

Synthesis and characterization of nickel manganite from different carboxylate precursors for thermistor sensors

By **R.K. Kamat**, *Electronics Section, Department of Physics, Goa University, Goa, India (email: rkkamat@unigoa.ernet.in)*,
G.M. Naik, *Electronics Section, Department of Physics, Goa University, Goa, India (email: gmnaik@unigoa.ernet.in)*,
 and **V.M.S. Verenkar**, *Department of Chemistry, Goa University, Goa, India (email: vmsv@unigoa.ernet.in)*

Introduction

The thermistor sensor is a widely used temperature transducer synthesized with a ceramic-like semiconductor material. Its basic temperature-sensing mechanism is the population of charge carriers in the conduction band. Initially the thermistor was designed for use during World War II, but since then it has continuously evolved for applications such as thermometers, temperature controllers, automatic gain control, and time-delay circuits. Its number of applications is increasing rapidly, encompassing office automation equipment, air conditioners, and other domestic appliances. Recently the thermistor has come into the limelight due to its use in portable phones, car phones, and transceivers. Expanding applications in delicate communications equipment and the rapid influx of such equipment into the consumer market has forced thermistor manufacturers to consider improving the specifications. In this article the authors investigate various thermistor anomalies from a materials point of view. Figure 1 shows thermistor samples we manufactured in various sizes. The small samples are suitable for applications where speed of measurement is crucial.

The thermistor sensor offers various advantages: high sensitivity; availability in a large range of resistance values (useful from a power dissipation point of view); ability to

operate over a wide temperature range in a solid, liquid, or gaseous environment; adaptable size and shape for a wide variety of mechanical environments; ability to withstand electrical and mechanical stress; and low cost. At the same time, this sensor has several limitations: lack of interchangeability; poor linearity and precision; limited range; instability at high temperatures; hysteresis; and low resolution. With the advent of microprocessors and microcontrollers, most of these drawbacks are no longer a problem except for lack of interchangeability. The authors investigate remedies for the bottlenecks posed by thermistors in References 16, 17, and 18. On several occasions we observed that the thermistor-based circuit needs tuning when it is changed. The reasons for lack of interchangeability are loose manufacturing standards and manufacturers' ignorance of standard material characterization tools used to check completion of solid-state reactions (formation).

Materials used

At present the thermistor materials of interest and use are mixed metal oxides (especially spinels) of manganese, nickel, cobalt, copper, iron, and titanium. The authors of References 1–5 show an interest in transition metal manganite, $Mn_{3-x}M_xO_4$ [$(0 < x < 1)$ and $M = \text{nickel, cobalt, etc.}$]. Nickel manganite, $NiMn_2O_4$, is a popular material for thermistors despite its poor stability at high temperature. The electrical conductivity is due to hopping between Mn^{3+} and Mn^{4+} ions in the octahedral sub-lattice of the spinel structure. In this article the carboxylate precursor method, used for the first time to synthesize $NiMn_2O_4$, is described. The different carboxylates used for precursor formation are fumarate, succinate, oxalate, tartarate, and malonate. The precursors as well as the $NiMn_2O_4$ obtained by thermal decomposition of these precursors have been characterized by X-ray diffraction, infrared analysis, and thermal analysis to study the formation and working.

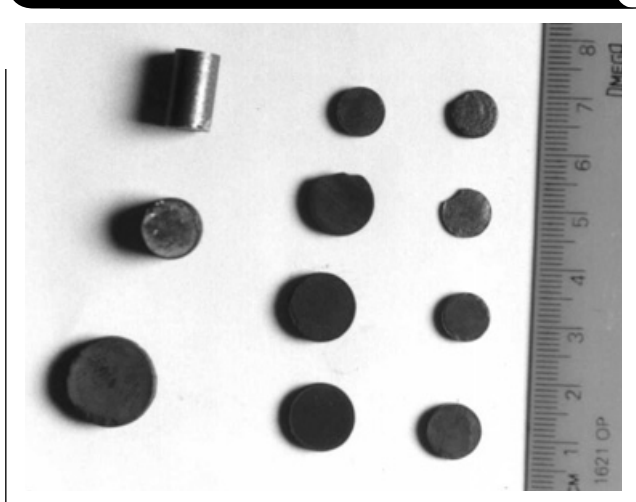
Preparation

Different nickel manganese carboxylate precursors were prepared by using salts of carboxylic acid and metal chlorides. Following is a description of how the metal chloride solution and the precursors were prepared.

Preparation of metal chloride solution

Around 11.8854 g of $NiCl_2 \cdot 6H_2O$ (0.5M) was accurately weighed on a Mettler balance and dissolved in distilled water. Similarly, 19.79056 g of $MnCl_2 \cdot 4H_2O$ (1M) was also accurately weighed and dissolved in acidified water [to prevent formation of $Mn(OH)_2$]. Both salt solutions were

Figure 1. Thermistor samples



then mixed together to make the volume 100 ml in a standard volumetric flask. This metal chloride solution was then used for the preparation of the nickel manganese carboxylate precursors.

Preparation of nickel manganese fumarate (NMF)

Sodium fumarate was accurately weighed at 32.008 g (2M) and dissolved in distilled water; the total volume was made 100 ml in a standard flask. This solution was then heated to 80°C. The hot metal chloride solution was added drop-by-drop, with constant stirring, to this hot fumarate solution. The precipitate of nickel manganese fumarate that formed was filtered in a Buchner funnel using a Whatmann filter No. 41. It was washed with distilled water until it was free of chloride ions, then dried with diethyl ether and stored in a desiccator.

Preparation of other precursors

The other precursors—nickel manganese succinate (NMS), nickel manganese oxalate (NMO), nickel manganese tartarate (NMT), and nickel manganese malonate (NMM)—were also prepared in the same manner as described for NMF by using sodium succinate, ammonium oxalate, sodium tartarate, and sodium malonate, respectively, along with metal chloride.

Characterization

The nickel manganese carboxylate precursors were characterized by chemical analysis. The NiMn_2O_4 obtained by thermal decomposition of the carboxylate precursors was also characterized by X-ray diffraction and IR analysis. The results of all the characterizations are summarized in Tables 1-9.

Chemical analysis

The percentage of nickel and manganese in the precursors was estimated by using the standard methods described in Reference 23. The elemental analysis was carried out on an AAS 201 Chemito GBC902, double-beam atomic absorption spectroscope. The wavelengths used for nickel and manganese estimation were 352.4 nm and 403.1 nm, respectively. The standard solutions prepared for nickel and manganese were in the range of 6 to 25 $\mu\text{g/ml}$ and 7 to 27 $\mu\text{g/ml}$, respectively.

IR analysis

IR analysis of the precursors and their decomposed products was carried out on Shimadzu FTIR instrument model 8101A. The pellets used for reading spectra were prepared by mixing 1 to 2 mg of the sample with a pinch of KBr. The IR spectra in the range of 400 to 4600 cm^{-1} was recorded at room temperature.

Density measurement

The pycnometric density measurement of the precursors and their decomposed products was determined at room temperature with CCl_4 as the medium by using the formula

$$P_{\text{sample}} = (\text{weight of the sample}) / (\text{weight of the liquid displaced} / \text{density of the liquid}).$$

Thermal analysis

The physical and chemical properties of the precursors were monitored by using thermal analysis techniques like isothermal weight loss studies, thermogravimetry analysis (TGA), and differential thermal analysis (DTA). For calculating the weight loss, precursors were accurately

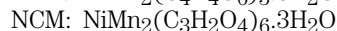
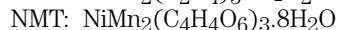
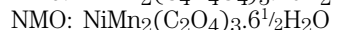
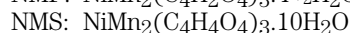
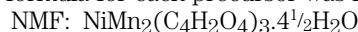
weighed and placed in silica crucibles, then heated in an oven for 20 minutes at various temperature ranges until the precursors exhibited no further weight loss. TGA was done on an STA 1500 instrument in air at a heating rate of 10°C/min. DTA was recorded on an STA 1500 instrument in air at a heating rate of 10°C/min.

X-ray diffraction (XRD) analysis

X-ray diffraction of the sintered and decomposed products was carried out on Philips X-ray Diffractometer model PW 3710 with $\text{Cu K}\alpha$ radiation and nickel as a filter. The studies were carried out to confirm the completion of solid state reaction, observe the impurity phases, and determine lattice constants, interplanar distances, octahedral and tetrahedral site radii, bond length, X-ray density, etc. The various parameters were calculated using standard values.

Formula fixation

Based on the characterization results previously described, a formula for each precursor was fixed as follows:

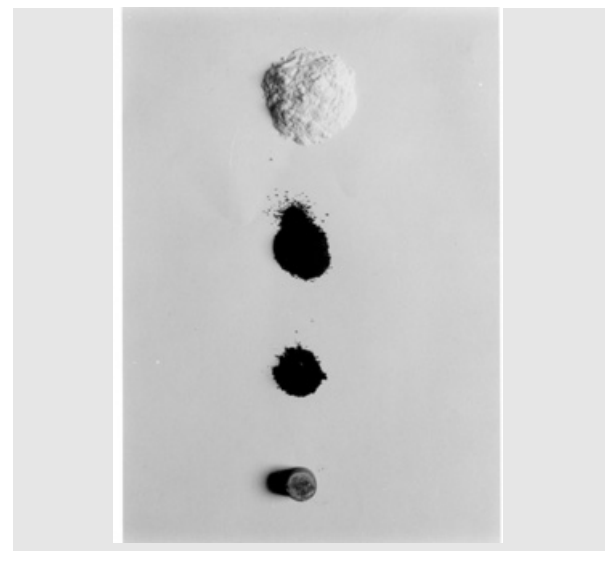


Pellet formation

Some of the steps in thermistor manufacture are shown in Figure 2. The thermistors were fabricated by preheating, presintering, grinding, and shaping them to the desired geometry and by a final sintering at elevated temperature. The thermally decomposed product of the precursors was preheated in a silica crucible to 400°C to drive off

Continued on next page

Figure 2. Some steps in thermistor manufacture



The light-colored powder at the top is raw precursor. Below that is pre-sintered powder before and after it is finely ground and filtered. The weight loss that results is evident. Compressing the sintered precursor in a hydraulic press produces the finished thermistor.

Continued from previous page

moisture. The preheated product was mixed thoroughly by grinding and then was compressed under 5 tons per square inch of pressure in a hydraulic press in a round die. These pellets were then heated to 900°C under a controlled temperature profile using a PID controller. The final products were disc thermistors with diameters of 1 mm (0.04 in.) to 3 mm (0.12 in.), targeting low-cost thermometry applications for domestic use.

Results and conclusion

This article presents our work on the preparation of nickel manganese carboxylates by various precursor methods; viz., nickel manganese fumarate, nickel manganese succinate, nickel manganese oxalate, nickel manganese tartarate, and nickel manganese malonate. Various characterization tools were applied to these precursors to verify the formation. The asymmetric and symmetric stretching

of carboxylate ions was seen in the range of 1550 to 1625 cm^{-1} and 1350 to 1400 cm^{-1} , respectively, with $\Delta\nu$ ($\nu_{\text{asym}} - \nu_{\text{sym}}$) separation of ~ 190 to 240 cm^{-1} , indicating the monodentate linkage of both carboxylates in the dianions. Thus the carboxylates coordinated to the metal as bidentate ligand via both carboxylate groups. Almost all the hydrate nickel manganese carboxylate precursors decomposed below 400°C to form NiMn_2O_4 . Most of the dehydration took place below 250°C, while the decarboxylation of anhydrous precursors occurred between 250 and 400°C. XRD confirmed the formation of NiMn_2O_4 . The lattice parameter values of all the samples agreed well with the reported ones. The IR data of NiMn_2O_4 showed high-frequency band ν_1 between 600 and 620 cm^{-1} and low-frequency band between 450 and 460 cm^{-1} . The I-V characterization of all the samples up to 200°C with four-probe setup revealed their thermistor behavior. The low value of resistivity at room temperature was attributed to the presence of moisture.

Table 1. Infrared data of hydrated nickel manganese carboxylates

CARBOXYLATES	INFRARED DATA			cm^{-1}		
	$\nu(\text{H}_2\text{O})$	$\nu_{\text{asym}}(\text{O-C-O})$	$\nu_{\text{sym}}(\text{O-C-O})$	$\delta(\text{O-C-O})$	$\nu(\text{M-O}) + \nu(\text{C-C})$	$\nu(\text{CH=CH})$
NMF	3475	1580	1390	800	590	990
	3400	1560				
NMS	3400	1550	1350	800	660	—
			1400			
NMO	3400	1625	1360	840	495	—
NMT	3400	1575	1380	800	575	—
NCM	3400	1575	1400	840	565	—
					530	

Table 2. Chemical analysis, total weight loss and density of hydrated nickel manganese carboxylates

CARBOXYLATES	CHEMICAL ANALYSIS				TOTAL WEIGHT LOSS (%)		DENSITY (gcm^{-3})
	NICKEL (%)		MANGANESE (%)		OBS.	CALC.	
	OBS.	CALC.	OBS.	CALC.			
NMF	9.4315	9.9176	17.855	18.5663	60.62	60.70	1.7929
NMS	10.8211	8.4217	14.28	15.7657	66.63	66.65	2.0192
NMO	9.8526	10.6768	20.8	19.98	57.46	57.38	2.1585
NMT	6.95	7.7545	15.34	14.5168	69.45	69.72	1.7304
NCM	11.00	11.1003	16.02	20.7804	56.14	56.01	1.7534

Table 3. Isothermal weight loss and TGA/DTA of nickel manganese carboxylates

CARBOXYLATES	TGA (AIR)		DTA PEAKS	ISOTHERMAL WEIGHT LOSS		
	TEMPERATURE RANGE (°C)	WT. LOSS (%)	EXO/ENDO PEAKS (°C)	TEMPERATURE RANGE (°C)	WT. LOSS (%)	REMARKS
NMS	RT–91.22	0.62		RT–100	16.80	Loss of $6\frac{1}{2}$ H_2O
	91.22–176.8	26.002	135.27 (endo)	100–120	6.40	Loss of $2\frac{1}{2}$ H_2O
				120–140	4.66	
	176.8–396.76	28.596	331.7 (exo hump) 387.44 (broad exo)	140–250	22.24	Loss of 1 H_2O
				250–380	11.93	
	396.76–526	11.081–0.376				Decarboxylation to form NiMn_2O_4
526–790		602.04 (exo)				

Table 4. Isothermal weight loss studies of hydrated nickel manganese carboxylates

CARBOXYLATES	TEMPERATURE RANGE (°C)	WEIGHT LOSS (%)	REMARKS
NMF	RT-120	7.61	Loss of 2½ H ₂ O
	120-140	2.69	Loss of 1 H ₂ O
	140-250	3.21	Loss of 1 H ₂ O
	250-280	48.19	Decarboxylation to form NiMn ₂ O ₄
NMO	RT-100	14.74	Loss of 4½ H ₂ O
	100-160	1.64	Loss of ½ H ₂ O
	160-200	4.92	Loss of 1½ H ₂ O
	200-280	36.39	Decarboxylation to form NiMn ₂ O ₄
NMT	RT-100	10.11	Loss of 4 H ₂ O
	100-120	2.38	Loss of 1 H ₂ O
	120-180	4.17	Loss of 2 H ₂ O
	180-225	2.33	Loss of 1 H ₂ O
	225-250	3.53	Decarboxylation to form NiMn ₂ O ₄
	250-380	46.70	
NMM	RT-120	1.73	Loss of ½ H ₂ O
	120-170	4.90	Loss of 1½ H ₂ O
	170-180	2.75	Loss of 1 H ₂ O
	180-260	32.65	Decarboxylation to form NiMn ₂ O ₄
	260-380	3.90	

Table 5. X-ray diffraction data of NiMn₂O₄ (NMF)*

SR. NO.	2θ (°)	d _{obs} (Å°)	d _{calc} (Å°)	HKL
1	30.25	2.9545	2.9611	220
2	35.55	2.5252	2.5252	311
3	43.20	2.0941	2.0938	400
4	53.60	1.7098	1.7096	422
5	57.05	1.6143	1.6132	333
6	62.80	1.4795	1.4805	440

*Lattice parameter a = 8.39805
Structure—cubic

Table 6. X-ray diffraction data of NiMn₂O₄ (NMS)*

SR. NO.	2θ (°)	d _{obs} (Å°)	d _{calc} (Å°)	HKL
1	18.33	4.8481	4.8441	111
2	30.16	2.9676	2.9664	220
3	35.54	2.5298	2.5298	311
4	37.17	2.4226	2.4221	222
5	43.20	2.0976	2.0975	400
6	53.61	1.7122	1.7127	422
7	62.78	1.4825	1.4832	440
8	75.35	1.2634	1.2649	622

*Lattice parameter a = 8.39005
Structure—cubic

Table 7. XRD data of NiMn₂O₄ obtained from carboxylates (NMO)*

SR. NO.	2θ (°)	d _{obs} (Å°)	d _{calc} (Å°)	HKL
1	18.36	4.8289	4.8449	111
2	30.13	2.9705	2.9705	220
3	35.49	2.5333	2.5333	311
4	37.15	2.4238	2.4254	222
5	43.14	2.1002	2.1003	400
6	53.53	1.7146	2.7151	422
7	57.23	1.6124	1.6169	333
8	62.84	1.4813	1.4853	440
9	74.15	1.2809	1.2813	533
10	75.18	1.2658	1.2666	622

*Lattice parameter a = 8.397742
Structure—cubic

Table 8. X-ray diffraction data of NiMn₂O₄ (NMT)*

SR. NO.	2θ (°)	d _{obs} (Å°)	d _{calc} (Å°)	HKL
1	30.15	2.9641	2.9692	220
2	35.45	2.5321	2.5321	311
3	43.25	2.0918	2.0995	400
4	53.70	1.7068	1.7143	422
5	57.10	1.6130	1.6162	333
6	62.7	1.4817	1.4845	440

*Lattice parameter a = 8.38848
Structure—cubic

Table 9. X-ray diffraction data of NiMn₂O₄ (NMM)*

SR. NO.	2θ (°)	d _{obs} (Å°)	d _{calc} (Å°)	HKL
1	35.53	2.5308	2.5308	311
2	37.34	2.4122	2.4230	222
3	43.37	2.0898	2.0984	400
4	57.31	1.6103	1.6154	333
5	63.01	1.4778	1.4838	440

*Lattice parameter a = 8.37677
Structure—cubic

Continued on next page

Continued from previous page

References

1. E.D. Macklen, *Thermistors* (Glasgow, Scotland: Electrochemical Publications, 1979), Chapter 3.
2. E. Jabry, G. Boissier, A. Rousset, R. Carnet and A. Lagrange, "Preparation of semiconducting ceramic NTC thermistors by a chemical method," *J. Phys. Colloque*, Vol. 47, Suppl. 2 (1986), p. C1-843.
3. J.P. Caffin, A. Rousset, R. Carnet and A. Lagrange, "Chemical preparation of NTC thermistors with low resistivity and high stability," *High Tech Ceramics*, ed. P. Vicenzini (Amsterdam: Elsevier, 1987), pp. 1743-1751.
4. R. Legros, R. Metz, J.P. Caffin, A. Rousset and A. Lagrange in *Better Ceramics Through Chemistry III*, ed. C.J. Brinker, et al. (New York: Elsevier, 1988), p. 251.
5. R. Metz, J.P. Caffin, R. Legros and A. Rousset, "The preparation, characterisation and electrical properties of copper manganite spinels, $\text{Cu}_x\text{Mn}_{3-x}\text{O}_4$, $0 \leq x \leq 1$," *J. Mater. Sci.*, Vol. 24 (1989), pp. 83-87.
6. S.T. Kshirsager, "Electrical and crystallographic studies of the system $\text{Cu}_x\text{Ni}_{1-x}\text{Mn}_2\text{O}_4$," *J. Phys. Soc. Japan*, Vol. 27 (1969), pp. 1164-1170.
7. V.A.M. Brabers and J.C.J.M. Terhell, "Electrical conductivity and cation valences in nickel manganite," *Phys. Status Solidi (A)*, Vol. 69, No. 1 (1982), p. 325.
8. S.K. Sarkar, M.L. Sharma, H.L. Bhaskar and K.C. Nagpal, "Preparation, temperature and composition dependence of some physical and electrical properties of mixture within NiO- Mn_3O_4 system," *J. Mater. Sci.*, Vol. 19 (1984), pp. 545-551.
9. Xiao-Xia Tang, A. Manthiram and J.B. Goodenough, "Ni Mn_2O_4 Revisited," *J. Less Common Metals*, Vol. 156 (1989), pp. 357-368.
10. S.M. Gurav and A.V. Salkar, "Synthesis, characterisation and catalytic CO oxidation studies over $\text{Ni}_{1-x}\text{Cu}_x\text{Mn}_2\text{O}_4$," *Ind. J. Chem.*, Vol. 38A (February 1999), pp. 130-135.
11. I.A. Vogel, *A Textbook of Quantitative Inorganic Analysis* (London: Longman ELBS, 1978).
12. JCPDS, "Power Diffraction File," Int. Centre for Diffraction Data, Swarthmore, P.A. No. 1-1110.
13. R. Legros, R. Metz, and A. Rousset, "Structural properties of nickel manganite $\text{Ni}_x\text{Mn}_{3-x}\text{O}_4$ with $0.5 \leq x \leq 1$," *J. Mater. Sci.*, Vol. 25 (1990), pp. 4410-4414.
14. S.K. Sarkar, M.L. Sharma and S.K. Lahairi, "Resistivity and I-V measurements of tetragonal Mn_3O_4 and dependence of nickel manganite on Mn_3O_4 content of NiO- Mn_3O_4 ," *J. Mater. Sci. Letters*, Vol. 6 (1987), pp. 958-960.
15. T.H. Ashemi and A.W. Brinkman, "X-ray photoelectron spectroscopy of nickel manganese oxide thermistors," *J. Mater. Res.*, Vol. 7, No. 5 (May 1992), pp. 1278-1283.
16. R.K. Kamat, G.M. Naik and G.G. Tengshe, "Thermistor based conditional output sensor," *Circuit Cellar Ink: A Computer Applications Journal*, Vol. 101 (April 1999), pp. 28-31.
17. R.K. Kamat and G.M. Naik, "Synthesis of thermistors with high resolution," National Symposium on Instrumentation, NSI-25, Goa University, Goa, India, February 2-5, 2000.
18. R.K. Kamat, G.M. Naik and V.M.S. Verenkar, "Synthesis of NTC thermistors by oxalic precursor route," National Symposium on Inorganic Materials for New Millennium, IMNM-2001, Indian Institute of Technology, Chennai, India, January 18-19, 2001.

Related Web sites

amplifier.ti.com

A web page of Sensor Scientific, Inc.:

www.sensorsci.com/letter.htm

Western Electronic Components, a U.S.-based thermistor manufacturer:

www.wecc.com/

Manufacturer of a wide variety of NTC and PTC thermistors and current surge limiters:

www.ametherm.com/

IMPORTANT NOTICE

Texas Instruments Incorporated and its subsidiaries (TI) reserve the right to make corrections, modifications, enhancements, improvements, and other changes to its products and services at any time and to discontinue any product or service without notice. Customers should obtain the latest relevant information before placing orders and should verify that such information is current and complete. All products are sold subject to TI's terms and conditions of sale supplied at the time of order acknowledgment.

TI warrants performance of its hardware products to the specifications applicable at the time of sale in accordance with TI's standard warranty. Testing and other quality control techniques are used to the extent TI deems necessary to support this warranty. Except where mandated by government requirements, testing of all parameters of each product is not necessarily performed.

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

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

Reproduction of information in TI data books or data sheets is permissible only if reproduction is without alteration and is accompanied by all associated warranties, conditions, limitations, and notices. Reproduction of this information with alteration is an unfair and deceptive business practice. TI is not responsible or liable for such altered documentation.

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

Following are URLs where you can obtain information on other Texas Instruments products and application solutions:

Products

Amplifiers	amplifier.ti.com
Data Converters	dataconverter.ti.com
DSP	dsp.ti.com
Interface	interface.ti.com
Logic	logic.ti.com
Power Mgmt	power.ti.com
Microcontrollers	microcontroller.ti.com

Applications

Audio	www.ti.com/audio
Automotive	www.ti.com/automotive
Broadband	www.ti.com/broadband
Digital control	www.ti.com/digitalcontrol
Military	www.ti.com/military
Optical Networking	www.ti.com/opticalnetwork
Security	www.ti.com/security
Telephony	www.ti.com/telephony
Video & Imaging	www.ti.com/video
Wireless	www.ti.com/wireless

TI Worldwide Technical Support

Internet

TI Semiconductor Product Information Center Home Page
support.ti.com

TI Semiconductor KnowledgeBase Home Page
support.ti.com/sc/knowledgebase

Product Information Centers

Americas

Phone	+1(972) 644-5580	Fax	+1(972) 927-6377
Internet/Email	support.ti.com/sc/pic/americas.htm		

Europe, Middle East, and Africa

Phone			
Belgium (English)	+32 (0) 27 45 54 32	Netherlands (English)	+31 (0) 546 87 95 45
Finland (English)	+358 (0) 9 25173948	Russia	+7 (0) 95 7850415
France	+33 (0) 1 30 70 11 64	Spain	+34 902 35 40 28
Germany	+49 (0) 8161 80 33 11	Sweden (English)	+46 (0) 8587 555 22
Israel (English)	1800 949 0107	United Kingdom	+44 (0) 1604 66 33 99
Italy	800 79 11 37		
Fax	+(49) (0) 8161 80 2045		
Internet	support.ti.com/sc/pic/euro.htm		

Japan

Fax			
International	+81-3-3344-5317	Domestic	0120-81-0036
Internet/Email			
International	support.ti.com/sc/pic/japan.htm		
Domestic	www.tij.co.jp/pic		

Asia

Phone			
International	+886-2-23786800		
Domestic	Toll-Free Number		Toll-Free Number
Australia	1-800-999-084	New Zealand	0800-446-934
China	800-820-8682	Philippines	1-800-765-7404
Hong Kong	800-96-5941	Singapore	800-886-1028
Indonesia	001-803-8861-1006	Taiwan	0800-006800
Korea	080-551-2804	Thailand	001-800-886-0010
Malaysia	1-800-80-3973		
Fax	886-2-2378-6808	Email	tiasia@ti.com
Internet	support.ti.com/sc/pic/asia.htm		ti-china@ti.com

C011905

Safe Harbor Statement: This publication may contain forward-looking statements that involve a number of risks and uncertainties. These "forward-looking statements" are intended to qualify for the safe harbor from liability established by the Private Securities Litigation Reform Act of 1995. These forward-looking statements generally can be identified by phrases such as "TI or its management believes," "expects," "anticipates," "foresees," "forecasts," "estimates" or other words or phrases of similar import. Similarly, such statements herein that describe the company's products, business strategy, outlook, objectives, plans, intentions or goals also are forward-looking statements. All such forward-looking statements are subject to certain risks and uncertainties that could cause actual results to differ materially from those in forward-looking statements. Please refer to TI's most recent Form 10-K for more information on the risks and uncertainties that could materially affect future results of operations. We disclaim any intention or obligation to update any forward-looking statements as a result of developments occurring after the date of this publication.

Trademarks: All trademarks are the property of their respective owners.

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

© 2005 Texas Instruments Incorporated

SLYT147