8	40	Green (RoHS & no Sb/Br)	CU SN	Level-1-NA-UNLIM	-40 to 85	LM 2904N	Samples
LM358AM	NRND	SOIC	D	8	95	TBD	Call TI	Call TI	0 to 70	LM 358AM	
LM358AM/NOPB	ACTIVE	SOIC	D	8	95	Green (RoHS & no Sb/Br)	CU SN	Level-1-260C-UNLIM	0 to 70	LM 358AM	Samples
LM358AMX	NRND	SOIC	D	8	2500	TBD	Call TI	Call TI	0 to 70	LM 358AM	

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead/Ball Finish (6)	MSL Peak Temp (3)	Op Temp (°C)	Device Marking (4/5)	Samples
LM358AMX/NOPB	ACTIVE	SOIC	D	8	2500	Green (RoHS & no Sb/Br)	CU SN	Level-1-260C-UNLIM	0 to 70	LM 358AM	Samples
LM358AN/NOPB	ACTIVE	PDIP	P	8	40	Green (RoHS & no Sb/Br)	CU SN	Level-1-NA-UNLIM	0 to 70	LM 358AN	Samples
LM358H/NOPB	ACTIVE	TO-99	LMC	8	500	Green (RoHS & no Sb/Br)	Call TI	Level-1-NA-UNLIM	0 to 70	(LM358H ~ LM358H)	Samples
LM358M	NRND	SOIC	D	8	95	TBD	Call TI	Call TI	0 to 70	LM 358M	
LM358M/NOPB	ACTIVE	SOIC	D	8	95	Green (RoHS & no Sb/Br)	CU SN	Level-1-260C-UNLIM	0 to 70	LM 358M	Samples
LM358MX	NRND	SOIC	D	8	2500	TBD	Call TI	Call TI	0 to 70	LM 358M	
LM358MX/NOPB	ACTIVE	SOIC	D	8	2500	Green (RoHS & no Sb/Br)	CU SN	Level-1-260C-UNLIM	0 to 70	LM 358M	Samples
LM358N/NOPB	ACTIVE	PDIP	P	8	40	Green (RoHS & no Sb/Br)	CU SN	Level-1-NA-UNLIM	0 to 70	LM 358N	Samples
LM358TP/NOPB	ACTIVE	DSBGA	YPB	8	250	Green (RoHS & no Sb/Br)	SNAGCU	Level-1-260C-UNLIM	0 to 70	A 07	Samples
LM358TPX/NOPB	ACTIVE	DSBGA	YPB	8	3000	Green (RoHS & no Sb/Br)	SNAGCU	Level-1-260C-UNLIM	0 to 70	A 07	Samples

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

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

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

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

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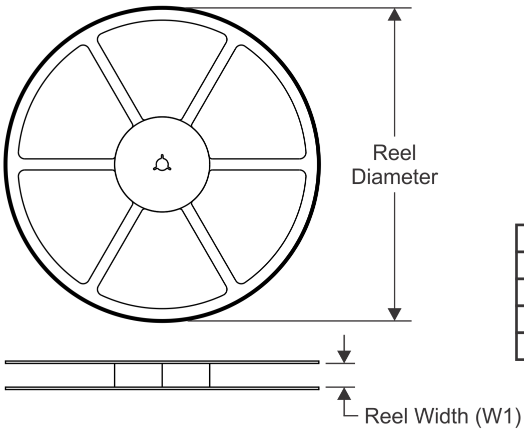
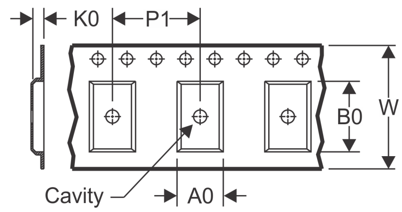
TAPE AND REEL INFORMATION

REEL DIMENSIONS

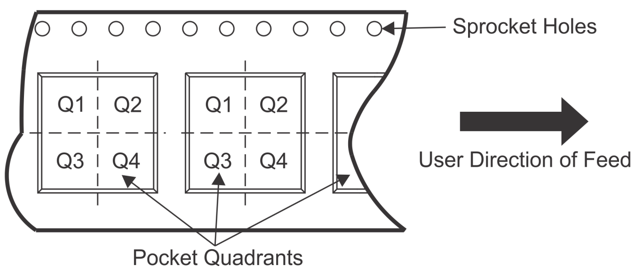


TAPE DIMENSIONS



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

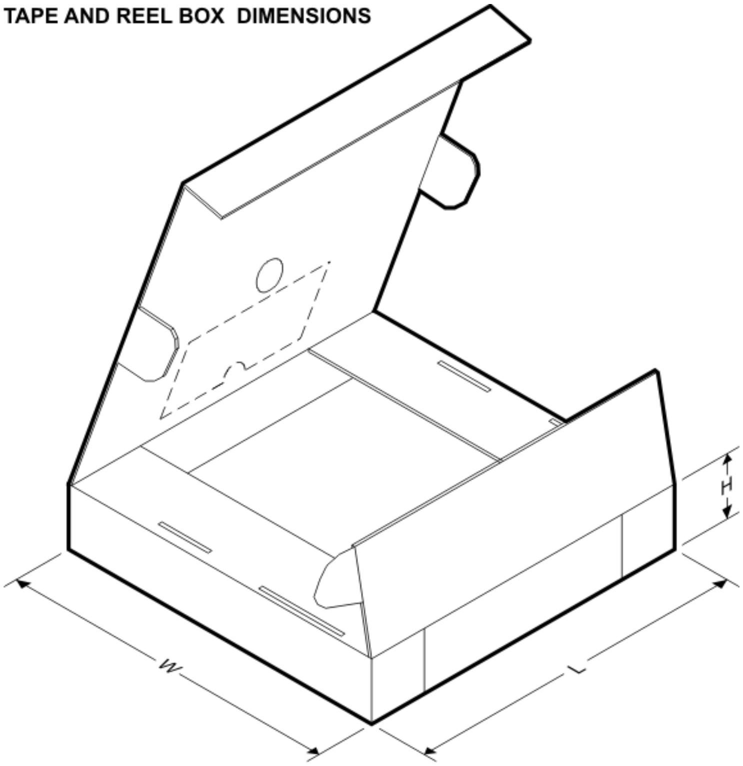
QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE



*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
LM2904ITP/NOPB	DSBGA	YPB	8	250	178.0	8.4	1.5	1.5	0.66	4.0	8.0	Q1
LM2904ITPX/NOPB	DSBGA	YPB	8	3000	178.0	8.4	1.5	1.5	0.66	4.0	8.0	Q1
LM2904MX	SOIC	D	8	2500	330.0	12.4	6.5	5.4	2.0	8.0	12.0	Q1
LM2904MX/NOPB	SOIC	D	8	2500	330.0	12.4	6.5	5.4	2.0	8.0	12.0	Q1
LM358AMX	SOIC	D	8	2500	330.0	12.4	6.5	5.4	2.0	8.0	12.0	Q1
LM358AMX/NOPB	SOIC	D	8	2500	330.0	12.4	6.5	5.4	2.0	8.0	12.0	Q1
LM358MX	SOIC	D	8	2500	330.0	12.4	6.5	5.4	2.0	8.0	12.0	Q1
LM358MX/NOPB	SOIC	D	8	2500	330.0	12.4	6.5	5.4	2.0	8.0	12.0	Q1
LM358TP/NOPB	DSBGA	YPB	8	250	178.0	8.4	1.5	1.5	0.66	4.0	8.0	Q1
LM358TPX/NOPB	DSBGA	YPB	8	3000	178.0	8.4	1.5	1.5	0.66	4.0	8.0	Q1

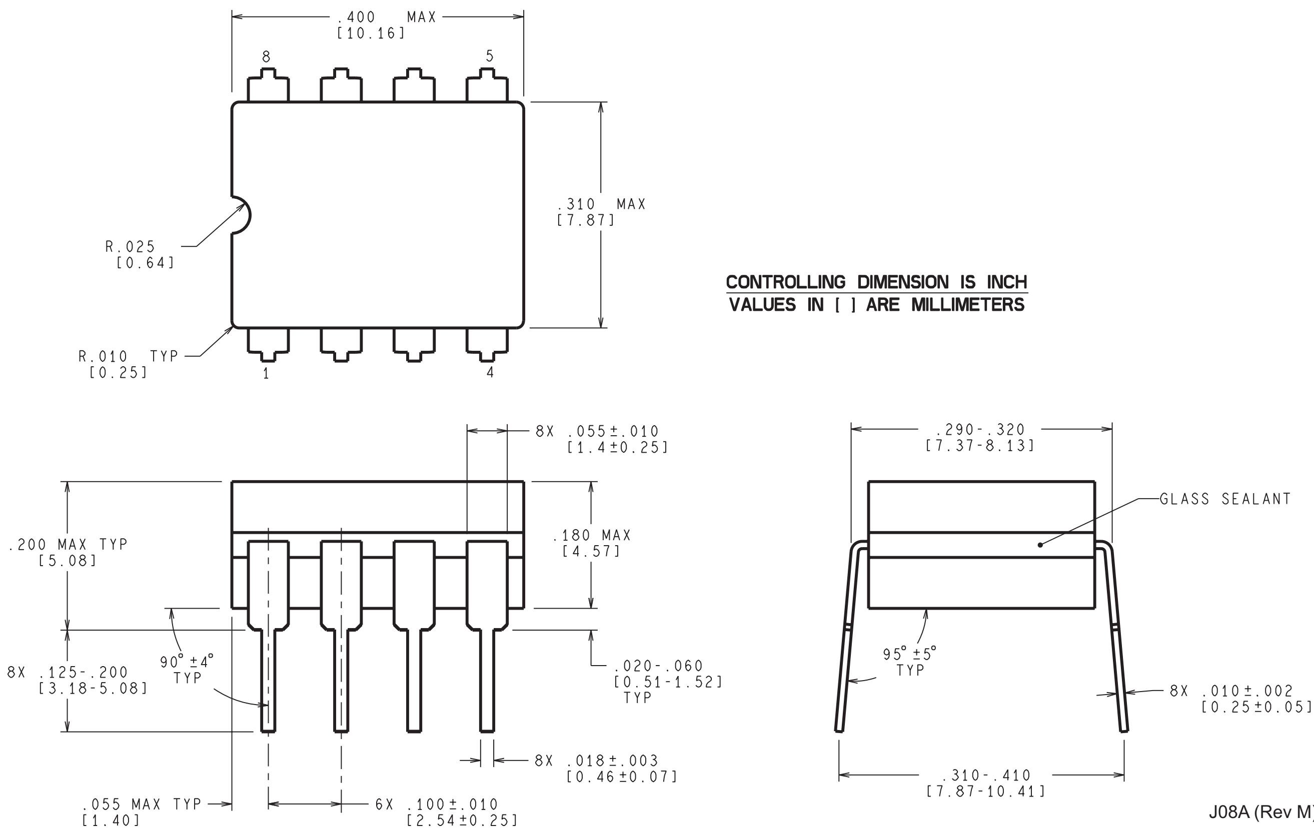
TAPE AND REEL BOX DIMENSIONS



*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
LM2904ITP/NOPB	DSBGA	YPB	8	250	210.0	185.0	35.0
LM2904ITPX/NOPB	DSBGA	YPB	8	3000	210.0	185.0	35.0
LM2904MX	SOIC	D	8	2500	367.0	367.0	35.0
LM2904MX/NOPB	SOIC	D	8	2500	367.0	367.0	35.0
LM358AMX	SOIC	D	8	2500	367.0	367.0	35.0
LM358AMX/NOPB	SOIC	D	8	2500	367.0	367.0	35.0
LM358MX	SOIC	D	8	2500	367.0	367.0	35.0
LM358MX/NOPB	SOIC	D	8	2500	367.0	367.0	35.0
LM358TP/NOPB	DSBGA	YPB	8	250	210.0	185.0	35.0
LM358TPX/NOPB	DSBGA	YPB	8	3000	210.0	185.0	35.0

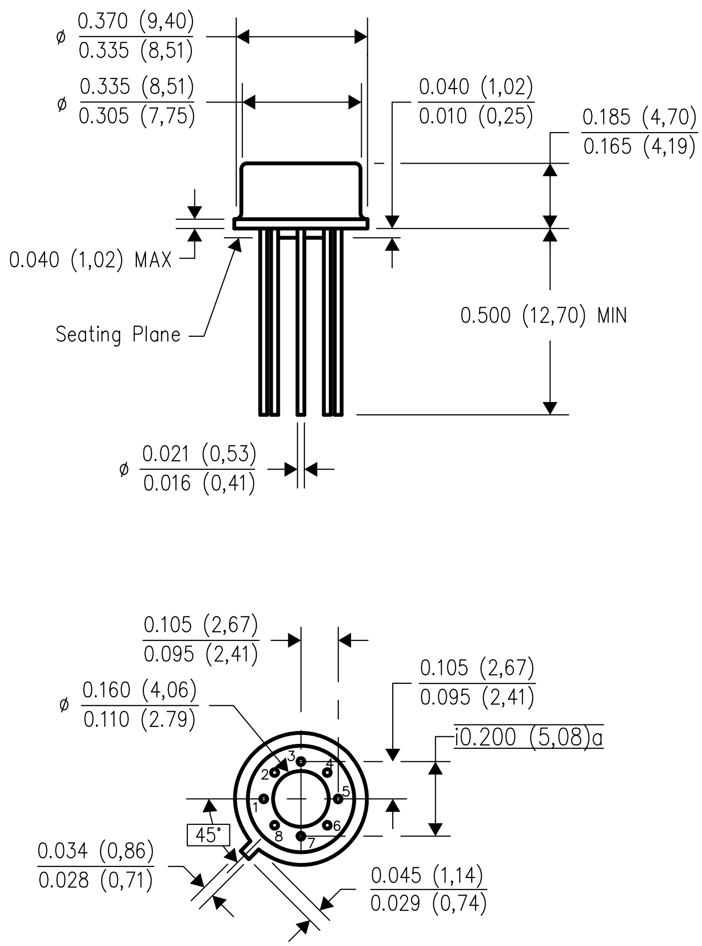
NAB0008A



CONTROLLING DIMENSION IS INCH
VALUES IN [ ] ARE MILLIMETERS

J08A (Rev M)

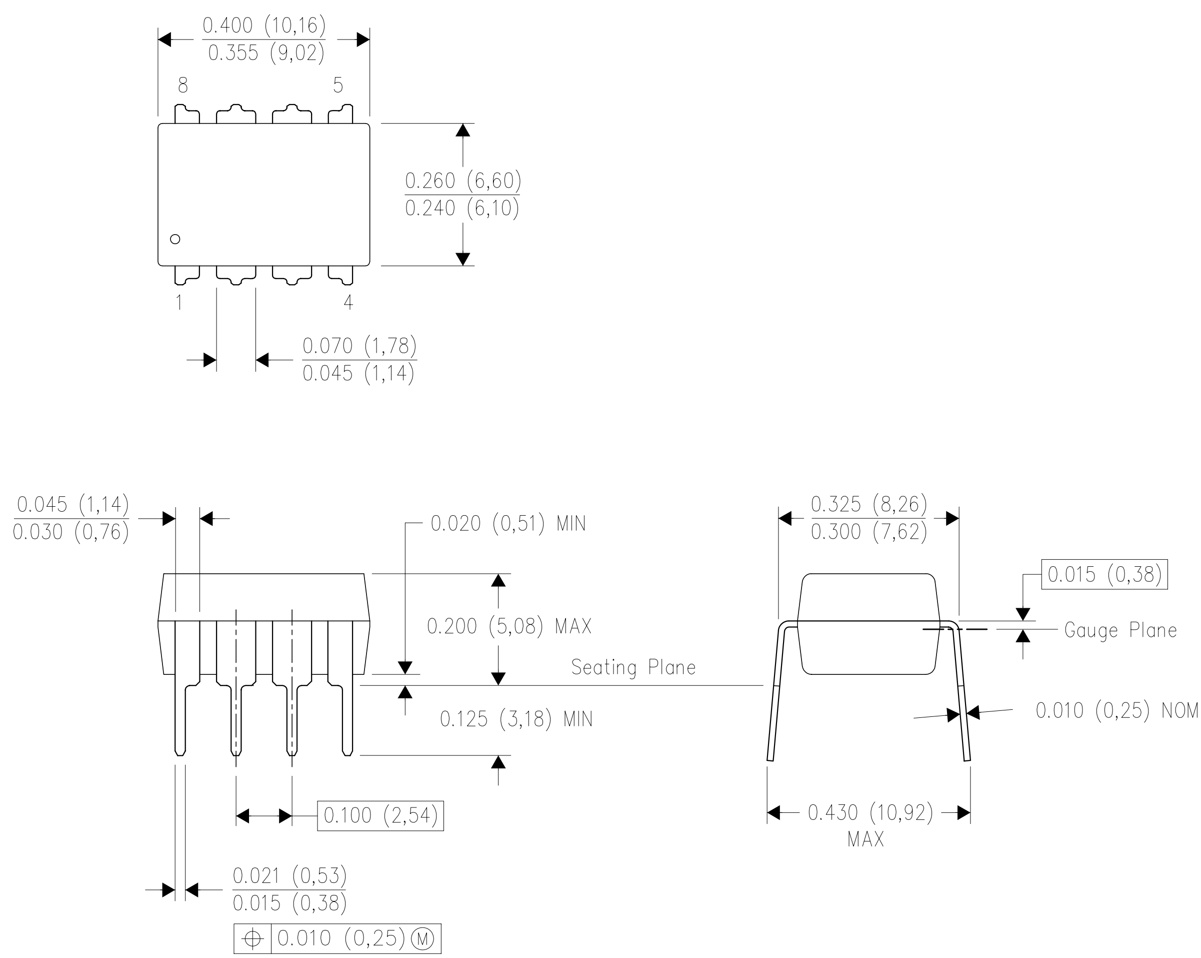
LMC (O-MBCY-W8) METAL CYLINDRICAL PACKAGE



4202483/B 09/07

NOTES:
A. All linear dimensions are in inches (millimeters).
B. This drawing is subject to change without notice.
C. Leads in true position within 0.010 (0,25) R @ MMC at seating plane.
D. Pin numbers shown for reference only. Numbers may not be marked on package.
E. Falls within JEDEC MO-002/TO-99.

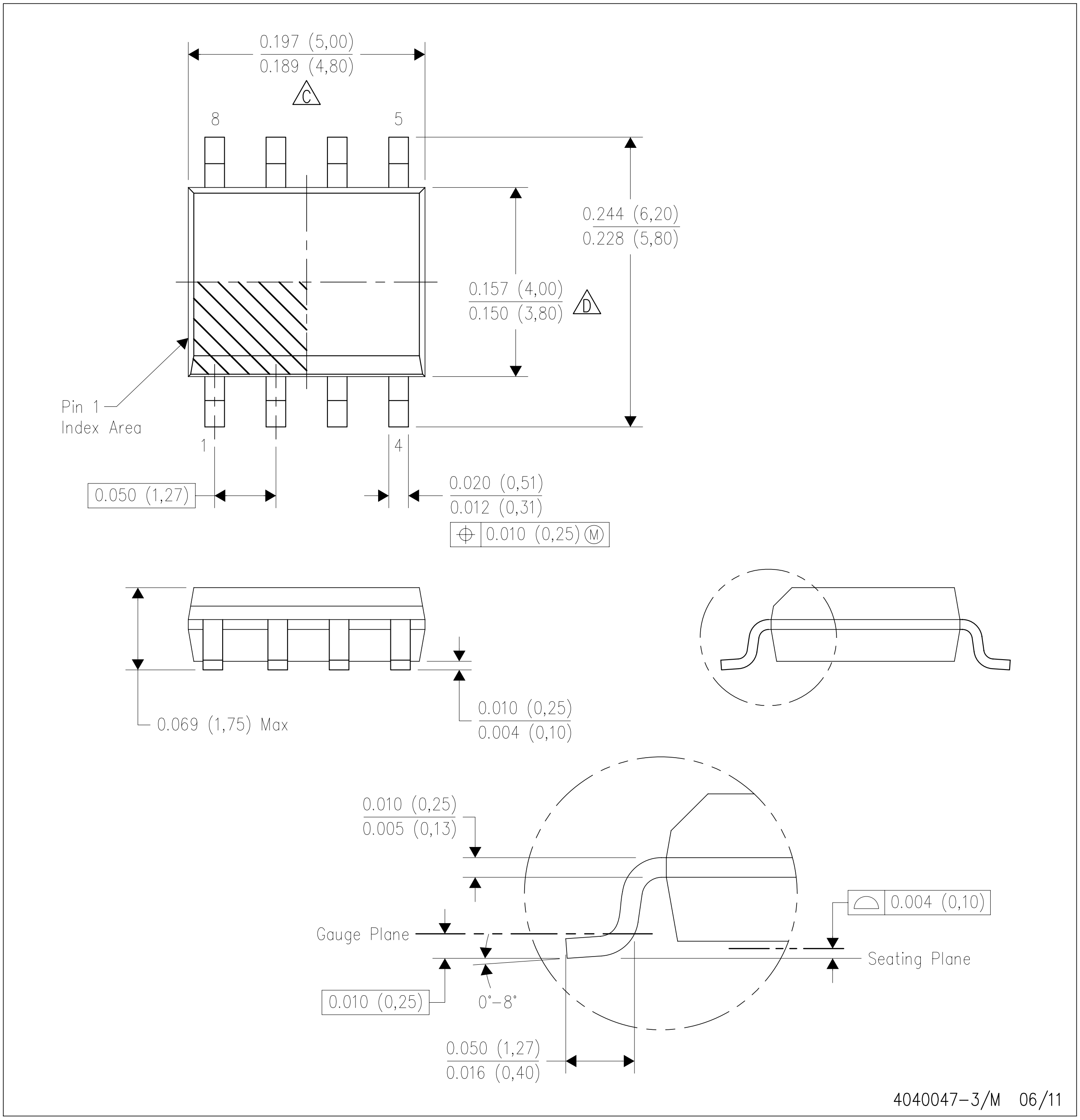
P (R–PDIP–T8) PLASTIC DUAL–IN–LINE PACKAGE



4040082/E 04/2010

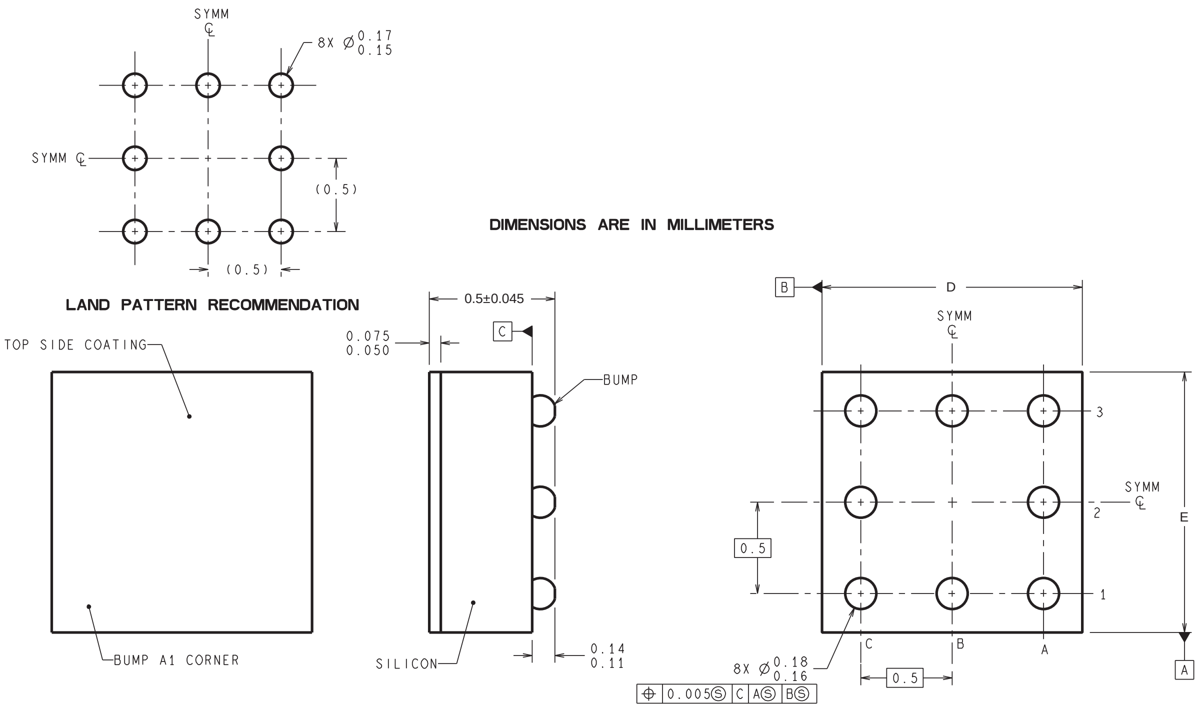
NOTES:
- A. All linear dimensions are in inches (millimeters).
- B. This drawing is subject to change without notice.
- C. Falls within JEDEC MS–001 variation BA.

D (R–PDSO–G8) PLASTIC SMALL OUTLINE



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

YPB0008



TPA08XXX (Rev A)

D: Max = 1.337 mm, Min =1.276 mm

E: Max = 1.337 mm, Min =1.276 mm

4215100/A 12/12

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.

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Ultralow Offset Voltage Operational Amplifier

Data Sheet **OP07**

FEATURES

Low V_{OS}: 75 μV maximum
Low V_{OS} drift: 1.3 μV/°C maximum
Ultrastable vs. time: 1.5 μV per month maximum
Low noise: 0.6 μV p-p maximum
Wide input voltage range: ±14 V typical
Wide supply voltage range: ±3 V to ±18 V
125°C temperature-tested dice

APPLICATIONS

Wireless base station control circuits
Optical network control circuits
Instrumentation
Sensors and controls
- **Thermocouples**
- **Resistor thermal detectors (RTDs)**
- **Strain bridges**
- **Shunt current measurements**

Precision filters

GENERAL DESCRIPTION

The OP07 has very low input offset voltage (75 μV maximum for OP07E) that is obtained by trimming at the wafer stage. These low offset voltages generally eliminate any need for external nulling. The OP07 also features low input bias current (±4 nA for the OP07E) and high open-loop gain (200 V/mV for the OP07E). The low offset and high open-loop gain make the OP07 particularly useful for high gain instrumentation applications.

PIN CONFIGURATION

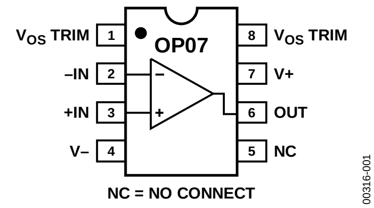
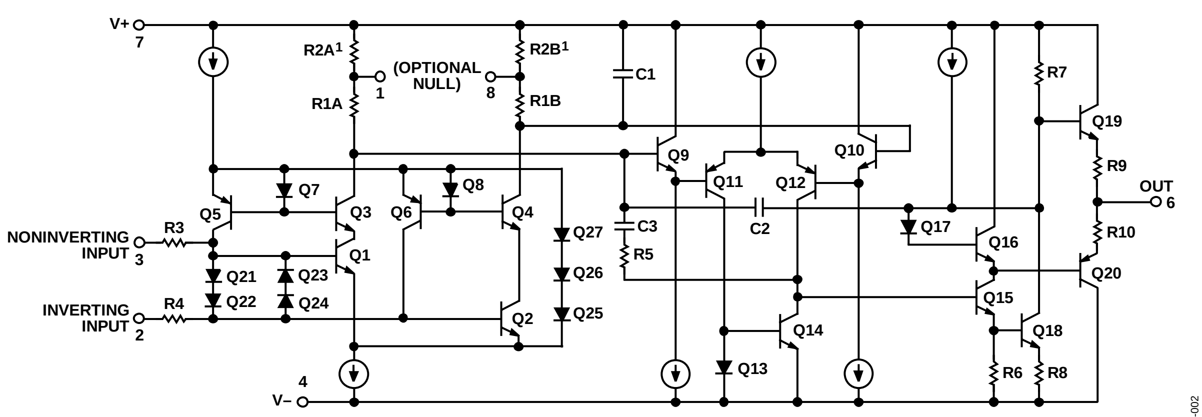


Figure 1.

The wide input voltage range of ±13 V minimum combined with a high CMRR of 106 dB (OP07E) and high input impedance provide high accuracy in the noninverting circuit configuration. Excellent linearity and gain accuracy can be maintained even at high closed-loop gains. Stability of offsets and gain with time or variations in temperature is excellent. The accuracy and stability of the OP07, even at high gain, combined with the freedom from external nulling have made the OP07 an industry standard for instrumentation applications.

The OP07 is available in two standard performance grades. The OP07E is specified for operation over the 0°C to 70°C range, and the OP07C is specified over the −40°C to +85°C temperature range.

The OP07 is available in epoxy 8-lead PDIP and 8-lead narrow SOIC packages. For CERDIP and TO-99 packages and standard microcircuit drawing (SMD) versions, see the OP77.



[1]R2A AND R2B ARE ELECTRONICALLY ADJUSTED ON CHIP AT FACTORY FOR MINIMUM INPUT OFFSET VOLTAGE.

Figure 2. Simplified Schematic

Rev. G

One Technology Way, P.O. Box 9106, Norwood, MA 02062-9106, U.S.A.
Tel: 781.329.4700 **www.analog.com**
Fax: 781.461.3113

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SPECIFICATIONS

OP07E ELECTRICAL CHARACTERISTICS

V_S = ±15 V, unless otherwise noted.

Table 1.

Parameter	Symbol	Conditions	Min	Typ	Max	Unit
INPUT CHARACTERISTICS						
T_A = 25°C						
Input Offset Voltage[1]	V_{OS}			30	75	µV
Long-Term V_{OS} Stability[2]	V_{OS}/Time			0.3	1.5	µV/Month
Input Offset Current	I_{OS}			0.5	3.8	nA
Input Bias Current	I_B			±1.2	±4.0	nA
Input Noise Voltage	e_n p-p	0.1 Hz to 10 Hz[3]		0.35	0.6	µV p-p
Input Noise Voltage Density	e_n	f_O = 10 Hz		10.3	18.0	nV/√Hz
		f_O = 100 Hz[3]		10.0	13.0	nV/√Hz
		f_O = 1 kHz		9.6	11.0	nV/√Hz
Input Noise Current	I_n p-p			14	30	pA p-p
Input Noise Current Density	I_n	f_O = 10 Hz		0.32	0.80	pA/√Hz
		f_O = 100 Hz[3]		0.14	0.23	pA/√Hz
		f_O = 1 kHz		0.12	0.17	pA/√Hz
Input Resistance, Differential Mode[4]	R_{IN}		15	50		MΩ
Input Resistance, Common Mode	R_{INCM}			160		GΩ
Input Voltage Range	IVR		±13	±14		V
Common-Mode Rejection Ratio	CMRR	V_{CM} = ±13 V	106	123		dB
Power Supply Rejection Ratio	PSRR	V_S = ±3 V to ±18 V		5	20	µV/V
Large Signal Voltage Gain	A_{VO}	R_L ≥ 2 kΩ, V_O = ±10 V	200	500		V/mV
		R_L ≥ 500 Ω, V_O = ±0.5 V, V_S = ±3 V[4]	150	400		V/mV
0°C ≤ T_A ≤ 70°C						
Input Offset Voltage[1]	V_{OS}			45	130	µV
Voltage Drift Without External Trim[4]	TCV_{OS}			0.3	1.3	µV/°C
Voltage Drift with External Trim[3]	TCV_{OSN}	R_P = 20 kΩ		0.3	1.3	µV/°C
Input Offset Current	I_{OS}			0.9	5.3	nA
Input Offset Current Drift	TCI_{OS}			8	35	pA/°C
Input Bias Current	I_B			±1.5	±5.5	nA
Input Bias Current Drift	TCI_B			13	35	pA/°C
Input Voltage Range	IVR		±13	±13.5		V
Common-Mode Rejection Ratio	CMRR	V_{CM} = ±13 V	103	123		dB
Power Supply Rejection Ratio	PSRR	V_S = ±3 V to ±18 V		7	32	µV/V
Large Signal Voltage Gain	A_{VO}	R_L ≥ 2 kΩ, V_O = ±10 V	180	450		V/mV
OUTPUT CHARACTERISTICS						
T_A = 25°C						
Output Voltage Swing	V_O	R_L ≥ 10 kΩ	±12.5	±13.0		V
		R_L ≥ 2 kΩ	±12.0	±12.8		V
		R_L ≥ 1 kΩ	±10.5	±12.0		V
0°C ≤ T_A ≤ 70°C						
Output Voltage Swing	V_O	R_L ≥ 2 kΩ	±12	±12.6		V

Parameter	Symbol	Conditions	Min	Typ	Max	Unit
DYNAMIC PERFORMANCE						
T_A = 25°C						
Slew Rate	SR	R_L ≥ 2 kΩ[3]	0.1	0.3		V/µs
Closed-Loop Bandwidth	BW	A_{VOL} = 1[5]	0.4	0.6		MHz
Open-Loop Output Resistance	R_O	V_O = 0, I_O = 0		60		Ω
Power Consumption	P_d	V_S = ±15 V, No load		75	120	mW
		V_S = ±3 V, No load		4	6	mW
Offset Adjustment Range		R_P = 20 kΩ		±4		mV

[1] Input offset voltage measurements are performed by automated test equipment approximately 0.5 seconds after application of power.
[2] Long-term input offset voltage stability refers to the averaged trend time of V_{OS} vs. the time over extended periods after the first 30 days of operation. Excluding the initial hour of operation, changes in V_{OS} during the first 30 operating days are typically 2.5 µV. Refer to the Typical Performance Characteristics section. Parameter is sample tested.
[3] Sample tested.
[4] Guaranteed by design.
[5] Guaranteed but not tested.

OP07C ELECTRICAL CHARACTERISTICS

V_S = ±15 V, unless otherwise noted.

Table 2.

Parameter	Symbol	Conditions	Min	Typ	Max	Unit
INPUT CHARACTERISTICS						
T_A = 25°C						
Input Offset Voltage[1]	V_{OS}			60	150	µV
Long-Term V_{OS} Stability[2]	V_{OS}/Time			0.4	2.0	µV/Month
Input Offset Current	I_{OS}			0.8	6.0	nA
Input Bias Current	I_B			±1.8	±7.0	nA
Input Noise Voltage	e_n p-p	0.1 Hz to 10 Hz[3]		0.38	0.65	µV p-p
Input Noise Voltage Density	e_n	f_O = 10 Hz		10.5	20.0	nV/√Hz
		f_O = 100 Hz[3]		10.2	13.5	nV/√Hz
		f_O = 1 kHz		9.8	11.5	nV/√Hz
Input Noise Current	I_n p-p			15	35	pA p-p
Input Noise Current Density	I_n	f_O = 10 Hz		0.35	0.90	pA/√Hz
		f_O = 100 Hz[3]		0.15	0.27	pA/√Hz
		f_O = 1 kHz		0.13	0.18	pA/√Hz
Input Resistance, Differential Mode[4]	R_{IN}		8	33		MΩ
Input Resistance, Common Mode	R_{INCM}			120		GΩ
Input Voltage Range	IVR		±13	±14		V
Common-Mode Rejection Ratio	CMRR	V_{CM} = ±13 V	100	120		dB
Power Supply Rejection Ratio	PSRR	V_S = ±3 V to ±18 V		7	32	µV/V
Large Signal Voltage Gain	A_{VO}	R_L ≥ 2 kΩ, V_O = ±10 V	120	400		V/mV
		R_L ≥ 500 Ω, V_O = ±0.5 V, V_S = ±3 V[4]	100	400		V/mV
−40°C ≤ T_A ≤ +85°C						
Input Offset Voltage[1]	V_{OS}			85	250	µV
Voltage Drift Without External Trim[4]	TCV_{OS}			0.5	1.8	µV/°C
Voltage Drift with External Trim[3]	TCV_{OSN}	R_P = 20 kΩ		0.4	1.6	µV/°C
Input Offset Current	I_{OS}			1.6	8.0	nA
Input Offset Current Drift	TCI_{OS}			12	50	pA/°C
Input Bias Current	I_B			±2.2	±9.0	nA
Input Bias Current Drift	TCI_B			18	50	pA/°C
Input Voltage Range	IVR		±13	±13.5		V
Common-Mode Rejection Ratio	CMRR	V_{CM} = ±13 V	97	120		dB
Power Supply Rejection Ratio	PSRR	V_S = ±3 V to ±18 V		10	51	µV/V
Large Signal Voltage Gain	A_{VO}	R_L ≥ 2 kΩ, V_O = ±10 V	100	400		V/mV

Parameter	Symbol	Conditions	Min	Typ	Max	Unit
OUTPUT CHARACTERISTICS						
T_A = 25°C						
Output Voltage Swing	V_O	R_L ≥ 10 kΩ	±12.0	±13.0		V
		R_L ≥ 2 kΩ	±11.5	±12.8		V
		R_L ≥ 1 kΩ		±12.0		V
−40°C ≤ T_A ≤ +85°C						
Output Voltage Swing	V_O	R_L ≥ 2 kΩ	±12	±12.6		V
DYNAMIC PERFORMANCE						
T_A = 25°C						
Slew Rate	SR	R_L ≥ 2 kΩ[3]	0.1	0.3		V/μs
Closed-Loop Bandwidth	BW	A_{VOL} = 1[5]	0.4	0.6		MHz
Open-Loop Output Resistance	R_O	V_O = 0, I_O = 0		60		Ω
Power Consumption	P_d	V_S = ±15 V, No load		80	150	mW
		V_S = ±3 V, No load		4	8	mW
Offset Adjustment Range		R_P = 20 kΩ		±4		mV

[1] Input offset voltage measurements are performed by automated test equipment approximately 0.5 seconds after application of power.
[2] Long-term input offset voltage stability refers to the averaged trend time of V_{OS} vs. the time over extended periods after the first 30 days of operation. Excluding the initial hour of operation, changes in V_{OS} during the first 30 operating days are typically 2.5 μV. Refer to the Typical Performance Characteristics section. Parameter is sample tested.
[3] Sample tested.
[4] Guaranteed by design.
[5] Guaranteed but not tested.

ABSOLUTE MAXIMUM RATINGS

Table 3.

Parameter	Ratings
Supply Voltage (V_S)	±22 V
Input Voltage[1]	±22 V
Differential Input Voltage	±30 V
Output Short-Circuit Duration	Indefinite
Storage Temperature Range	
S and P Packages	−65°C to +125°C
Operating Temperature Range	
OP07E	0°C to 70°C
OP07C	−40°C to +85°C
Junction Temperature	150°C
Lead Temperature, Soldering (60 sec)	300°C

[1] For supply voltages less than ±22 V, the absolute maximum input voltage is equal to the supply voltage.

Stresses above those listed under Absolute Maximum Ratings may cause permanent damage to the device. This is a stress rating only; functional operation of the device at these or any other conditions above those indicated in the operational section of this specification is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

THERMAL RESISTANCE

θ_{JA} is specified for the worst-case conditions, that is, a device soldered in a circuit board for surface-mount packages.

Table 4. Thermal Resistance

Package Type	θ_{JA}	θ_{JC}	Unit
8-Lead PDIP (P-Suffix)	103	43	°C/W
8-Lead SOIC_N (S-Suffix)	158	43	°C/W

ESD CAUTION

ESD (electrostatic discharge) sensitive device. Electrostatic charges as high as 4000 V readily accumulate on the human body and test equipment and can discharge without detection. Although this product features proprietary ESD protection circuitry, permanent damage may occur on devices subjected to high energy electrostatic discharges. Therefore, proper ESD precautions are recommended to avoid performance degradation or loss of functionality.

TYPICAL PERFORMANCE CHARACTERISTICS

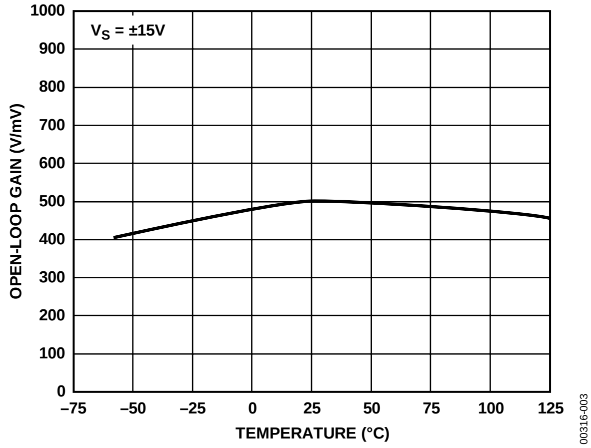


Figure 3. Open-Loop Gain vs. Temperature

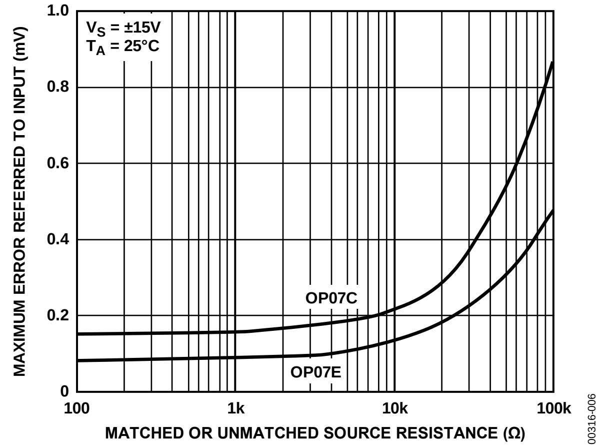


Figure 6. Maximum Error vs. Source Resistance

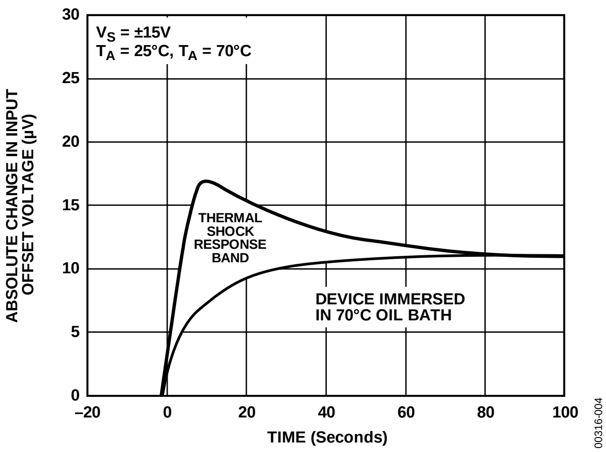


Figure 4. Offset Voltage Change due to Thermal Shock

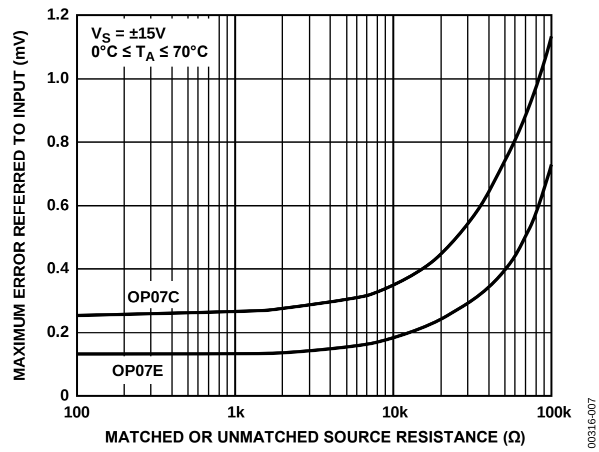


Figure 7. Maximum Error vs. Source Resistance

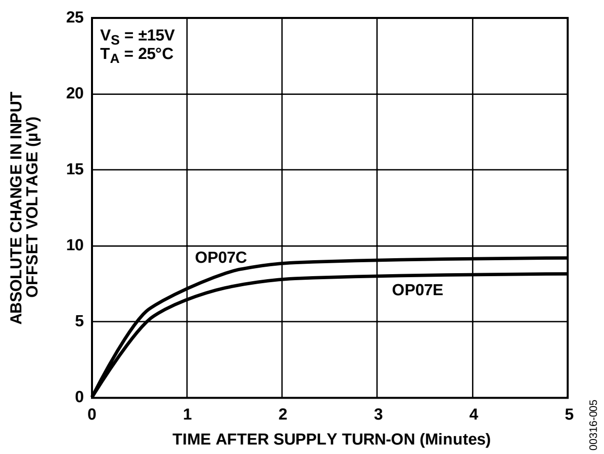


Figure 5. Warm-Up Drift

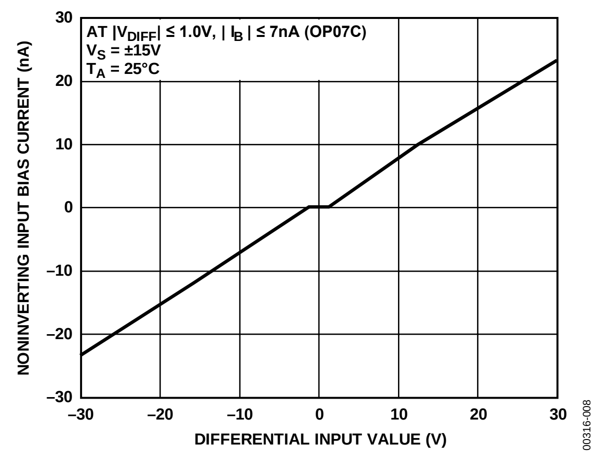


Figure 8. Input Bias Current vs. Differential Input Voltage

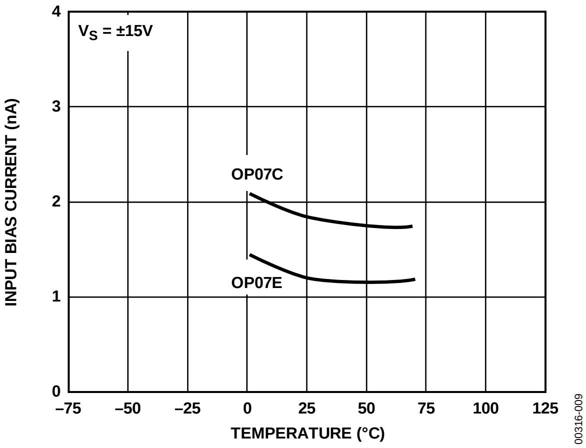


Figure 9. Input Bias Current vs. Temperature

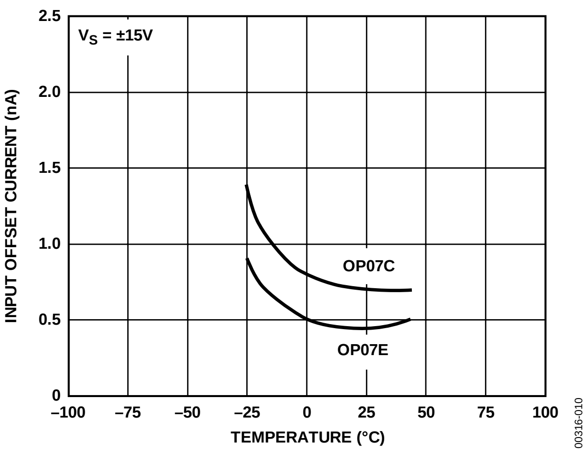


Figure 10. Input Offset Current vs. Temperature

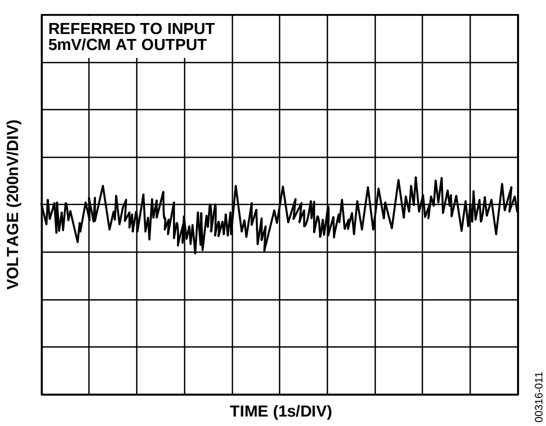


Figure 11. Low Frequency Noise

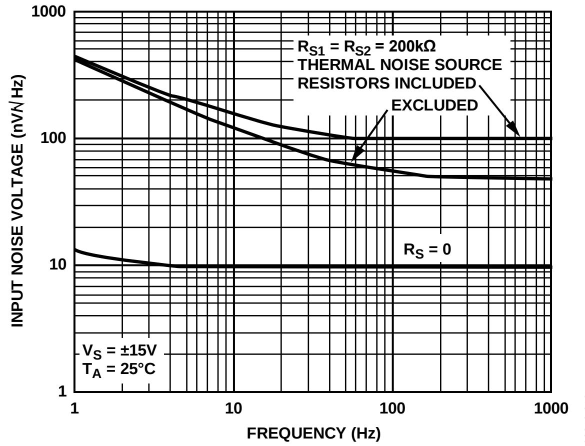


Figure 12. Total Input Noise Voltage vs. Frequency

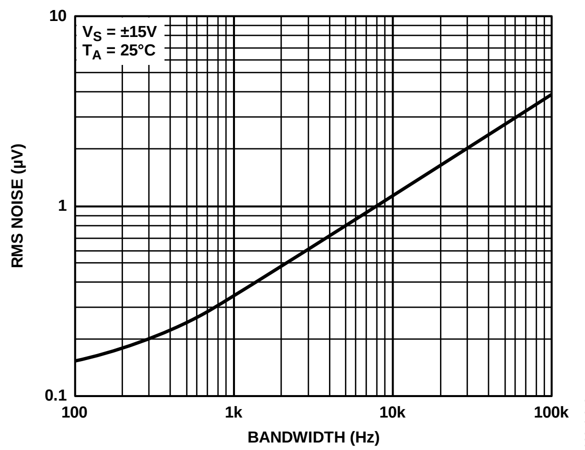


Figure 13. Input Wideband Noise vs. Bandwidth, 0.1 Hz to Frequency Indicated

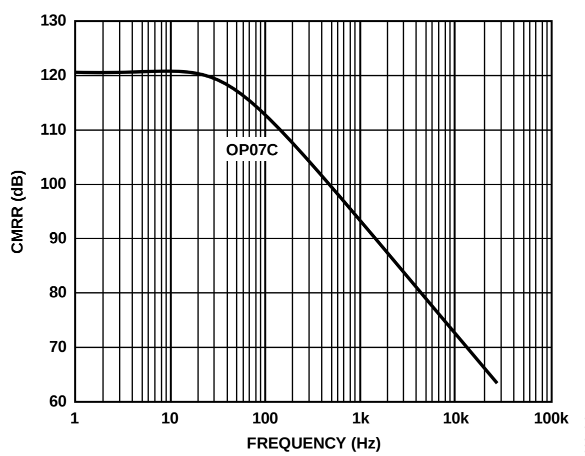


Figure 14. CMRR vs. Frequency

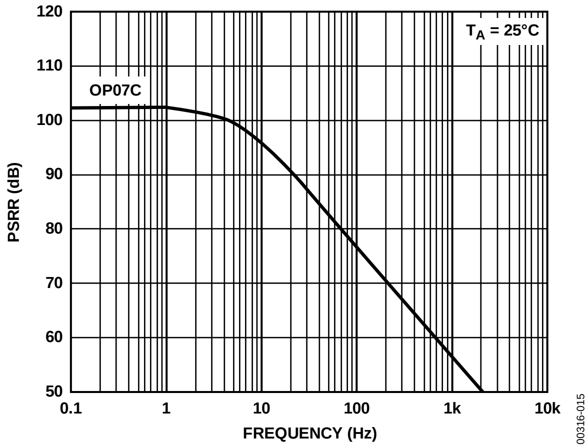


Figure 15. PSRR vs. Frequency

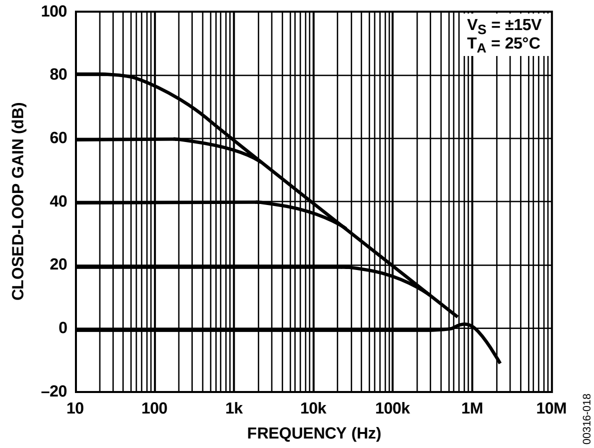


Figure 18. Closed-Loop Frequency Response for Various Gain Configurations

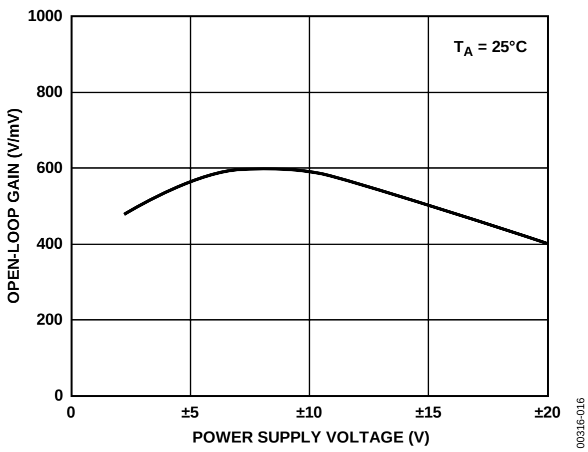


Figure 16. Open-Loop Gain vs. Power Supply Voltage

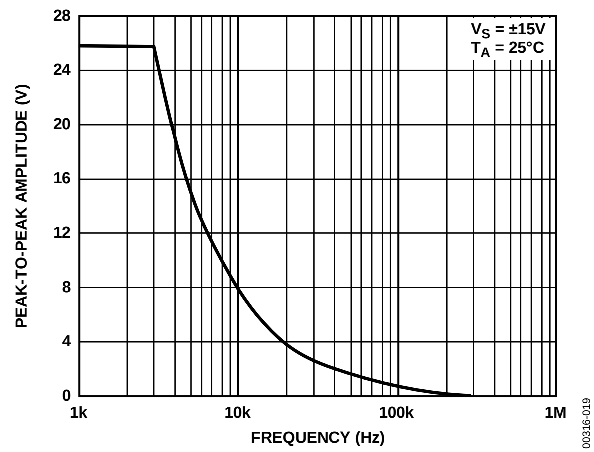


Figure 19. Maximum Output Swing vs. Frequency

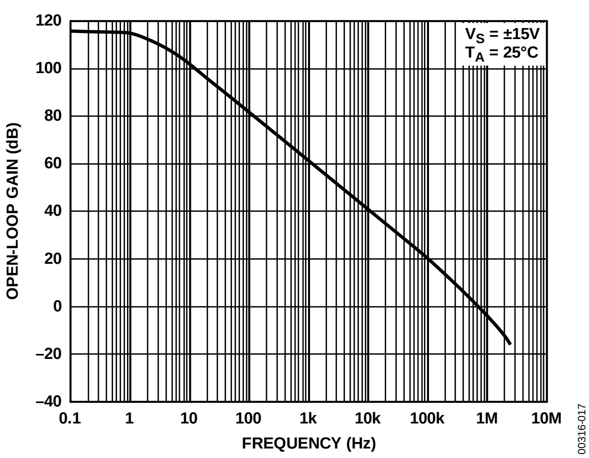


Figure 17. Open-Loop Frequency Response

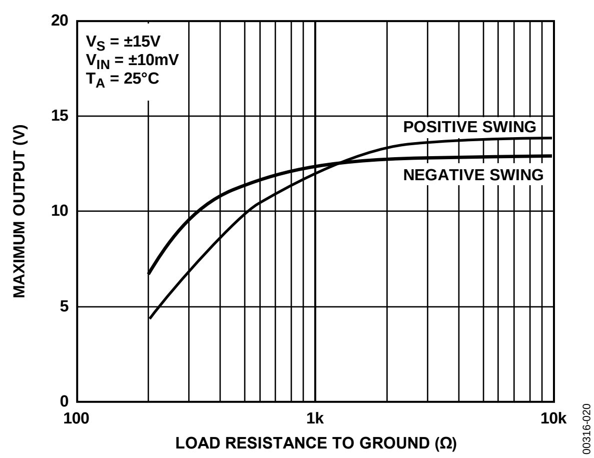


Figure 20. Maximum Output Voltage vs. Load Resistance

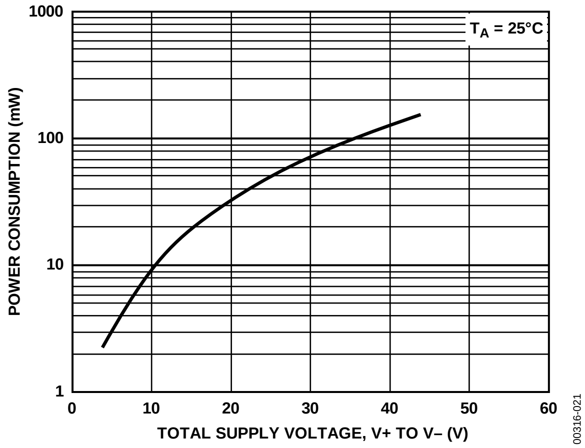


Figure 21. Power Consumption vs. Power Supply

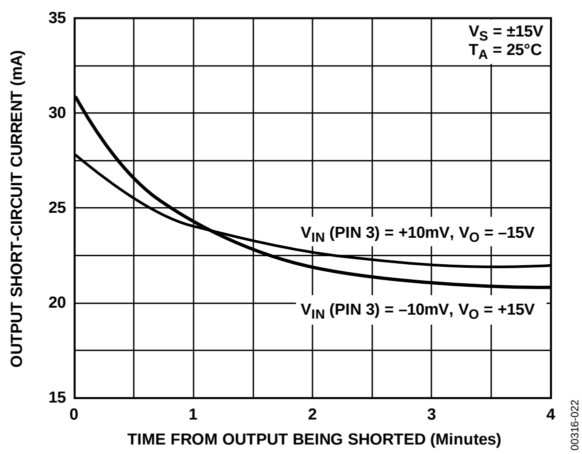


Figure 22. Output Short-Circuit Current vs. Time

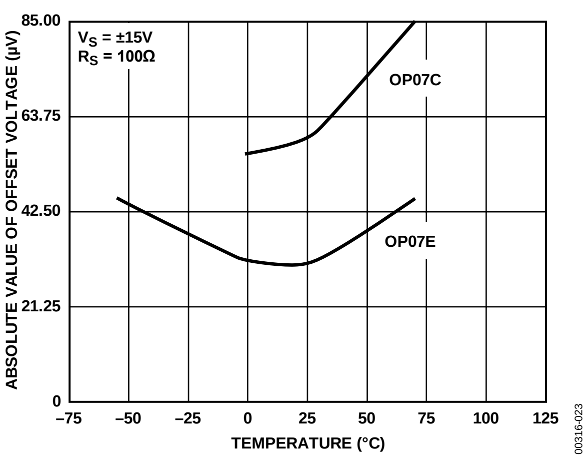


Figure 23. Untrimmed Offset Voltage vs. Temperature

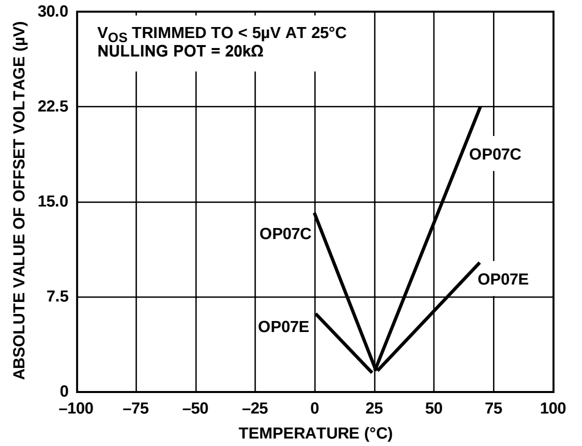


Figure 24. Trimmed Offset Voltage vs. Temperature

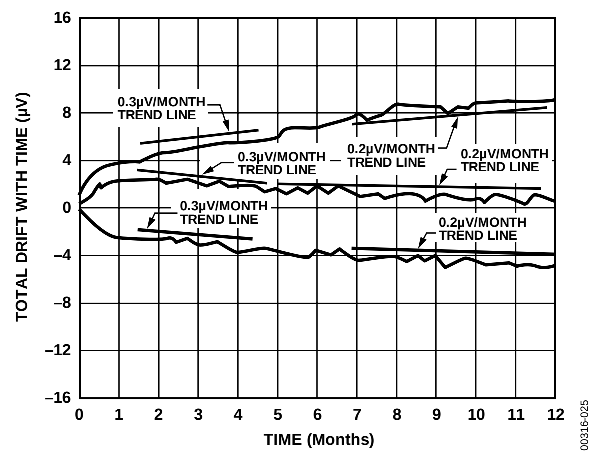


Figure 25. Offset Voltage Drift vs. Time

TYPICAL APPLICATIONS

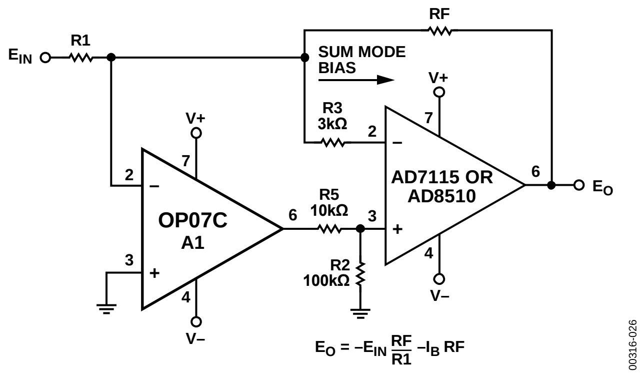


Figure 26. Typical Offset Voltage Test Circuit

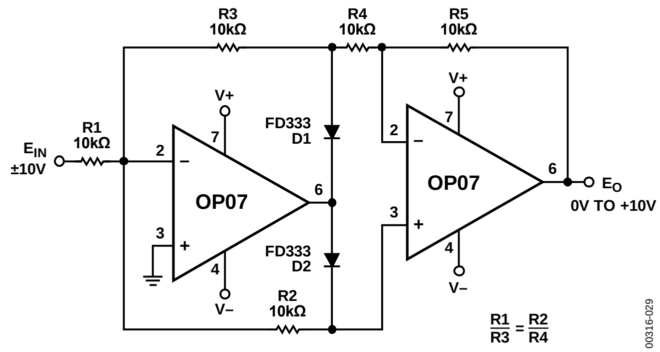


Figure 29. Absolute Value Circuit

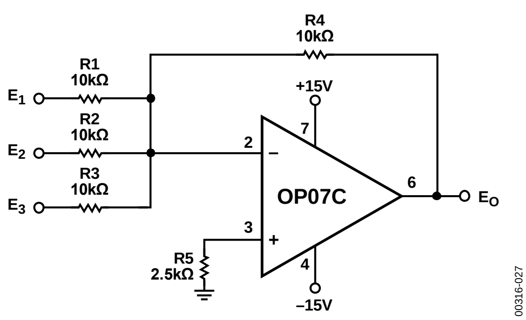


Figure 27. Typical Low Frequency Noise Circuit

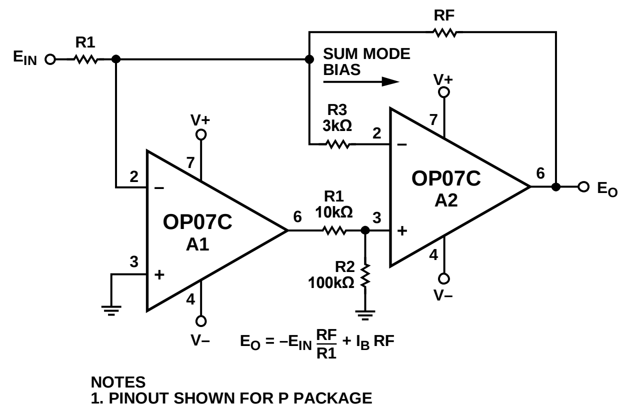


Figure 30. High Speed, Low V_{OS} Composite Amplifier

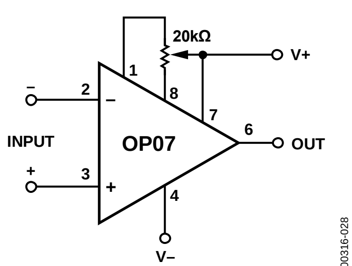


Figure 28. Optional Offset Nulling Circuit

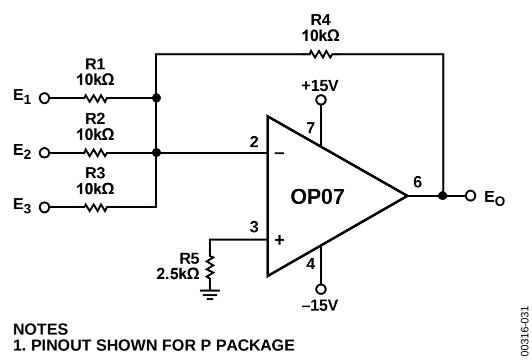


Figure 31. Adjustment-Free Precision Summing Amplifier

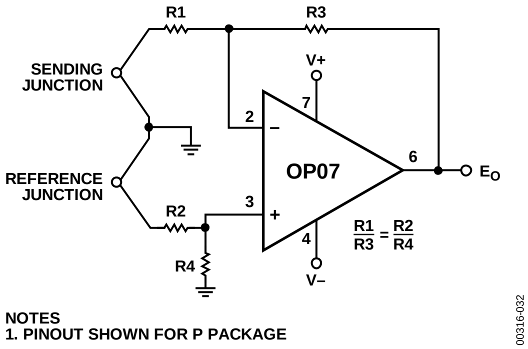


Figure 32. High Stability Thermocouple Amplifier

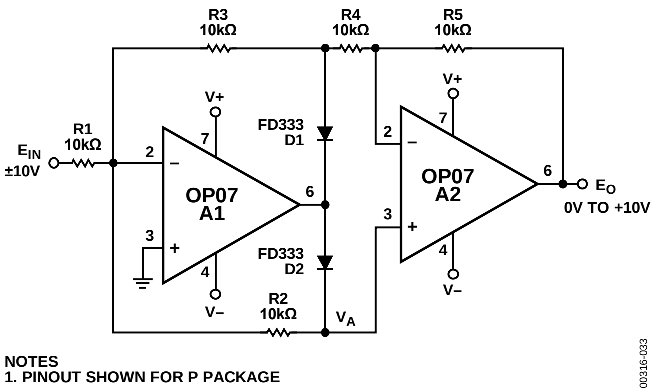


Figure 33. Precision Absolute-Value Circuit

APPLICATIONS INFORMATION

The OP07 provides stable operation with load capacitance of up to 500 pF and ±10 V swings; larger capacitances should be decoupled with a 50 Ω decoupling resistor.

Stray thermoelectric voltages generated by dissimilar metals at the contacts to the input terminals can degrade drift performance. Therefore, best operation is obtained when both input contacts are maintained at the same temperature, preferably close to the package temperature.

OUTLINE DIMENSIONS

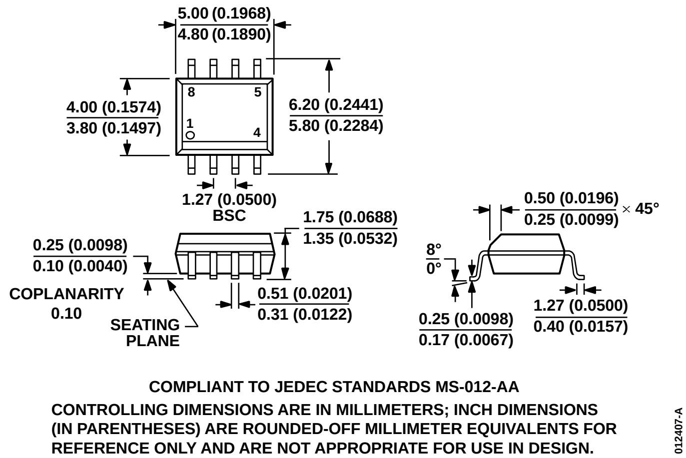


Figure 34. 8-Lead Standard Small Outline Package [SOIC_N]
Narrow Body S-Suffix
(R-8)
Dimensions shown in millimeters and (inches)

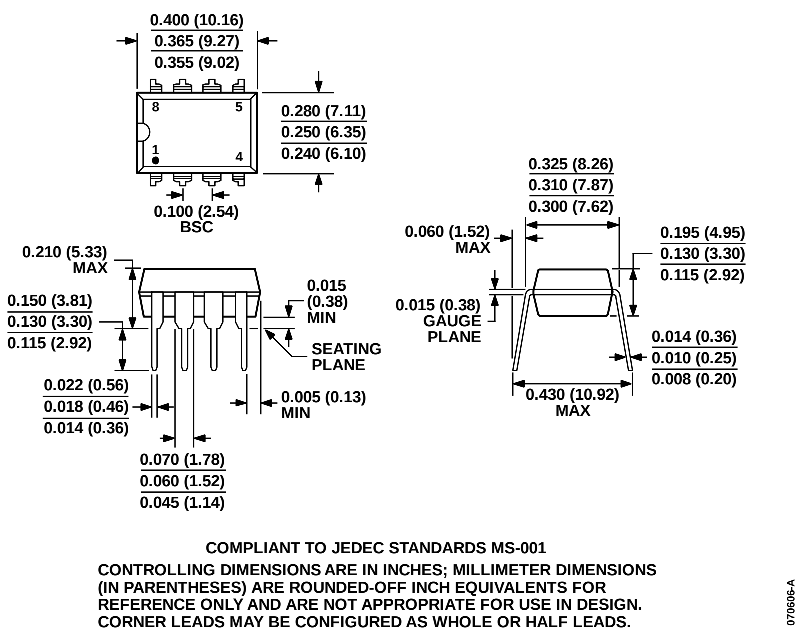


Figure 35. 8-Lead Plastic Dual-in-Line Package [PDIP]
P-Suffix
(N-8)
Dimensions shown in inches and (millimeters)

ORDERING GUIDE

Model[1]	Temperature Range	Package Description	Package Option
OP07EPZ	0°C to 70°C	8-Lead PDIP	N-8 (P-Suffix)
OP07CPZ	−40°C to +85°C	8-Lead PDIP	N-8 (P-Suffix)
OP07CSZ	−40°C to +85°C	8-Lead SOIC_N	R-8 (S-Suffix)
OP07CSZ-REEL	−40°C to +85°C	8-Lead SOIC_N	R-8 (S-Suffix)
OP07CSZ-REEL7	−40°C to +85°C	8-Lead SOIC_N	R-8 (S-Suffix)

[1] Z = RoHS Compliant Part.

NOTES

NOTES

ANALOG DEVICES

Low-Noise, Precision Operational Amplifier

OP27

FEATURES

Low Noise: 80 nV p-p (0.1 Hz to 10 Hz), 3 nV/√Hz
Low Drift: 0.2 µV/°C
High Speed: 2.8 V/µs Slew Rate, 8 MHz Gain Bandwidth
Low V_{OS}: 10 µV
Excellent CMRR: 126 dB at V_{CM} of ±11 V
High Open-Loop Gain: 1.8 Million
Fits 725, OP07, 5534A Sockets
Available in Die Form

GENERAL DESCRIPTION

The OP27 precision operational amplifier combines the low offset and drift of the OP07 with both high speed and low noise. Offsets down to 25 µV and maximum drift of 0.6 µV/°C, makes the OP27 ideal for precision instrumentation applications. Exceptionally low noise, e_n = 3.5 nV/√Hz, at 10 Hz, a low 1/f noise corner frequency of 2.7 Hz, and high gain (1.8 million), allow accurate high-gain amplification of low-level signals. A gain-bandwidth product of 8 MHz and a 2.8 V/µsec slew rate provides excellent dynamic accuracy in high-speed, data-acquisition systems.

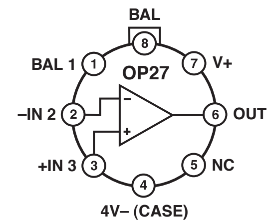
A low input bias current of ±10 nA is achieved by use of a bias-current-cancellation circuit. Over the military temperature range, this circuit typically holds I_B and I_{OS} to ±20 nA and 15 nA, respectively.

The output stage has good load driving capability. A guaranteed swing of ±10 V into 600 Ω and low output distortion make the OP27 an excellent choice for professional audio applications.

(Continued on page 7)

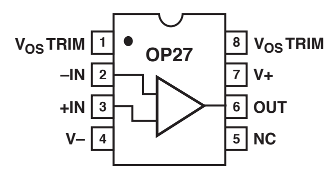
PIN CONNECTIONS

TO-99
(J-Suffix)



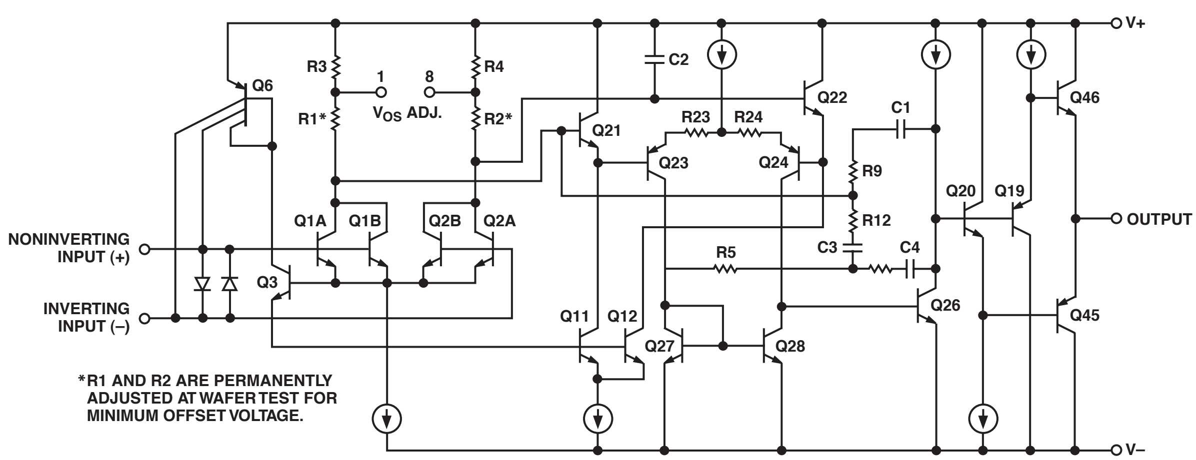
NC = NO CONNECT

8-Pin Hermetic DIP
(Z-Suffix)
Epoxy Mini-DIP
(P-Suffix)
8-Pin SO
(S-Suffix)



NC = NO CONNECT

SIMPLIFIED SCHEMATIC



REV. C

One Technology Way, P.O. Box 9106, Norwood, MA 02062-9106, U.S.A.
Tel: 781/329-4700 www.analog.com
Fax: 781/326-8703

OP27–SPECIFICATIONS

ELECTRICAL CHARACTERISTICS (@ V_S = ±15 V, T_A = 25°C, unless otherwise noted.)

Parameter	Symbol	Conditions	OP27A/E Min	OP27A/E Typ	OP27A/E Max	OP27F Min	OP27F Typ	OP27F Max	OP27C/G Min	OP27C/G Typ	OP27C/G Max	Unit
INPUT OFFSET VOLTAGE[1]	V_{OS}			10	25		20	60		30	100	μV
LONG-TERM V_{OS} STABILITY[2, 3]	V_{OS}/Time			0.2	1.0		0.3	1.5		0.4	2.0	μV/M_O
INPUT OFFSET CURRENT	I_{OS}			7	35		9	50		12	75	nA
INPUT BIAS CURRENT	I_B			±10	±40		±12	±55		±15	±80	nA
INPUT NOISE VOLTAGE[3, 4]	$e_{n\ p\text{-}p}$	0.1 Hz to 10 Hz		0.08	0.18		0.08	0.18		0.09	0.25	μV p-p
INPUT NOISE Voltage Density[3]	e_n	f_O = 10 Hz		3.5	5.5		3.5	5.5		3.8	8.0	nV/√Hz
		f_O = 30 Hz		3.1	4.5		3.1	4.5		3.3	5.6	nV/√Hz
		f_O = 1000 Hz		3.0	3.8		3.0	3.8		3.2	4.5	nV/√Hz
INPUT NOISE Current Density[3, 5]	i_n	f_O = 10 Hz		1.7	4.0		1.7	4.0		1.7		pA/√Hz
		f_O = 30 Hz		1.0	2.3		1.0	2.3		1.0		pA/√Hz
		f_O = 1000 Hz		0.4	0.6		0.4	0.6		0.4	0.6	pA/√Hz
INPUT RESISTANCE Differential-Mode[6]	R_{IN}		1.3	6		0.94	5		0.7	4		MΩ
Common-Mode	R_{INCM}			3			2.5			2		GΩ
INPUT VOLTAGE RANGE	IVR		±11.0	±12.3		±11.0	±12.3		±11.0	±12.3		V
COMMON-MODE REJECTION RATIO	CMRR	V_{CM} = ±11 V	114	126		106	123		100	120		dB
POWER SUPPLY REJECTION RATIO	PSRR	V_S = ±4 V to ±18 V		1	10		1	10		2	20	μV/V
LARGE-SIGNAL VOLTAGE GAIN	A_{VO}	R_L ≥ 2 kΩ, V_O = ±10 V	1000	1800		1000	1800		700	1500		V/mV
		R_L ≥ 600 Ω, V_O = ±10 V	800	1500		800	1500		600	1500		V/mV
OUTPUT VOLTAGE SWING	V_O	R_L ≥ 2 kΩ	±12.0	±13.8		±12.0	±13.8		±11.5	±13.5		V
		R_L ≥ 600 Ω	±10.0	±11.5		±10.0	±11.5		±10.0	±11.5		V
SLEW RATE[7]	SR	R_L ≥ 2 kΩ	1.7	2.8		1.7	2.8		1.7	2.8		V/μs
GAIN BANDWIDTH PRODUCT[7]	GBW		5.0	8.0		5.0	8.0		5.0	8.0		MHz
OPEN-LOOP OUTPUT RESISTANCE	R_O	V_O = 0, I_O = 0		70			70			70		Ω
POWER CONSUMPTION	P_d	V_O		90	140		90	140		100	170	mW
OFFSET ADJUSTMENT RANGE		R_P = 10 kΩ		±4.0			±4.0			±4.0		mV

NOTES

[1]Input offset voltage measurements are performed ~ 0.5 seconds after application of power. A/E grades guaranteed fully warmed up.

[2]Long-term input offset voltage stability refers to the average trend line of V_{OS} versus. Time over extended periods after the first 30 days of operation. Excluding the initial hour of operation, changes in V_{OS} during the first 30 days are typically 2.5 μV. Refer to typical performance curve.

[3]Sample tested.

[4]See test circuit and frequency response curve for 0.1 Hz to 10 Hz tester.

[5]See test circuit for current noise measurement.

[6]Guaranteed by input bias current.

[7]Guaranteed by design.

ELECTRICAL CHARACTERISTICS (@ V_S = ±15 V, –55°C ≤ T_A ≤ 125°C, unless otherwise noted.)

Parameter	Symbol	Conditions	OP27A Min	OP27A Typ	OP27A Max	OP27C Min	OP27C Typ	OP27C Max	Unit
INPUT OFFSET VOLTAGE[1]	V_{OS}			30	60		70	300	µV
AVERAGE INPUT OFFSET DRIFT	TCV_{OS}[2] TCV_{OSn}[3]			0.2	0.6		4	1.8	µV/°C
INPUT OFFSET CURRENT	I_{OS}			15	50		30	135	nA
INPUT BIAS CURRENT	I_B			±20	±60		±35	±150	nA
INPUT VOLTAGE RANGE	IVR		±10.3	±11.5		±10.2	±11.5		V
COMMON-MODE REJECTION RATIO	CMRR	V_{CM} = ±10 V	108	122		94	118		dB
POWER SUPPLY REJECTION RATIO	PSRR	V_S = ±4.5 V to ±18 V		2	16		4	51	µV/V
LARGE-SIGNAL VOLTAGE GAIN	A_{VO}	R_L ≥ 2 kΩ, V_O = ±10 V	600	1200		300	800		V/mV
OUTPUT VOLTAGE SWING	V_O	R_L ≥ 2 kΩ	±11.5	±13.5		±10.5	±13.0		V

NOTES

[1]Input offset voltage measurements are performed by automated test equipment approximately 0.5 seconds after application of power. A/E grades guaranteed fully warmed up.

[2]The TCV_{OS} performance is within the specifications unnulled or when nulled with R_P = 8 kΩ to 20 kΩ. TCV_{OS} is 100% tested for A/E grades, sample tested for C/F/G grades.

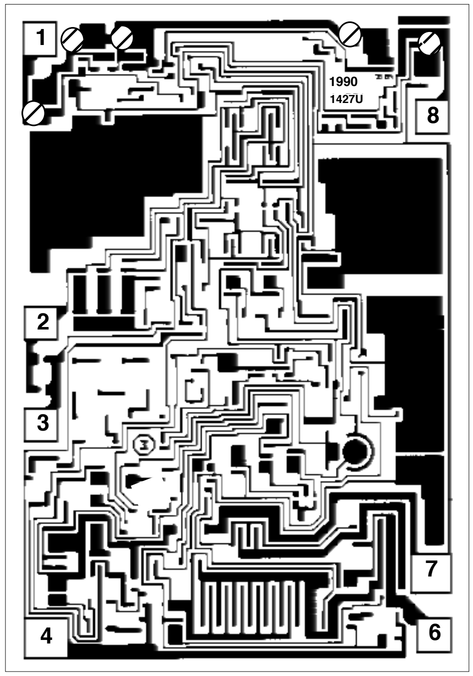
[3]Guaranteed by design.

ELECTRICAL CHARACTERISTICS (@ V_S = ±15 V, –25°C ≤ T_A ≤ 85°C for OP27J, OP27Z, 0°C ≤ T_A ≤ 70°C for OP27EP, OP27FP, and –40°C ≤ T_A ≤ 85°C for OP27GP, OP27GS, unless otherwise noted.)

Parameter	Symbol	Conditions	OP27E Min	OP27E Typ	OP27E Max	OP27F Min	OP27F Typ	OP27F Max	OP27G Min	OP27G Typ	OP27G Max	Unit
INPUT ONSET VOLTAGE	V_{OS}			20	50		40	140		55	220	µV
AVERAGE INPUT OFFSET DRIFT	TCV_{OS}[1]			0.2	0.6		0.3	1.3		0 4	1.8	µV/°C
	TCV_{OSn}[2]			0.2	0.6		0.3	1.3		0 4	1.8	µV/°C
INPUT OFFSET CURRENT	I_{OS}			10	50		14	85		20	135	nA
INPUT BIAS CURRENT	I_B			±14	±60		±18	±95		±25	±150	nA
INPUT VOLTAGE RANGE	IVR		±10.5	±11.8		±10.5	±11.8		±10.5	±11.8		V
COMMON-MODE REJECTION RATIO	CMRR	V_{CM} = ±10 V	110	124		102	121		96	118		dB
POWER SUPPLY REJECTION RATIO	PSRR	V_S = ±4.5 V to ±18 V		2	15		2	16		2	32	µV/V
LARGE-SIGNAL VOLTAGE GAIN	A_{VO}	R_L ≥ 2 kΩ, V_O = ±10 V	750	1500		700	1300		450	1000		V/mV
OUTPUT VOLTAGE SWING	V_O	R_L ≥ 2 kΩ	±11.7	±13.6		±11.4	±13.5		±11.0	±13.3		V

NOTES
[1]The TCV_{OS} performance is within the specifications unnulled or when nulled with R_P = 8 kΩ to 20 kΩ. TCV_{OS} is 100% tested for A/E grades, sample tested for C/F/G grades.
[2]Guaranteed by design.

DIE CHARACTERISTICS



1. NULL
2. (–) INPUT
3. (+) INPUT
4. V–
6. OUTPUT
7. V+
8. NULL

WAFER TEST LIMITS (@ V_S = ±15 V, T_A = 25°C unless otherwise noted.)

Parameter	Symbol	Conditions	OP27N Limit	OP27G Limit	OP27GR Limit	Unit
INPUT OFFSET VOLTAGE*	V_{OS}		35	60	100	µV Max
INPUT OFFSET CURRENT	I_{OS}		35	50	75	nA Max
INPUT BIAS CURRENT	IB		±40	±55	±80	nA Max
INPUT VOLTAGE RANGE	IVR		±11	±11	±11	V Min
COMMON-MODE REJECTION RATIO	CMRR	V_{CM} = IVR	114	106	100	dB Min
POWER SUPPLY	PSRR	V_S = ±4 V to ±18 V	10	10	20	µV/V Max
LARGE-SIGNAL VOLTAGE GAIN	A_{VO}	R_L ≥ 2 kΩ, V_O = ±10 V	1000	1000	700	V/mV Min
	A_{VO}	R_L ≥ 600 Ω, V_O = ±10 V	800	800	600	V/mV Min
OUTPUT VOLTAGE SWING	V_O	R_L ≥ 2 kΩ	±12.0	±12.0	+11.5	V Min
	V_O	RL2600n	±10.0	±10.0	±10.0	V Min
POWER CONSUMPTION	P_d	V_O = 0	140	140	170	mW Max

NOTE
*Electrical tests are performed at wafer probe to the limits shown. Due to variations in assembly methods and normal yield loss, yield after packaging is not guaranteed for standard product dice. Consult factory to negotiate specifications based on dice lot qualification through sample lot assembly and testing.

TYPICAL ELECTRICAL CHARACTERISTICS (@ V_S = ±15 V, T_A = 25°C unless otherwise noted.)

Parameter	Symbol	Conditions	OP27N Typical	OP27G Typical	OP27GR Typical	Unit
AVERAGE INPUT OFFSET VOLTAGE DRIFT*	TCV_{OS} or TCV_{OSn}	Nulled or Unnulled R_P = 8 kΩ to 20 kΩ	0.2	0.3	0.4	µV/°C
AVERAGE INPUT OFFSET CURRENT DRIFT	TCI_{OS}		80	130	180	pA/°C
AVERAGE INPUT BIAS CURRENT DRIFT	TCI_B		100	160	200	pA/°C
INPUT NOISE VOLTAGE DENSITY	e_n	f_O = 10 Hz	3.5	3.5	3.8	$nV/\sqrt{Hz}$
	e_n	f_O = 30 Hz	3.1	3.1	3.3	$nV/\sqrt{Hz}$
	e_n	f_O = 1000 Hz	3.0	3.0	3.2	$nV/\sqrt{Hz}$
INPUT NOISE CURRENT DENSITY	i_n	f_O = 10 Hz	1.7	1.7	1.7	$pA/\sqrt{Hz}$
	i_n	f_O = 30 Hz	1.0	1.0	1.0	$pA/\sqrt{Hz}$
	i_n	f_O = 1000 Hz	0.4	0.4	0.4	$pA/\sqrt{Hz}$
INPUT NOISE VOLTAGE	e_{np-p}	0.1 Hz to 10 Hz	0.08	0.08	0.09	µV p-p
SLEW RATE	SR	R_L ≥ 2 kΩ	2.8	2.8	2.8	V/µs
GAIN BANDWIDTH PRODUCT	GBW		8	8	8	MHz

NOTE
*Input offset voltage measurements are performed by automated test equipment approximately 0.5 seconds after application of power.

(Continued from page 1)

PSRR and CMRR exceed 120 dB. These characteristics, coupled with long-term drift of 0.2 µV/month, allow the circuit designer to achieve performance levels previously attained only by discrete designs.

Low-cost, high-volume production of OP27 is achieved by using an on-chip Zener zap-trimming network. This reliable and stable offset trimming scheme has proved its effectiveness over many years of production history.

The OP27 provides excellent performance in low-noise, high-accuracy amplification of low-level signals. Applications include stable integrators, precision summing amplifiers, precision voltage-threshold detectors, comparators, and professional audio circuits such as tape-head and microphone preamplifiers.

The OP27 is a direct replacement for 725, OP06, OP07, and OP45 amplifiers; 741 types may be directly replaced by removing the 741's nulling potentiometer.

ABSOLUTE MAXIMUM RATINGS[4]

Supply Voltage . . . . ±22 V
Input Voltage[1] . . . . ±22 V
Output Short-Circuit Duration . . . . Indefinite
Differential Input Voltage[2] . . . . ±0.7 V
Differential Input Current[2] . . . . ±25 mA
Storage Temperature Range . . . . –65°C to +150°C
Operating Temperature Range
  OP27A, OP27C (J, Z) . . . . –55°C to +125°C
  OP27E, OP27F (J, Z) . . . . –25°C to +85°C
  OP27E, OP27F (P) . . . . 0°C to 70°C
  OP27G (P, S, J, Z) . . . . –40°C to +85°C
Lead Temperature Range (Soldering, 60 sec) . . . . 300°C
Junction Temperature . . . . –65°C to +150°C

Package Type	θ_{JA}[3]	θ_{JC}	Unit
TO 99 (J)	150	18	°C/W
8-Lead Hermetic DIP (Z)	148	16	°C/W
8-Lead Plastic DIP (P)	103	43	°C/W
20-Contact LCC (RC)	98	38	°C/W
8-Lead SO (S)	158	43	°C/W

NOTES
[1]For supply voltages less than ±22 V, the absolute maximum input voltage is equal to the supply voltage.
[2]The OP27's inputs are protected by back-to-back diodes. Current limiting resistors are not used in order to achieve low noise. If differential input voltage exceeds ±0.7 V, the input current should be limited to 25 mA.
[3]θ_{JA} is specified for worst-case mounting conditions, i.e., θ_{JA} is specified for device in socket for TO, CERDIP, and P-DIP packages; θ_{JA} is specified for device soldered to printed circuit board for SO package.
[4]Absolute Maximum Ratings apply to both DICE and packaged parts, unless otherwise noted.

ORDERING INFORMATION[1]

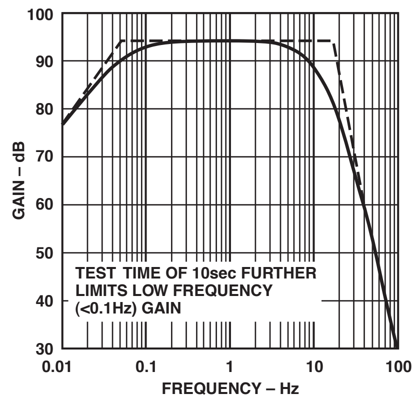
	Package			
T_A = 25°C V_{OS} Max (µV)	TO-99	CERDIP 8-Lead	Plastic 8-Lead	Operating Temperature Range
25	OP27AJ[2, 3]	OP27AZ[2]		MIL
25	OP27EJ[2, 3]	OP27EZ	OP27EP	IND/COM
60			OP27FP[3]	IND/COM
100		OP27CZ[3]		MIL
100	OP27GJ	OP27GZ	OP27GP	XIND
100			OP27GS[4]	XIND

NOTES
[1]Burn-in is available on commercial and industrial temperature range parts in CERDIP, plastic DIP, and TO-can packages.
[2]For devices processed in total compliance to MIL-STD-883, add /883 after part number. Consult factory for 883 data sheet.
[3]Not for new design; obsolete April 2002.
[4]For availability and burn-in information on SO and PLCC packages, contact your local sales office.

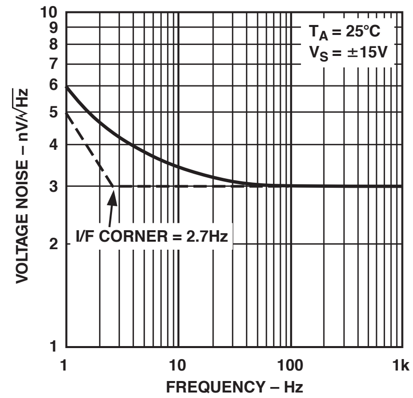
CAUTION

ESD (electrostatic discharge) sensitive device. Electrostatic charges as high as 4000 V readily accumulate on the human body and test equipment and can discharge without detection. Although the OP27 features proprietary ESD protection circuitry, permanent damage may occur on devices subjected to high-energy electrostatic discharges. Therefore, proper ESD precautions are recommended to avoid performance degradation or loss of functionality.

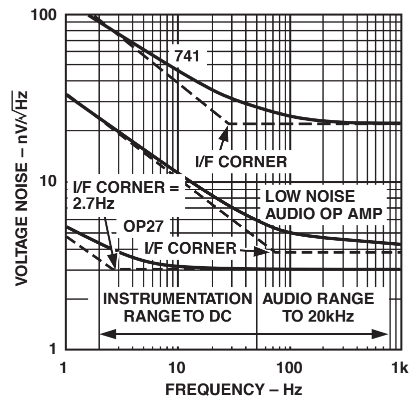
OP27–Typical Performance Characteristics



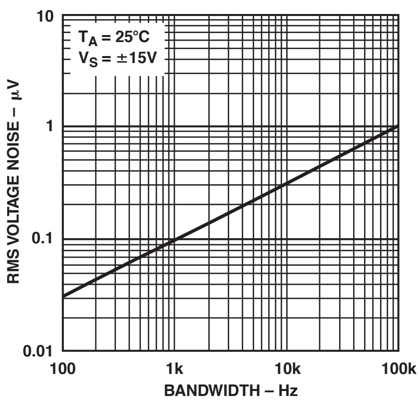
TPC 1. 0.1 Hz to 10 Hz_{p-p} Noise Tester Frequency Response



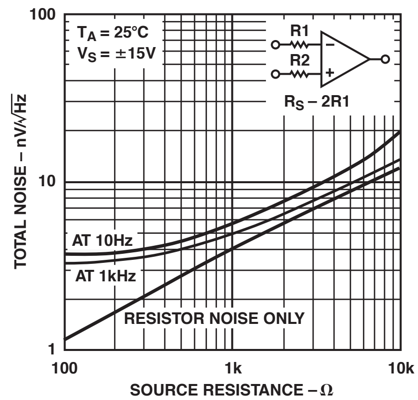
TPC 2. Voltage Noise Density vs. Frequency



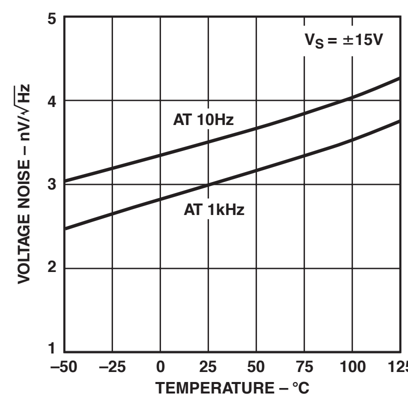
TPC 3. A Comparison of Op Amp Voltage Noise Spectra



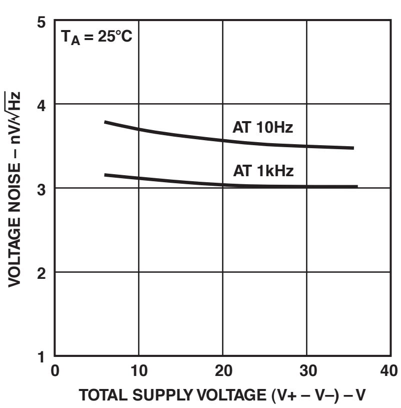
TPC 4. Input Wideband Voltage Noise vs. Bandwidth (0.1 Hz to Frequency Indicated)



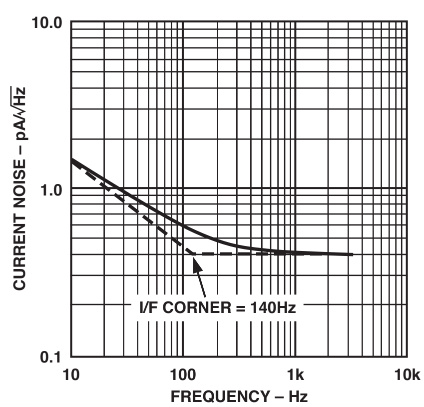
TPC 5. Total Noise vs. Sourced Resistance



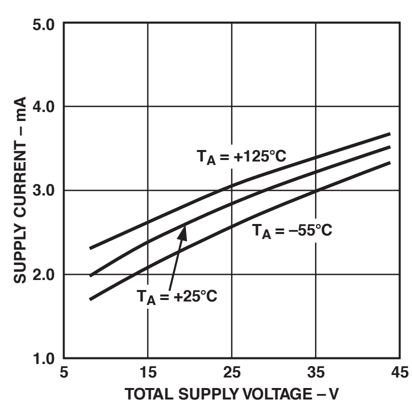
TPC 6. Voltage Noise Density vs. Temperature



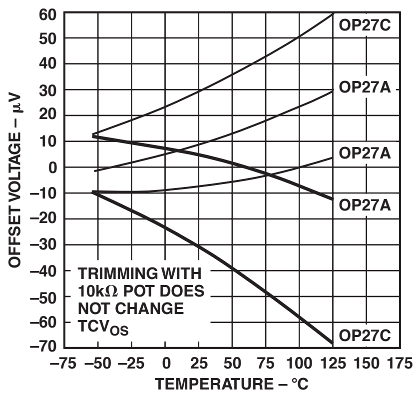
TPC 7. Voltage Noise Density vs. Supply Voltage



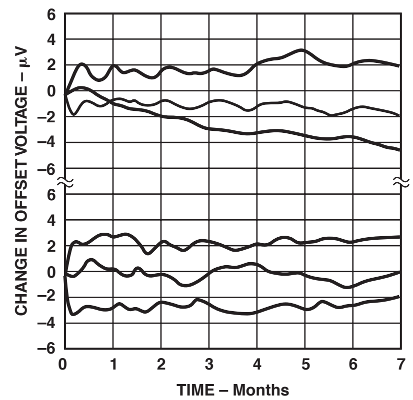
TPC 8. Current Noise Density vs. Frequency



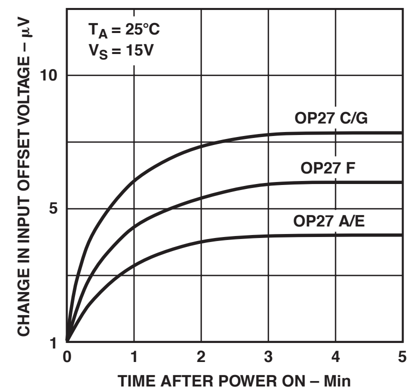
TPC 9. Supply Current vs. Supply Voltage



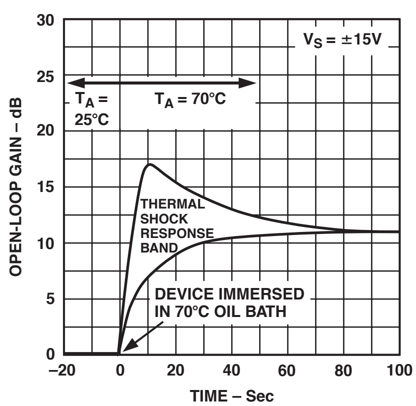
TPC 10. *Offset Voltage Drift of Five Representative Units vs. Temperature*



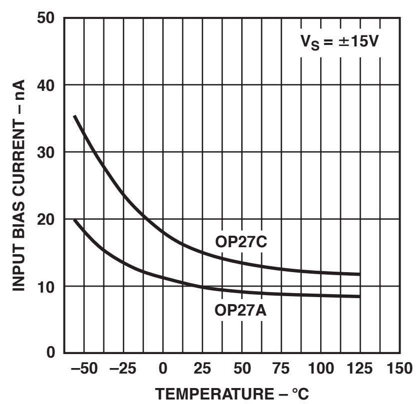
TPC 11. *Long-Term Offset Voltage Drift of Six Representative Units*



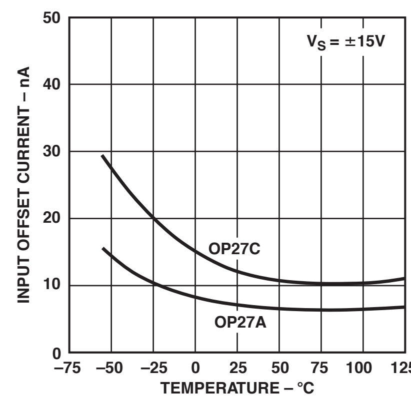
TPC 12. *Warm-Up Offset Voltage Drift*



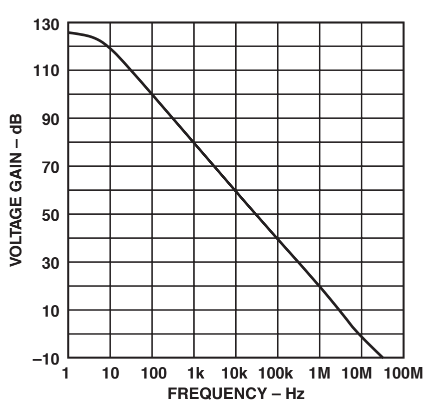
TPC 13. *Offset Voltage Change Due to Thermal Shock*



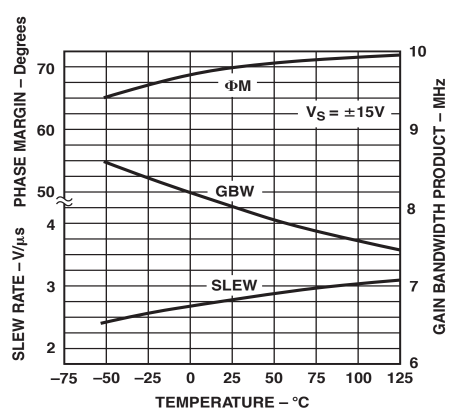
TPC 14. *Input Bias Current vs. Temperature*



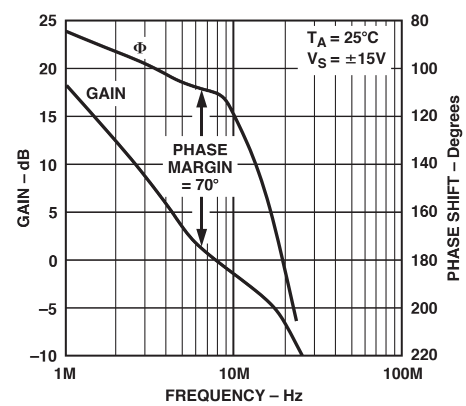
TPC 15. *Input Offset Current vs. Temperature*



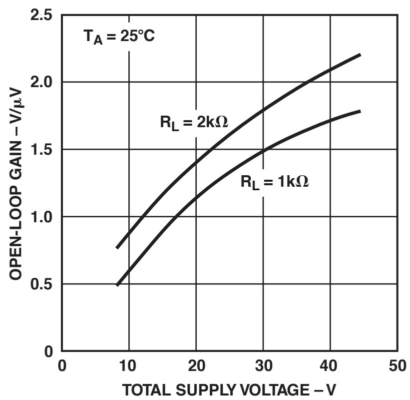
TPC 16. *Open-Loop Gain vs. Frequency*



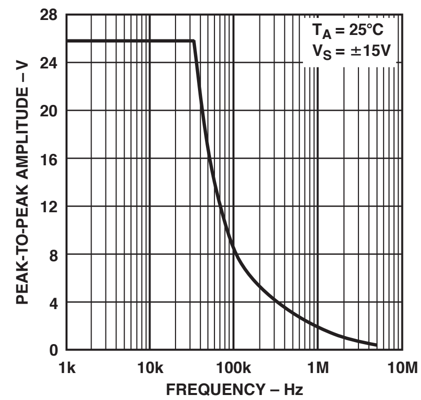
TPC 17. *Slew Rate, Gain-Bandwidth Product, Phase Margin vs. Temperature*



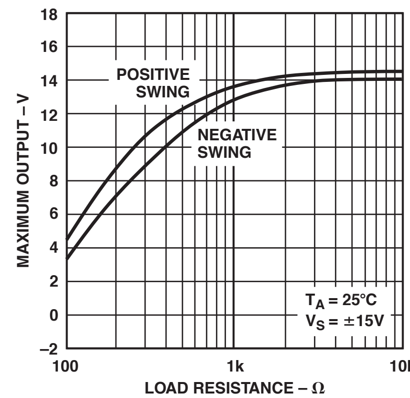
TPC 18. *Gain, Phase Shift vs. Frequency*



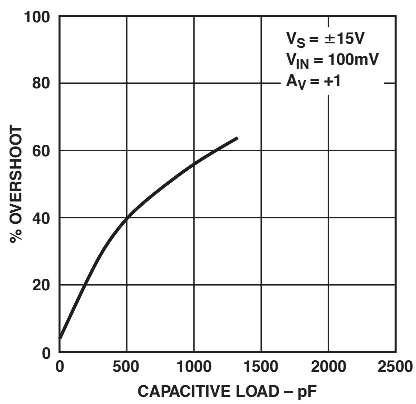
TPC 19. Open-Loop Voltage Gain vs. Supply Voltage



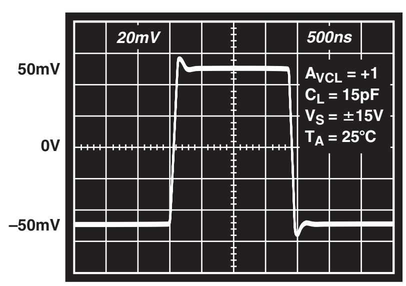
TPC 20. Maximum Output Swing vs. Frequency



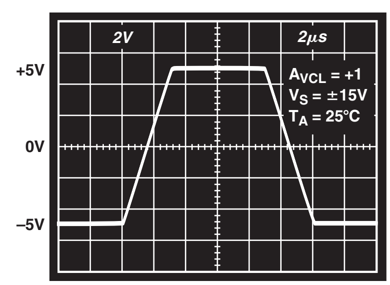
TPC 21. Maximum Output Voltage vs. Load Resistance



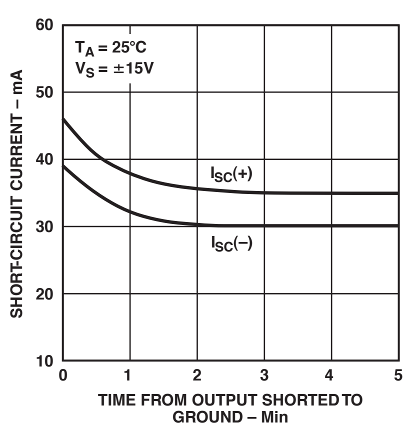
TPC 22. Small-Signal Overshoot vs. Capacitive Load



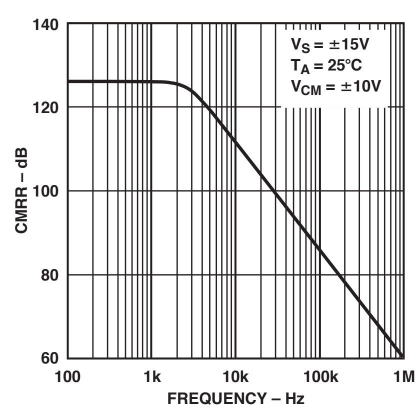
TPC 23. Small-Signal Transient Response



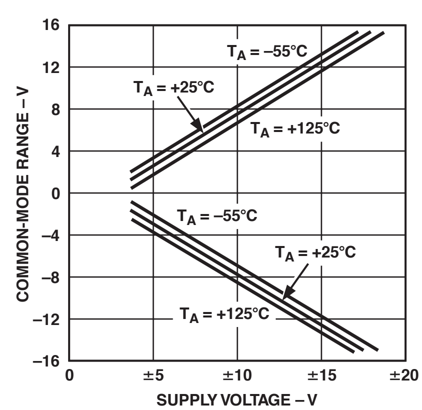
TPC 24. Large-Signal Transient Response



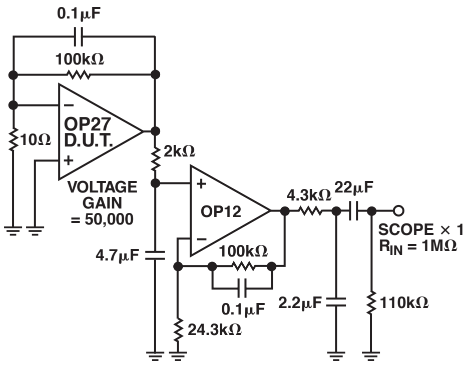
TPC 25. Short-Circuit Current vs. Time



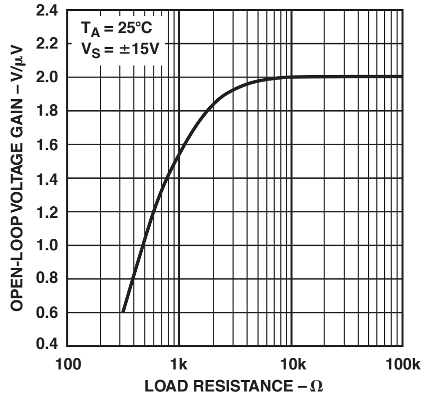
TPC 26. CMRR vs. Frequency



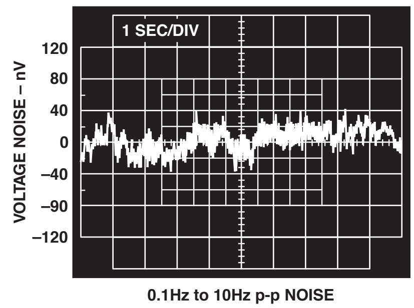
TPC 27. Common-Mode Input Range vs. Supply Voltage



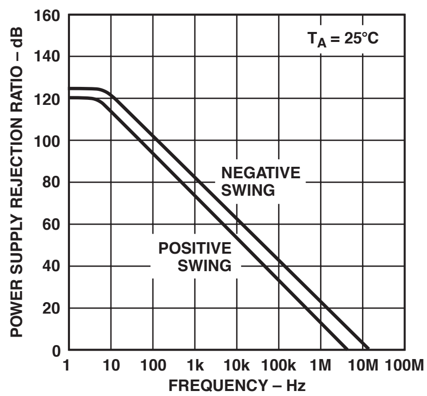
TPC 28. Voltage Noise Test Circuit (0.1 Hz to 10 Hz)



TPC 29. Open-Loop Voltage Gain vs. Load Resistance



TPC 30. Low-Frequency Noise



TPC 31. PSRR vs. Frequency

APPLICATION INFORMATION

OP27 series units may be inserted directly into 725 and OP07 sockets with or without removal of external compensation or nulling components. Additionally, the OP27 may be fitted to unnulled 741-type sockets; however, if conventional 741 nulling circuitry is in use, it should be modified or removed to ensure correct OP27 operation. OP27 offset voltage may be nulled to zero (or another desired setting) using a potentiometer (see Figure 1).

The OP27 provides stable operation with load capacitances of up to 2000 pF and ±10 V swings; larger capacitances should be decoupled with a 50 Ω resistor inside the feedback loop. The OP27 is unity-gain stable.

Thermoelectric voltages generated by dissimilar metals at the input terminal contacts can degrade the drift performance. Best operation will be obtained when both input contacts are maintained at the same temperature.

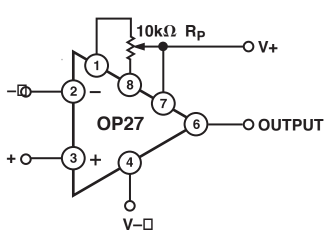


Figure 1. Offset Nulling Circuit

OFFSET VOLTAGE ADJUSTMENT

The input offset voltage of the OP27 is trimmed at wafer level. However, if further adjustment of V_{OS} is necessary, a 10 kΩ trim potentiometer can be used. TCV_{OS} is not degraded (see Offset Nulling Circuit). Other potentiometer values from 1 kΩ to 1 MΩ can be used with a slight degradation (0.1 μV/°C to 0.2 μV/°C) of TCV_{OS}. Trimming to a value other than zero creates a drift of approximately (V_{OS}/300) μV/°C. For example, the change in TCV_{OS} will be 0.33 μV/°C if V_{OS} is adjusted to 100 μV. The offset voltage adjustment range with a 10 kΩ potentiometer is ±4 mV. If smaller adjustment range is required, the nulling sensitivity can be reduced by using a smaller pot in conjuction with fixed resistors. For example, Figure 2 shows a network that will have a ±280 μV adjustment range.

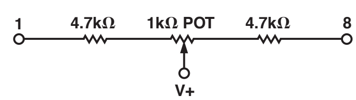


Figure 2. Offset Voltage Adjustment

NOISE MEASUREMENTS

To measure the 80 nV peak-to-peak noise specification of the OP27 in the 0.1 Hz to 10 Hz range, the following precautions must be observed:

1. The device must be warmed up for at least five minutes. As shown in the warm-up drift curve, the offset voltage typically changes 4 µV due to increasing chip temperature after power-up. In the 10-second measurement interval, these temperature-induced effects can exceed tens-of-nanovolts.
2. For similar reasons, the device has to be well-shielded from air currents. Shielding minimizes thermocouple effects.
3. Sudden motion in the vicinity of the device can also "feedthrough" to increase the observed noise.
4. The test time to measure 0.1 Hz to 10 Hz noise should not exceed 10 seconds. As shown in the noise-tester frequency response curve, the 0.1 Hz corner is defined by only one zero. The test time of 10 seconds acts as an additional zero to eliminate noise contributions from the frequency band below 0.1 Hz.
5. A noise-voltage-density test is recommended when measuring noise on a large number of units. A 10 Hz noise-voltage-density measurement will correlate well with a 0.1 Hz to 10 Hz peak-to-peak noise reading, since both results are determined by the white noise and the location of the 1/f corner frequency.

UNITY-GAIN BUFFER APPLICATIONS

When $R_f \leq 100\ \Omega$ and the input is driven with a fast, large signal pulse (>1 V), the output waveform will look as shown in the pulsed operation diagram (Figure 3).

During the fast feedthrough-like portion of the output, the input protection diodes effectively short the output to the input and a current, limited only by the output short-circuit protection, will be drawn by the signal generator. With $R_f \geq 500\ \Omega$, the output is capable of handling the current requirements ($I_L \leq 20$ mA at 10 V); the amplifier will stay in its active mode and a smooth transition will occur.

When $R_f > 2$ kΩ, a pole will be created with R_f and the amplifier's input capacitance (8 pF) that creates additional phase shift and reduces phase margin. A small capacitor (20 pF to 50 pF) in parallel with R_f will eliminate this problem.

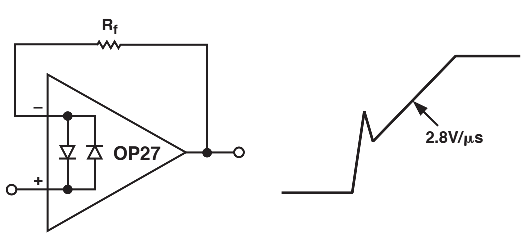


Figure 3. Pulsed Operation

COMMENTS ON NOISE

The OP27 is a very low-noise monolithic op amp. The outstanding input voltage noise characteristics of the OP27 are achieved mainly by operating the input stage at a high quiescent current. The input bias and offset currents, which would normally increase, are held to reasonable values by the input bias-current cancellation circuit. The OP27A/E has I_B and I_{OS} of only ±40 nA and 35 nA at 25°C respectively. This is particularly important when the input has a high source resistance. In addition, many audio amplifier designers prefer to use direct coupling. The high I_B, V_{OS}, and TCV_{OS} of previous designs have made direct coupling difficult, if not impossible, to use.

Voltage noise is inversely proportional to the square root of bias current, but current noise is proportional to the square root of bias current. The OP27's noise advantage disappears when high source-resistors are used. Figures 4, 5, and 6 compare OP27's observed total noise with the noise performance of other devices in different circuit applications.

$$\text{Total Noise} = \begin{bmatrix} (\text{Voltage Noise})^2 + \\ (\text{Current Noise} \times R_S)^2 + \\ (\text{Resistor Noise})^2 \end{bmatrix}^{1/2}$$

Figure 4 shows noise versus source-resistance at 1000 Hz. The same plot applies to wideband noise. To use this plot, multiply the vertical scale by the square root of the bandwidth.

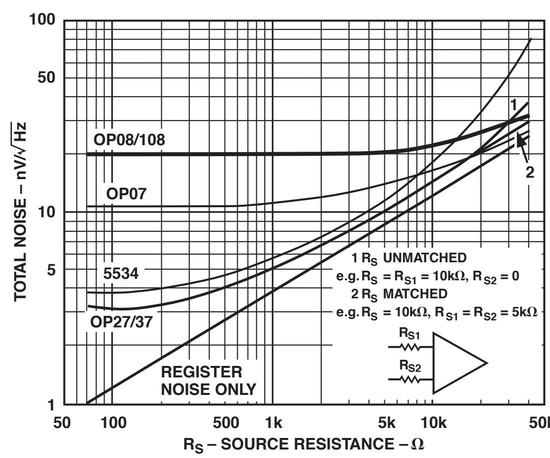


Figure 4. Noise vs. Source Resistance (Including Resistor Noise) at 1000 Hz

At R_S <1 kΩ, the OP27's low voltage noise is maintained. With R_S <1 kΩ, total noise increases, but is dominated by the resistor noise rather than current or voltage noise. lt is only beyond R_S of 20 kΩ that current noise starts to dominate. The argument can be made that current noise is not important for applications with low to moderate source resistances. The crossover between the OP27, OP07, and OP08 noise occurs in the 15 kΩ to 40 kΩ region.

Figure 5 shows the 0.1 Hz to 10 Hz peak-to-peak noise. Here the picture is less favorable; resistor noise is negligible and current noise becomes important because it is inversely proportional to the square root of frequency. The crossover with the OP07 occurs in the 3 kΩ to 5 kΩ range depending on whether balanced or unbalanced source resistors are used (at 3 kΩ the I_B and I_{OS} error also can be three times the V_{OS} spec.).

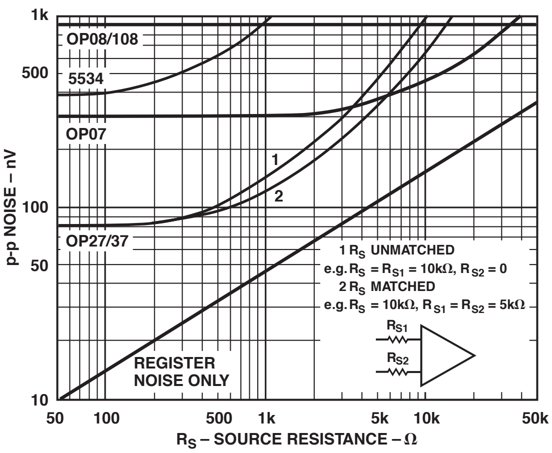


Figure 5. Peak-to-Peak Noise (0.1 Hz to 10 Hz) as Source Resistance (Includes Resistor Noise)

Therefore, for low-frequency applications, the OP07 is better than the OP27/OP37 when $R_S > 3$ kΩ. The only exception is when gain error is important. Figure 6 illustrates the 10 Hz noise. As expected, the results are between the previous two figures.

For reference, typical source resistances of some signal sources are listed in Table I.

Table I.

Device	Source Impedance	Comments
Strain Gauge	<500 Ω	Typically used in low-frequency applications.
Magnetic Tapehead	<1500 Ω	Low is very important to reduce self-magnetization problems when direct coupling is used. OP27 I_B can be neglected.
Magnetic Phonograph Cartridges	<1500 Ω	Similar need for low I_B in direct coupled applications. OP27 will not introduce any self-magnetization problem.
Linear Variable Differential Transformer	<1500 Ω	Used in rugged servo-feedback applications. Bandwidth of interest is 400 Hz to 5 kHz.

Open-Loop Gain

Frequency at	OP07	OP27	OP37
3 Hz	100 dB	124 dB	125 dB
10 Hz	100 dB	120 dB	125 dB
30 Hz	90 dB	110 dB	124 dB

For further information regarding noise calculations, see "Minimization of Noise in Op Amp Applications," Application Note AN-15.

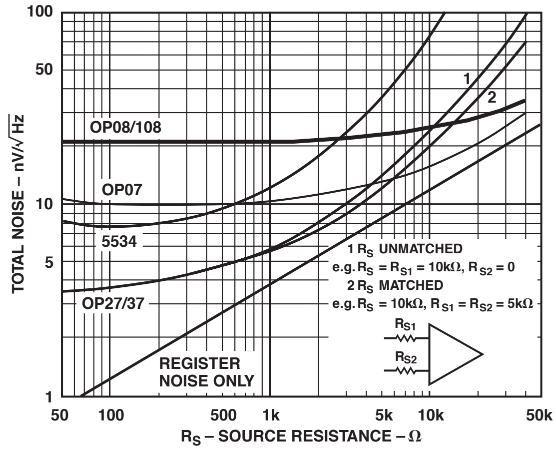


Figure 6. 10 Hz Noise vs. Source Resistance (Includes Resistor Noise)

AUDIO APPLICATIONS

The following applications information has been abstracted from a PMI article in the 12/20/80 issue of Electronic Design magazine and updated.

Figure 7 is an example of a phono pre-amplifier circuit using the OP27 for A1; R1-R2-C1-C2 form a very accurate RIAA network with standard component values. The popular method to accomplish RIAA phono equalization is to employ frequency-dependent feedback around a high-quality gain block. Properly chosen, an RC network can provide the three necessary time constants of 3180, 318, and 75 µs.[1]

For initial equalization accuracy and stability, precision metal film resistors and film capacitors of polystyrene or polypropylene are recommended since they have low voltage coefficients, dissipation factors, and dielectric absorption.[4] (High-K ceramic capacitors should be avoided here, though low-K ceramics—such as NPO types, which have excellent dissipation factors and somewhat lower dielectric absorption—can be considered for small values.)

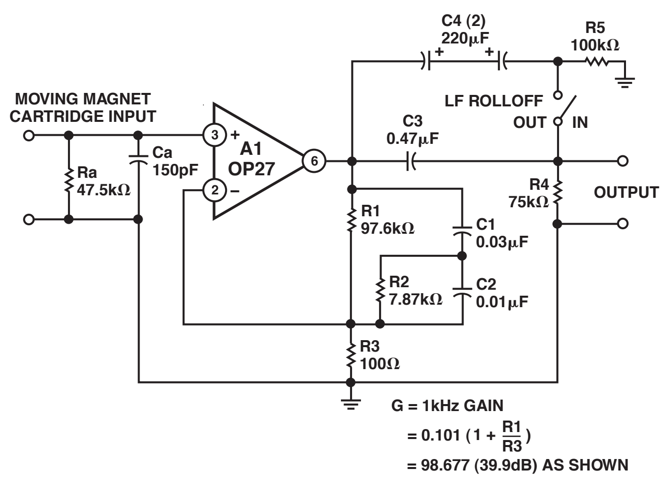


Figure 7. Phono Preamplifier Circuit

The OP27 brings a 3.2 nV/√Hz voltage noise and 0.45 pA/√Hz current noise to this circuit. To minimize noise from other sources, R3 is set to a value of 100 Ω, which generates a voltage noise of 1.3 nV/√Hz. The noise increases the 3.2 nV/√Hz of the amplifier by only 0.7 dB. With a 1 kΩ source, the circuit noise measures 63 dB below a 1 mV reference level, unweighted, in a 20 kHz noise bandwidth.

Gain (G) of the circuit at 1 kHz can be calculated by the expression:

$$G = 0.101\left(1 + \frac{R1}{R3}\right)$$

For the values shown, the gain is just under 100 (or 40 dB). Lower gains can be accommodated by increasing R3, but gains higher than 40 dB will show more equalization errors because of the 8 MHz gain-bandwidth of the OP27.

This circuit is capable of very low distortion over its entire range, generally below 0.01% at levels up to 7 V rms. At 3 V output levels, it will produce less than 0.03% total harmonic distortion at frequencies up to 20 kHz.

Capacitor C3 and resistor R4 form a simple –6 dB-per-octave rumble filter, with a corner at 22 Hz. As an option, the switch-selected shunt capacitor C4, a nonpolarized electrolytic, bypasses the low-frequency rolloff. Placing the rumble filter's high-pass action after the preamp has the desirable result of discriminating against the RIAA-amplified low-frequency noise components and pickup-produced low-frequency disturbances.

A preamplifier for NAB tape playback is similar to an RIAA phono preamp, though more gain is typically demanded, along with equalization requiring a heavy low-frequency boost. The circuit in Figure 7 can be readily modified for tape use, as shown by Figure 8.

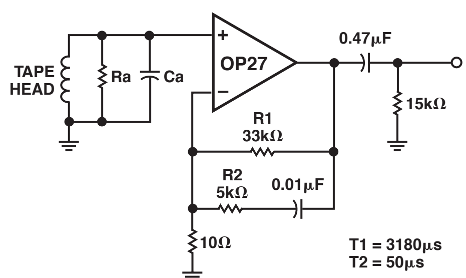


Figure 8. Tape-Head Preamplifier

While the tape-equalization requirement has a flat high-frequency gain above 3 kHz (T_2 = 50 µs), the amplifier need not be stabilized for unity gain. The decompensated OP37 provides a greater bandwidth and slew rate. For many applications, the idealized time constants shown may require trimming of R1 and R2 to optimize frequency response for nonideal tapehead performance and other factors.[5]

The network values of the configuration yield a 50 dB gain at 1 kHz, and the dc gain is greater than 70 dB. Thus, the worst-case output offset is just over 500 mV. A single 0.47 µF output capacitor can block this level without affecting the dynamic range.

The tapehead can be coupled directly to the amplifier input, since the worst-case bias current of 80 nA with a 400 mH, 100 µ inch head (such as the PRB2H7K) will not be troublesome.

One potential tapehead problem is presented by amplifier bias-current transients which can magnetize a head. The OP27 and OP37 are free of bias-current transients upon power-up or power-down. However, it is always advantageous to control the speed of power supply rise and fall, to eliminate transients.

In addition, the dc resistance of the head should be carefully controlled, and preferably below 1 kΩ. For this configuration, the bias-current-induced offset voltage can be greater than the 100pV maximum offset if the head resistance is not sufficiently controlled.

A simple, but effective, fixed-gain transformerless microphone preamp (Figure 9) amplifies differential signals from low impedance microphones by 50 dB, and has an input impedance of 2 kΩ. Because of the high working gain of the circuit, an OP37 helps to preserve bandwidth, which will be 110 kHz. As the OP37 is a decompensated device (minimum stable gain of 5), a dummy resistor, Rp, may be necessary, if the microphone is to be unplugged. Otherwise the 100% feedback from the open input may cause the amplifier to oscillate.

Common-mode input-noise rejection will depend upon the match of the bridge-resistor ratios. Either close-tolerance (0.1%) types should be used, or R4 should be trimmed for best CMRR. All resistors should be metal film types for best stability and low noise.

Noise performance of this circuit is limited more by the input resistors R1 and R2 than by the op amp, as R1 and R2 each generate a 4 nV/√Hz noise, while the op amp generates a 3.2 nV/√Hz noise. The rms sum of these predominant noise sources will be about 6 nV/√Hz, equivalent to 0.9 µV in a 20 kHz noise bandwidth, or nearly 61 dB below a 1 mV input signal. Measurements confirm this predicted performance.

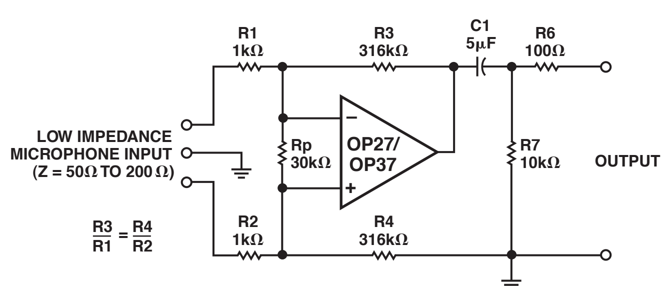


Figure 9. Fixed Gain Transformerless Microphone Preamplifier

For applications demanding appreciably lower noise, a high quality microphone transformer-coupled preamp (Figure 10) incorporates the internally compensated OP27. T1 is a JE-115K-E 150 Ω/15 kΩ transformer which provides an optimum source resistance for the OP27 device. The circuit has an overall gain of 40 dB, the product of the transformer's voltage setup and the op amp's voltage gain.

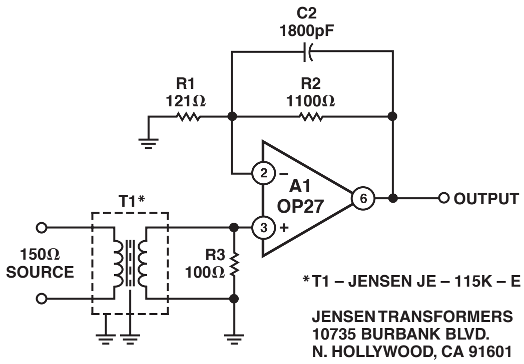


Figure 10. High Quality Microphone Transformer-Coupled Preamplifier

Gain may be trimmed to other levels, if desired, by adjusting R2 or R1. Because of the low offset voltage of the OP27, the output offset of this circuit will be very low, 1.7 mV or less, for a 40 dB gain. The typical output blocking capacitor can be eliminated in such cases, but is desirable for higher gains to eliminate switching transients.

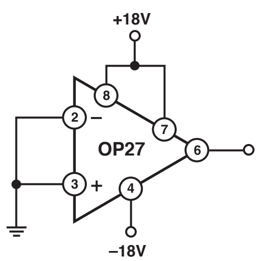


Figure 11. Burn-In Circuit

Capacitor C2 and resistor R2 form a 2 μs time constant in this circuit, as recommended for optimum transient response by the transformer manufacturer. With C2 in use, A1 must have unity-gain stability. For situations where the 2 μs time constant is not necessary, C2 can be deleted, allowing the faster OP37 to be employed.

Some comment on noise is appropriate to understand the capability of this circuit. A 150 Ω resistor and R1 and R2 gain resistors connected to a noiseless amplifier will generate 220 nV of noise in a 20 kHz bandwidth, or 73 dB below a 1 mV reference level. Any practical amplifier can only approach this noise level; it can never exceed it. With the OP27 and T1 specified, the additional noise degradation will be close to 3.6 dB (or –69.5 referenced to 1 mV).

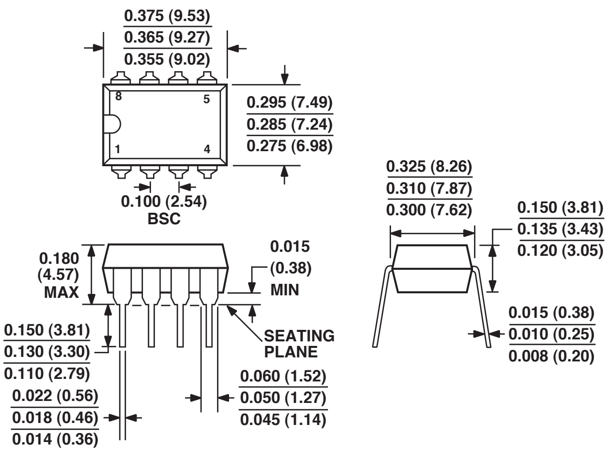
References

1. Lipshitz, S.R, "On RIAA Equalization Networks," JAES, Vol. 27, June 1979, p. 458–481.
2. Jung, W.G., *IC Op Amp Cookbook*, 2nd. Ed., H.W. Sams and Company, 1980.
3. Jung, W.G., *Audio IC Op Amp Applications*, 2nd. Ed., H.W. Sams and Company, 1978.
4. Jung, W.G., and Marsh, R.M., "Picking Capacitors," *Audio*, February and March, 1980.
5. Otala, M., "Feedback-Generated Phase Nonlinearity in Audio Amplifiers," London AES Convention, March 1980, preprint 1976.
6. Stout, D.F., and Kautman, M., *Handbook of Operational Amplifier Circuit Design*, New York, McGraw-Hill, 1976.

OUTLINE DIMENSIONS

8-Lead Plastic Dual-in-Line Package [PDIP] (N-8)

Dimensions shown in inches and (millimeters)

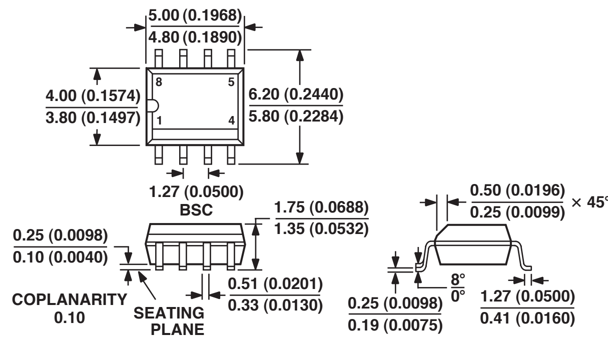


COMPLIANT TO JEDEC STANDARDS MO-095AA

CONTROLLING DIMENSIONS ARE IN INCHES; MILLIMETERS DIMENSIONS (IN PARENTHESES)

8-Lead Standard Small Outline Package [SOIC] Narrow Body (R-8)

Dimensions shown in millimeters and (inches)

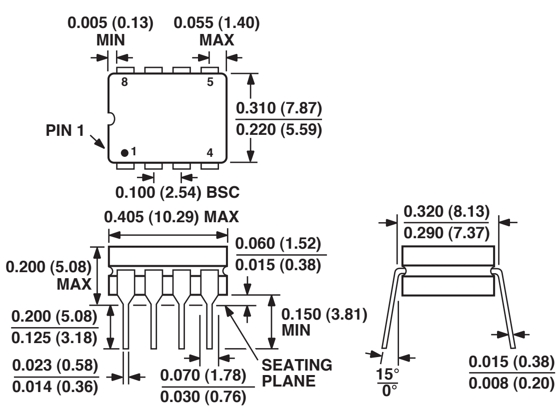


COMPLIANT TO JEDEC STANDARDS MS-012AA

CONTROLLING DIMENSIONS ARE IN MILLIMETERS; INCH DIMENSIONS (IN PARENTHESES) ARE ROUNDED-OFF MILLIMETER EQUIVALENTS FOR REFERENCE ONLY AND ARE NOT APPROPRIATE FOR USE IN DESIGN

8-Lead Ceramic DIP – Glass Hermetic Seal [CERDIP] (Q-8)

Dimensions shown in inches and (millimeters)



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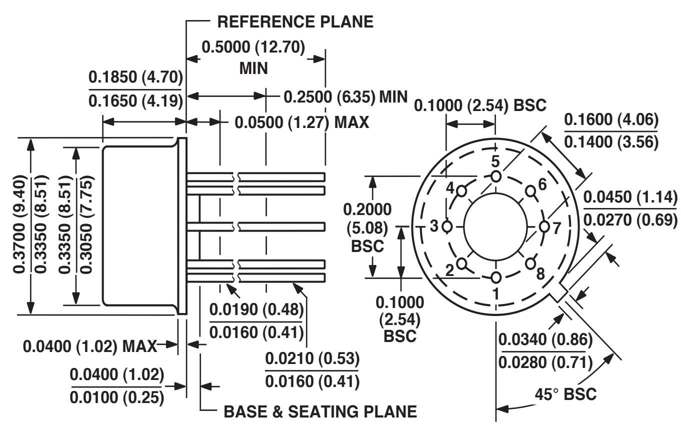
8-Lead Metal Can [TO-99] (H-08)

Dimensions shown in inches and (millimeters)



COMPLIANT TO JEDEC STANDARDS MO-002AK

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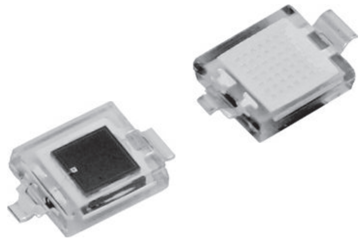
Revision History

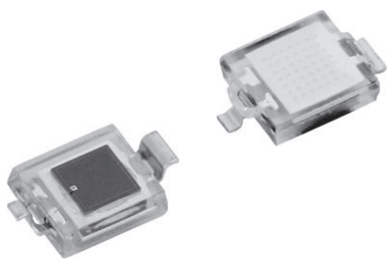
PRINTED IN U.S.A.

C00317–0–1/03(C)

Silicon PIN Photodiode



VBP104S



VBP104SR

FEATURES

- Package type: surface mount
- Package form: GW, RGW
- Dimensions (L x W x H in mm): 6.4 x 3.9 x 1.2
- Radiant sensitive area (in mm^2): 4.4
- High photo sensitivity
- High radiant sensitivity
- Suitable for visible and near infrared radiation
- Fast response times
- Angle of half sensitivity: φ = ± 65°
- Floor life: 168 h, MSL 3, acc. J-STD-020
- Lead (Pb)-free reflow soldering
- Compliant to RoHS Directive 2002/95/EC and in accordance to WEEE 2002/96/EC
- Halogen-free according to IEC 61249-2-21 definition

Pb-free
e3
RoHS
COMPLIANT
HALOGEN
FREE

DESCRIPTION

VBP104S and VBP104SR are high speed and high sensitive PIN photodiodes. It is a surface mount device (SMD) including the chip with a 4.4 mm^2 sensitive area detecting visible and near infrared radiation.

APPLICATIONS

- High speed photo detector

PRODUCT SUMMARY			
COMPONENT	I_{ra} (μA)	φ (deg)	$\lambda_{0.1}$ (nm)
VBP104S	35	± 65	430 to 1100
VBP104SR	35	± 65	430 to 1100

Note

- Test conditions see table “Basic Characteristics”

ORDERING INFORMATION			
ORDERING CODE	PACKAGING	REMARKS	PACKAGE FORM
VBP104S	Tape and reel	MOQ: 1000 pcs, 1000 pcs/reel	Gullwing
VBP104SR	Tape and reel	MOQ: 1000 pcs, 1000 pcs/reel	Reverse gullwing

Note

- MOQ: minimum order quantity

ABSOLUTE MAXIMUM RATINGS (T_{amb} = 25 °C, unless otherwise specified)				
PARAMETER	TEST CONDITION	SYMBOL	VALUE	UNIT
Reverse voltage		V_R	60	V
Power dissipation	$T_{amb} \leq 25$ °C	P_V	215	mW
Junction temperature		T_j	100	°C
Operating temperature range		T_{amb}	- 40 to + 100	°C
Storage temperature range		T_{stg}	- 40 to + 100	°C
Soldering temperature	Acc. reflow solder profile fig. 8	T_{sd}	260	°C
Thermal resistance junction/ambient		R_{thJA}	350	K/W

BASIC CHARACTERISTICS (T_{amb} = 25 °C, unless otherwise specified)						
PARAMETER	**TEST CONDITION**	**SYMBOL**	**MIN.**	**TYP.**	**MAX.**	**UNIT**
Forward voltage	I_F = 50 mA	V_F		1	1.3	V
Breakdown voltage	I_R = 100 μA, E = 0	$V_{(BR)}$	60			V
Reverse dark current	V_R = 10 V, E = 0	I_{ro}		2	30	nA
Diode capacitance	V_R = 0 V, f = 1 MHz, E = 0	C_D		48		pF
	V_R = 3 V, f = 1 MHz, E = 0	C_D		17	40	pF
Open circuit voltage	E_e = 1 mW/cm², λ = 950 nm	V_o		350		mV
Temperature coefficient of V_o	E_e = 1 mW/cm², λ = 950 nm	TK_{Vo}		- 2.6		mV/K
Short circuit current	E_e = 1 mW/cm², λ = 950 nm	I_k		32		μA
Temperature coefficient of I_k	E_e = 1 mW/cm², λ = 950 nm	TK_{Ik}		0.1		%/K
Reverse light current	E_e = 1 mW/cm², λ = 950 nm, V_R = 5 V	I_{ra}	25	35		μA
Angle of half sensitivity		φ		± 65		deg
Wavelength of peak sensitivity		λ_p		940		nm
Range of spectral bandwidth		$\lambda_{0.1}$		430 to 1100		nm
Noise equivalent power	V_R = 10 V, λ = 950 nm	NEP		4 x 10^{-14}		W/√Hz
Rise time	V_R = 10 V, R_L = 1 kΩ, λ = 820 nm	t_r		100		ns
Fall time	V_R = 10 V, R_L = 1 kΩ, λ = 820 nm	t_f		100		ns

BASIC CHARACTERISTICS (T_{amb} = 25 °C, unless otherwise specified)

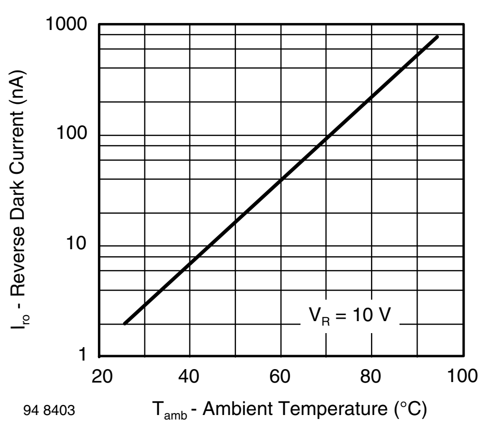


Fig. 1 - Reverse Dark Current vs. Ambient Temperature

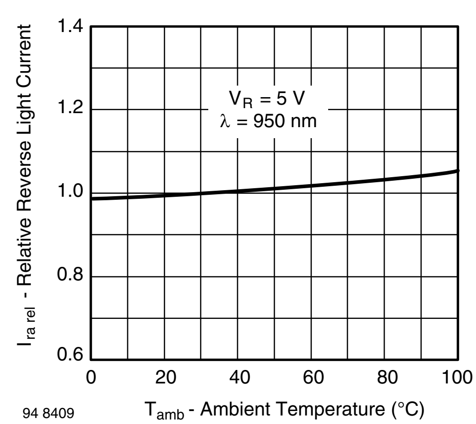


Fig. 2 - Relative Reverse Light Current vs. Ambient Temperature

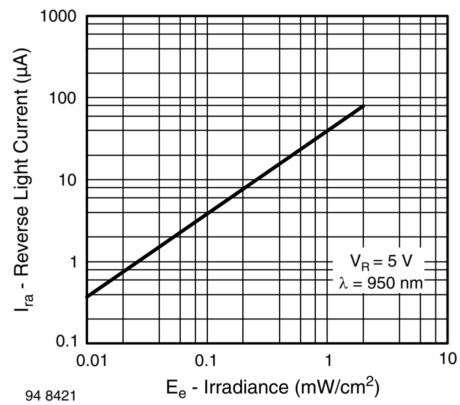


Fig. 3 - Reverse Light Current vs. Irradiance

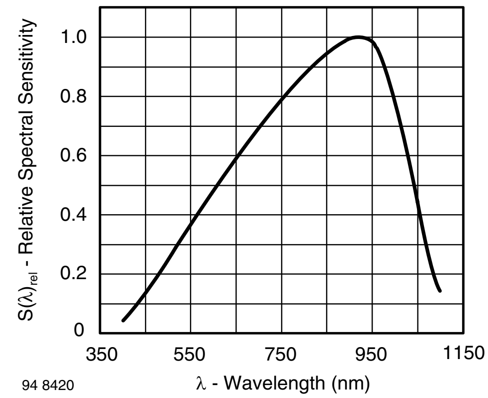


Fig. 6 - Relative Spectral Sensitivity vs. Wavelength

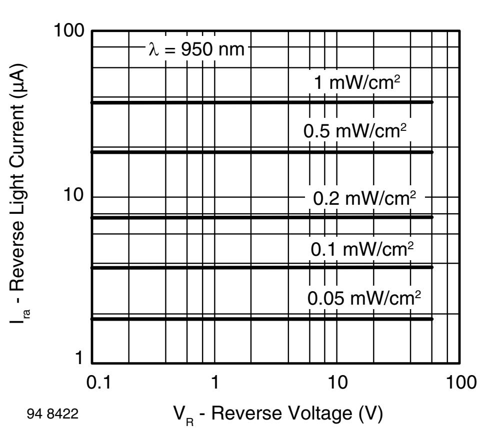


Fig. 4 - Reverse Light Current vs. Reverse Voltage

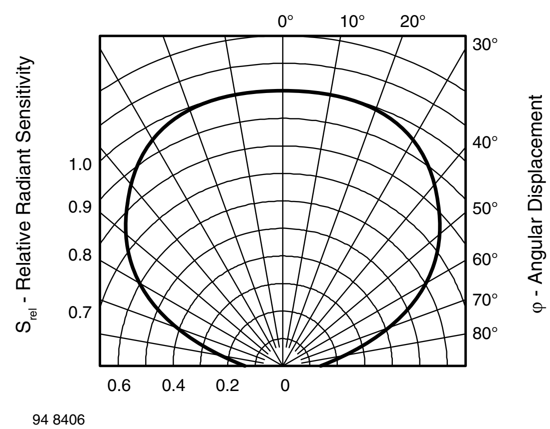


Fig. 7 - Relative Radiant Sensitivity vs. Angular Displacement

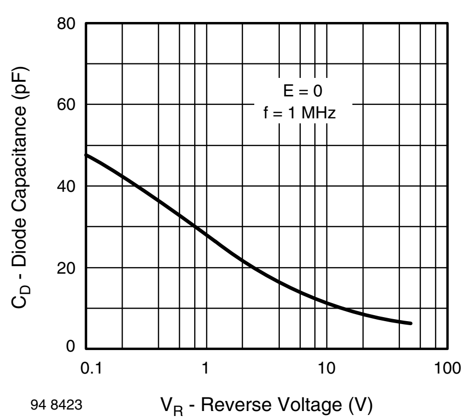
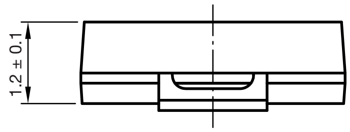
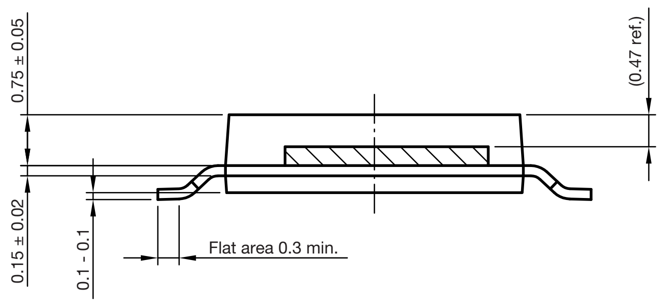
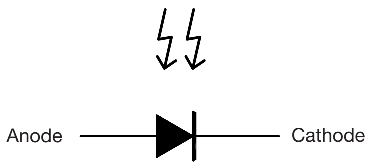


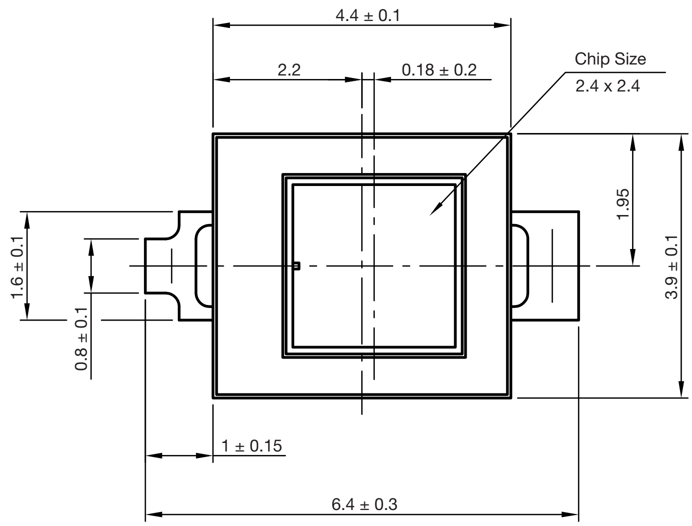
Fig. 5 - Diode Capacitance vs. Reverse Voltage

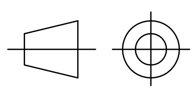
PACKAGE DIMENSIONS FOR VBP104S in millimeters





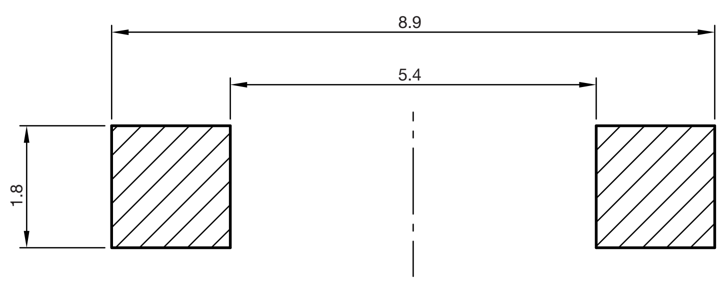






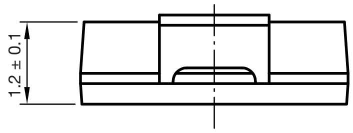
technical drawings
according to DIN
specifications

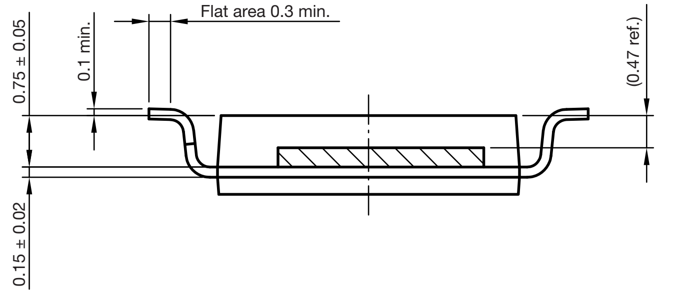
Recommended solder pad

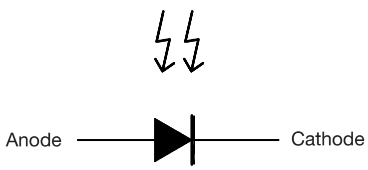


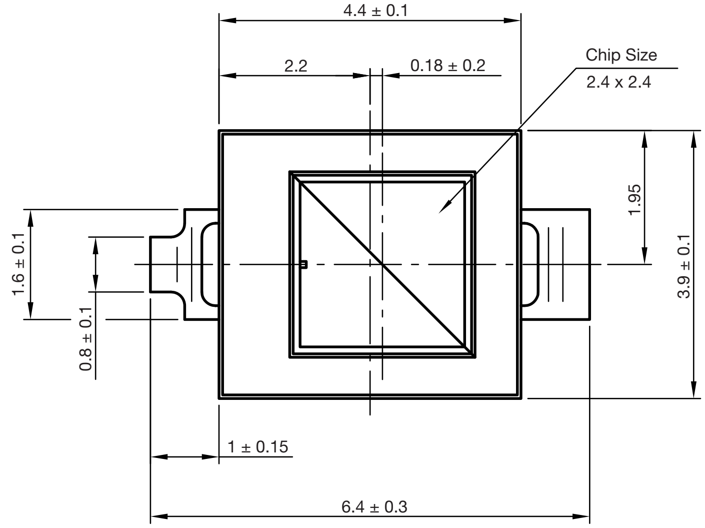
Drawing-No.: 6.541-5088.01-4
Issue: 1; 15.04.10
22107

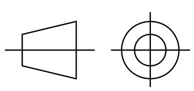
PACKAGE DIMENSIONS FOR VBP104SR in millimeters





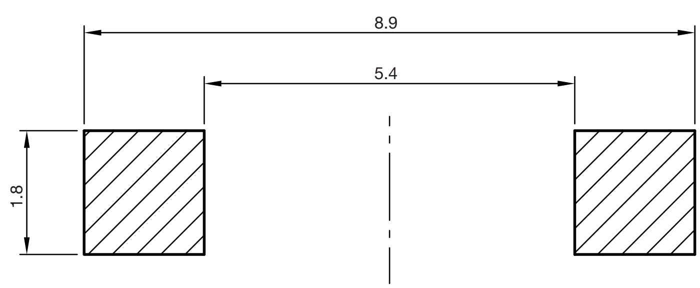






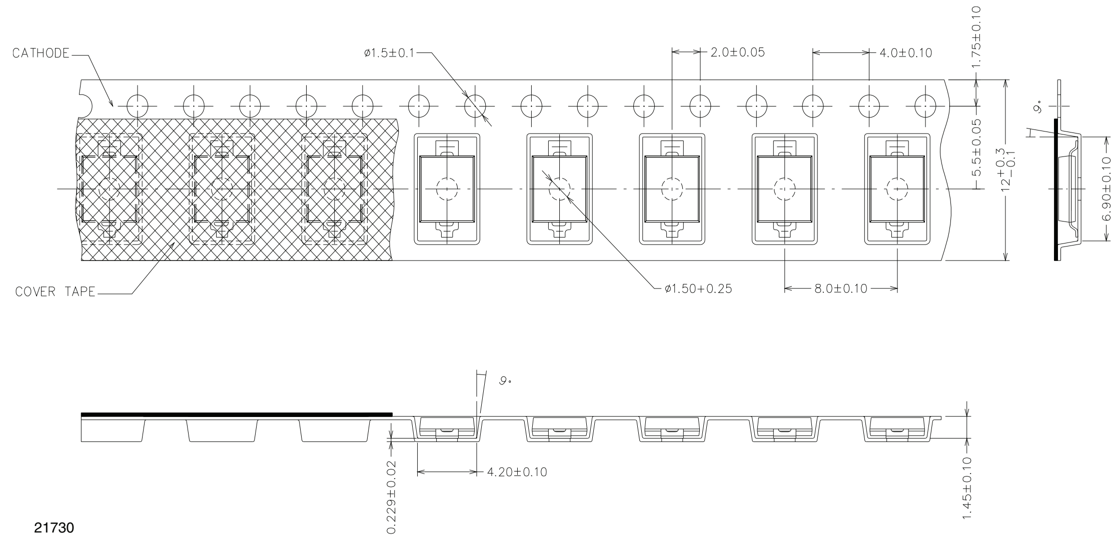
technical drawings
according to DIN
specifications

Recommended solder pad

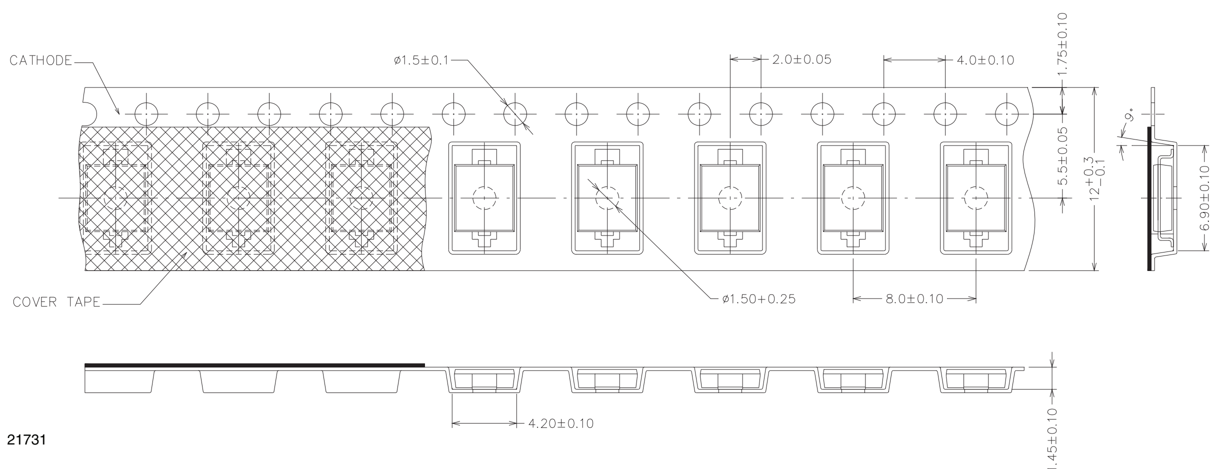


Drawing-No.: 6.541-5087.01-4
Issue: 1; 15.04.10
22106

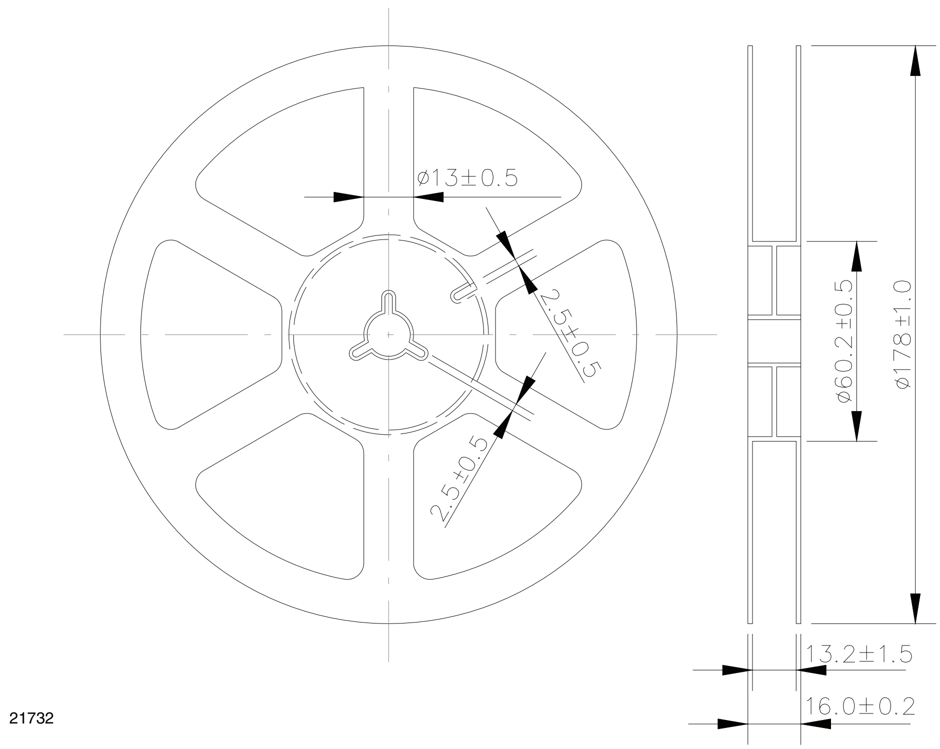
TAPING DIMENSIONS FOR VBP104S in millimeters



TAPING DIMENSIONS FOR VBP104SR in millimeters



REEL DIMENSIONS FOR VBP104S AND VBP104SR in millimeters



SOLDER PROFILE

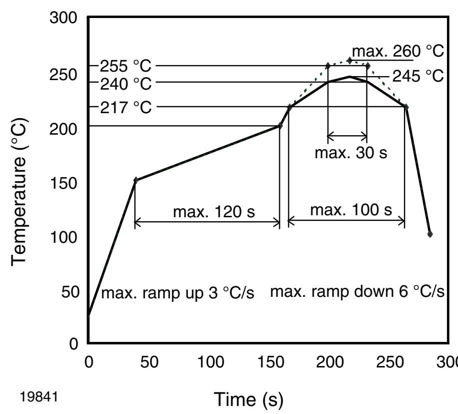


Fig. 8 - Lead (Pb)-free Reflow Solder Profile acc. J-STD-020

DRYPACK

Devices are packed in moisture barrier bags (MBB) to prevent the products from moisture absorption during transportation and storage. Each bag contains a desiccant.

FLOOR LIFE

Time between soldering and removing from MBB must not exceed the time indicated in J-STD-020:
Moisture sensitivity: level 3
Floor life: 168 h
Conditions: T_{amb} < 30 °C, RH < 60 %

DRYING

In case of moisture absorption devices should be baked before soldering. Conditions see J-STD-020 or recommended conditions:
192 h at 40 °C (+ 5 °C), RH < 5 %
or
96 h at 60 °C (+ 5 °C), RH < 5 %.

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Please note that some Vishay documentation may still make reference to RoHS Directive 2002/95/EC. We confirm that all the products identified as being compliant to Directive 2002/95/EC conform to Directive 2011/65/EU.

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Résumé

- ✓ Notre système représente un oxymètre de pouls connecté à base d'une carte LINKIT ONE qui sert à calculer le taux d'oxygénation et le rythme cardiaque chez des personnes hospitalisés et non hospitalisés (malades à domiciles). On l'utilise généralement dans les salles de réanimation et Son rôle est très important pour les malades et pour le médecin permet de surveiller et enregistrer puis la sauvegarder les donnes vers un centre de transmission.
- ✓ Cet appareil permet de façon non invasive la mesure, en temps réel, de la saturation en oxygène de l'hémoglobine .IL doit pouvoir être utilisé par un personnel non médical, une fois que celui-ci sera formé à son fonctionnement.

Mots Clés

Oxymètre de pouls, Saturomètre, SpO2, Hémoglobine, O2, linkit ONE, filtre passe bande, amplificateur à trans impédance, comparateur.