| Goddard Space Flight Center | # GSFC NASA ADVISORY |
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| **1. Advisory Number** | **2. Subject** |
|---|---|
| NA-GSFC-2002-02 | Single Event Induced Transients in Linear Technology Microcircuits. |

| **3. Manufacturer** | **4. Manufacturer CAGE Code** | **5. Federal Stock Code** |
|---|---|---|
| N/A | N/A | N/A |

| **6. Part/Material/Process Number** | **7. Lot Date Code/Batch Code/Serial Number** | **8. Controlling Spec/Document Number** |
|---|---|---|
| N/A | N/A | N/A |

**9. References** See attached Radiation Effects and Analysis Group Application Notes & NEPAG furnished linear device list.

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**11. Problem Description and Details:** *(Use continuation sheet if necessary)*

The radiation hardness community has observed that most types of linear technology microcircuits will produce transient signals at the device output when exposed to the space radiation environment.

Single Event Transients (SETs) in linear devices were first identified following an in flight anomaly in TOPEX POSEIDON. Since that event, SETs have been identified as the cause of several anomalies on multiple satellites including INMARSAT, SOHO, CASSINI, MAP, and TDRSS.

A SET, caused by the generation of charge by a single particle (proton or heavy ion), consists of a transient pulse generated within the device that produces an effect at the device output. That effect can be the same voltage transient, an amplified version of that voltage transient, or a change in the logical output (e.g., in an Analog to Digital Converter (ADC)).

A transient pulse from a linear device can propagate and produce effects that could cause failures in flight hardware and systems. False information potentially generated by a SET in flight hardware should be taken into account at the system level, especially if the function being performed is deemed critical (equipment RESET, shutdown, etc…). The study of and hardening to such events is a three-step process. First, a description of the consequences of a SET at equipment level must be done. Second, an analysis of the SET impact at the system level and identification of critical events and acceptable event rates needs to be developed. Finally, any required mitigation of critical events at system/subsystem or equipment level must be implemented.

Depending on the input and bias conditions utilized, the SET sensitivity of a linear device could be significant and lead to a substantial event rate. Additionally, variations of these input and bias conditions, in a number of linear devices, are known to dramatically change the event rate and generated transient characteristics (peak heights and widths). This implies that either the radiation test data must be taken over a very large parameters space or application-specific testing must be done for each application of each device type. Of course, the ideal case would be to have mitigation designed into the system at the beginning of the design and therefore, no radiation data would be required.

As a reminder and for raising user awareness of radiation issues with linear devices, the application notes on pages 2, 3, and 4 are provided as guidelines to the designer. These guidelines are not intended to be a subsitute for consulting with radiation effects engineers who have the expertise to evaluate the application of linear devices in a radiation environment.

**12. Action Taken:** *(Use continuation sheet if necessary)*

(1) All spacecraft electronic system/subsystem designers should consult with the radiation effects engineers as early as possible in the design stage for ensuring that the SET mitigation procedures are implemented for all linear devices.

(2) For reference purposes only, the NEPAG furnished Appendix A on pages 5, 6, and 7 contain a partial list of potentially affected linear devices that were obtained from the following four sources: (1) NASA Parts Selection List (NPSL), (2) GSFC Preferred Parts List PPL-21, (3) MIL-STD-975M, & (4) NASA EPIMS (EEE Parts Information Management System). **Please be advised that this list is not a complete list of linear devices and other linear devices not listed may be affected.**


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| *Original signed by GSFC NASA Advisory Coordinator* | | July 9, 2002 |

GSFC 4-36 (6/02)

# APPLICATION NOTES FOR ANALOG LINEAR DEVICES

## INTRODUCTION

Single Event Transients (SETs) in linear devices were first identified following an in flight anomaly in TOPEX POSEIDON[i]. Since that event, SETs have been identified as the cause of several anomalies on multiple satellites including INMARSAT, SOHO, CASSINI, MAP, and TDRSS.

## PROBLEM DESCRIPTION

A SET, caused by the generation of charge by a single particle (proton or heavy ion), consists of a transient pulse generated within the device that produces an effect at the device output. That effect can be the same voltage transient, an amplified version of that voltage transient, or a change in the logical output (e.g., in an Analog to Digital Converter (ADC)).

A transient pulse from a linear device can propagate and produce effects that could cause failures in flight hardware and systems. False information potentially generated by a SET in flight hardware should be taken into account at the system level, especially if the function being performed is deemed critical (equipment RESET, shutdown, etc…). The study of and hardening to such events is a three-step process. First, a description of the consequences of a SET at equipment level must be done. Second, an analysis of the SET impact at the system level and identification of critical events and acceptable rates needs to be developed. Finally, any required mitigation of critical events at system/subsystem or equipment level must be implemented.

Depending on the input and bias conditions utilized, the SET sensitivity of a linear device could be significant and lead to a significant event rate. Additionally, variations of these input and bias conditions, in a number of linear devices, are known to dramatically change the event rate and generated transient characteristics (peak heights and widths). This implies that either the radiation test data must be taken over a very large parameters space or application-specific testing must be done for each application of each device type. Of course, the ideal case would be to have mitigation designed into the system at the beginning of the design and therefore, no radiation data would be required.

Most of the data available in the literature is heavy ion data. Only a few sets of proton data are available. As the heavy ion Linear Energy Transfer (LET) threshold (i.e., a measure of the device's susceptibility to these effects) is generally very low, proton sensitivity is expected. However, available proton data on the LM139 voltage comparator, for example, shows that the proton sensitivity is much lower than heavy ion sensitivity. This instance, though, is not expected to be the norm.

The following paragraphs give a general description of the potential SETs for different types of linear devices. Some recommendations are given to mitigate the effects of SETs. More detailed and device-specific information is available at the Radiation Effect and Analysis Group (REAG, GSFC code 561).

## MITIGATION TECHNIQUES

There are as many ways to mitigate SETs are there are ways to utilize linear devices. The most simplistic, and often the most effective, is through filtering the output of the linear devices. In some applications, filtering may not be an option and other techniques will have to be employed. In some devices, their susceptibility to SETs and the transient characteristics are a strong function of the input and bias conditions. Therefore, a very simple way to mitigate transients in these devices is have input and biasing scheme that is less susceptible, if possible. Next, as with other transient events, a very powerful way to avoid transients is to use a synchronous design. Finally, some other mitigation methods available are voting, over-sampling, and/or software.

## DEVICE DESCRIPTIONS

*Voltage Comparators*

The effect of a SET in a voltage comparator is a transient pulse at the device output that can have characteristics of a rail-to-rail change of state of the comparator output with duration of a few microseconds. In general, it has been observed that the lower the comparator differential input voltage, the higher the device sensitivity.

*Operational Amplifiers*

The effect of a SET in an operational amplifier is an output glitch. A large variety of transient waveforms has been observed (positive-going unipolar, negative-going unipolar, or bipolar, and of short or long duration, etc.). The worst-case glitch is an amplitude of the power supply rail and of duration of tens of microseconds. These SETs may be very difficult to mitigate in an analog chain. Careful analysis of the potentially destructive impact of a SET should be performed. If an amplifier is used to trigger a security signal, voting techniques or filtering should be used.

*Voltage References*

The effect of a SET is an output glitch. The best way to mitigate such effects is by the addition of a filter at the device output.

*Voltage Regulators*

The effect of a SET is an output glitch. These types of devices, though, are generally filtered by the large capacitors used in typical applications by the designers of the regulators. Therefore, no specific action is typically necessary for such devices.

*MOSFET Drivers*

Little data is available on these devices. They are generally considered as not very sensitive to SET. However, the use of MOSFET driver types that allow a short circuit on the driven MOSFETs should be avoided.

*Analog to Digital/Digital to Analog Converters (ADC/DAC)*

For the ADCs there are two possible mechanisms for SETs. The first of these is easily covered under the umbrella of Single Event Upset (SEU) as the effect seen is typically just a spread in the distribution of digital output for a given analog input. Here a comparator in the converter is hit and output code can be shifted by a bit. However, if the analog input is a rapidly varying input (on the time scale of a transient), then an SET on the analog input to the ADC could be carried through the entire chain and the SET survives as digital output of the ADC.

For DACs, the SET issue is much simpler. With the analog side on the output of the device, the SET is observed as an output transient on the analog output. It should be noted that these changes in the analog output are in addition to any SEU events that may be occurring (an upset can occur in the digital input latches that change the state of the affected latch, thereby changing the analog output).

*Line Drivers/Receivers/Transceivers*

This general category of devices is used for the transmission of data between two locations. At either end of the data transmission transients can be generated in the form of glitches in the data lines. The transmit end can have SETs that place transients on the data line that the receiver would have to see as valid data for the error to propagate. A receiver can have an SET on its input side that can then be interpreted as valid data. The primary mitigation for this class of parts is via software with data error detection and correction.

*Sample and Hold Amplifiers*

These devices are designed to sample analog inputs and hold this information for near-future use. The typical SET response of this device type would be having a transient form on the analog input of the device that the sample and hold circuitry that follows cannot distinguish the transient from real data. Therefore, any transient generated in the input would be locked into the output data. However, by their very nature, SETs are transient in nature. Therefore, over-sampling, redundant sampling and voting can be used to counter these effects.

*Timers*

Timer devices are design to produce pulsed output at specified intervals. SETs can affect this output either by placing glitches on the output pulse train or by adding or removing pulses from the pulse train. Depending on the speed of the timer, glitches may or may not be a concern. However, extraneous or missing pulses can affect system performance if it is not designed to deal with these events.

*Pulse Width Modulators (PWM)*

Three different types of SETs have been identified: These are: (1) both outputs return to a low output state for a period of time correlated with the soft start feature or the shutdown feature of the device. The time it takes the duty cycle to increase from 0% to Dcmax after the onset of the upset is equal to the time it takes to discharge and recharge the soft start capacitor (C). (2) The second type of SET has a disturbance of much shorter duration. These short disturbances come in two forms. In the first form, the complementary outputs both return to the low reference. This event lasts for less than one clock period after which they would return to normal output amplitude and frequency. The second form of upset manifests as a toggling of the outputs not related to the clock. The correct function is restored before the next clock cycle begins. (3) The third type of SET is a phase shift of the clock circuit. The outputs follow the change in the clock phase. This event also affects the device frequency output. Therefore, depending on how the device is used in a circuit, this sort of upset can affect more than one function of the device.

Generally, the two last types of SETs do not affect the operations of the applications where PWM are used (mainly DC/DC converters). This is due to the short duration of the event. On the contrary, the first type of SET could have an impact on the application depending on the soft start circuitry. The longer the duration of the soft start, the higher the impact on the application. It could be very critical on devices like UC1846 where the user could not use the soft start circuitry. After shutdown, the device never starts again. The PWMs that do not implement the soft/start and/or shutdown functions are not sensitive to this type of events.

*Hybrid Devices*

This general category of devices is added to this list as, in general, there are linear devices used within the hybrid design. Hybrid devices span a large range of device types from as simple as an optocoupler to an oscillator to a complex DC/DC converter. For these three examples, the SETs are widely different.

An optocoupler will have simple output transients, but as with other linear devices, that transient varies widely with the application biasing.

An oscillator can have either SETs as output glitches or extra or missing pulses, depending on which device within the oscillator has the initial SET.

DC/DC converters can have simple transients on their outputs if the SET is generated in one of the devices near the output. However, these converters can have output voltage dropouts, where the output voltage typically drops to zero. These dropouts can be for the short (microsecond) durations or require a reset to recover the output voltage.

In general, hybrid devices need to be selected very carefully for SET effects (as always the best way to mitigate an effect is to choose a part that is not susceptible). If a hybrid is selected that has unknown SET characteristics and utilized in an important system, radiation characterization for SETs will be required.

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[i] R. Koga, etal., “Observation of Single Event Upsets in Analog Microcircuits,” IEEE TNS, Vol. 40, N°6, December 1993, pp. 1838-1844.

# Appendix A

**This attachment is provided by NEPAG (NASA EEE Parts Assurance Group).**

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Caution: This attachment is **not** a complete list of linear devices. Note: XXXXX = Prefix/Suffix

## Voltage Comparator

| Generic/Supplier Number | Specification |
|---|---|
| TLC139MXXX, TLC374MXXX | 5962-876590XXX |
| LM139XXXXX, PM139XXXXX | 5962-877390XXXX |
| LM139AN | 5962-947110XXXX |
| LM139XXXXXXX | 5962-9673801XXX |
| IS0-139XXXXX, IS9-139XXXXXX | 5962F0151001XXX |
| HS0-139XXX,HS1-139XXX, HS9-139XXX | 5962F9861301XXX |
| LM139XXXXX, PM139XXXXX | 7700801XX |
| JL139XXX,LM139,MM139XXX,PM139XXX | M38510/11201XXX |
| TLC139M | 5962-9555001NXD |
| AD9696XXXXXX, AD9698TXXXXX | 5962-923470XXXX |
| LM119XXXXXXX | 5962-9679801XXX |
| LM119XXXXX,LT119XXXXX,PM119XXXXX | 860140XXX |
| JL119BXX, LM119X | M38510/10306XXX |
| LT119A, LT119AX | M38510/10307XXX |
| LM111XXXXX,LT111AXXXXX,PM111XXXXX | 5962-868770XXXX |
| LM111XXXXXXX | 5962P0052401XXX |
| 111,JL111XXX,MM0111XXX,PM111XXX | M38510/10304XXX |
| 2111, MM2111XXX, MTL2111XXX | M38510/10305XXX |
| LM193XXXXXX | 5962-945260XXXX |
| TLC193MDQ, TLC193MJGB | 5962-9555101XXX |
| 193, JL193XXX, LM193 | M38510/11202XXX |
| LM710XXX, ML1710XXX | M38510/10301XXX |
| LM7711XXX | M38510/10302XXX |
| MTL1011XXX | 5962-906270XXX |

## Line Driver/Receiver/Transceiver

| Generic/Supplier Number | Specification |
|---|---|
| XX26C31XXXXXX | 5962-9163901XXX |
| HSX-26C31XXX, HSX-26CLV31XXX | 5962X966630XXXX |
| XX26C32XXXXXX | 5962-9164001XXX |
| HSX-26C32XXX, HSX-26CLV32XXX | 5962X956890XXXX |
| HSX-26CT31RH-X | 5962X9563201XXX |
| HSX-26CT32RH-X | 5962X9563101XXX |
| 55107A | M38510/10401XXX |
| SNJ55107AXX, SNJ55108AXX | 5962-969030XXXX |
| 55108, 55108A | M38510/10402XXX |
| SNJ55113XX, SNJ55114XX | 5962-887440XXXX |
| 55113 | M38510/10405XXX |
| 55114 | M38510/10403XXX |
| 55115, 9615 | M38510/10404XXX |
| SNJ55115XX | 5962-8874501XX |
| 55451 | M38510/12902XXX |
| XXX55451XXXXXX, XXX55452XXXXX | 770490XXX |
| 55452, 55452BYJAN | M38510/12903XXX |
| 55454 | M38510/12905XXX |
| SG554X4XX/883B | 5962-887150XXX |
| 55462 | M38510/12908XXX |
| 55463 | M38510/12909XXX |

## Voltage Regulator

| Generic/Supplier Number | Specification |
|---|---|
| LM109KSTEEL/883 | 5962-8777401XX |
| 109, 109TJAN, JL109XXX | M38510/10701XXX |
| LM117XXXXXX, LM137XXXXXXX | 5962-995170XXXX |
| SDP117XXXXX, SDP137XXXXX | 5962-996120XXXX |
| HSXX-117RH-X | 5962X9954701XXX |
| OMR132XSTM/883B | 5962R770340XXXX |
| XXX117XXXX,XX137XXXXX,OM132XXX | 770340XXX |
| 7812TJAN, JL140-12XXX | M38510/10703XXX |
| 140-15, 7815TJAN, JL140-15BXA | M38510/10704XXX |
| XX79M05XXX, XX120XXXXXXX | 7704001XX |
| XX79M12HM, XX7912KM, LM120X-12 | 7704003XX |
| XX79M15HM, XX7915KM, LM120X-15 | 7704004XX |
| XX79M24HM, XX7924KM, LM120H-24 | 7704005XX |
| LM120H-24 | M38510/11504XXX |
| 7905TJAN, JL120-5XXX | M38510/11501XXX |
| 7912TJAN, JL120-12BXA, 120-12 | M38510/11502XXX |
| 7915TJAN, JL120-15BXA, JL120-15SXA | M38510/11503XXX |
| 7905KJAN, JL120-5XXX | M38510/11505XXX |
| 7912KJAN,JL120-12BYA, 120-12 | M38510/11506XXX |
| 7915KJAN,JL120-15BYA, 120-15 | M38510/11507XXX |
| SDP7912AXXX | 5962-99614XXXXX |
| OMR1912STM/883B | 5962F8874701UA |
| XX7912XXXXXX,FM912S7,IP79M12AH | 5962-8874701XXX |
| LM123K/883B, LM123AK/883B | 5962-877750XXX |
| XXX7915XXXXX,FM915S7,OM1915XXX | 5962-8874801XX |
| SDP7915AXXX | 5962-9864101XXX |
| IP7924X/883B | 5962-8874901XX |
| 7924KJAN | M38510/11508XXX |
| LM137HV, LM137HVK-QMLV | 5962-7703404XXX |
| LM117XXXXXX, LM137XXXXXXX | 5962-995170XXXX |
| SDP117XXXXX, SDP137XXXXX | 5962-996120XXXX |
| 137KJAN, XX137XXX | M38510/11804XXX |
| LM138, MTL138AMK | M38510/11706XXX |
| 7805KJAN, JL140-5BYA, JL140-5SYA | M38510/10706XXX |
| 7812KJAN, JL140-12XXX | M38510/10707XXX |
| 7815KJAN, JL140-15XXX | M38510/10708XXX |
| JL140-24BYA | M38510/10709XXX |
| 7805TJAN, JL140-5XXX | M38510/10702XXX |
| 723, 723XXXX, XX723XXXX | M38510/10201XXX |

## Voltage Reference

| Generic/Supplier Number | Specification |
|---|---|
| LT1009XXXXX | 5962-8961001XX |
| LT1009, LT1009MH | M38510/14802XXX |
| AD584XXXXXX, MX584XXXXXX | 5962-381280XXXX |
| AD584SH | M38510/12801XXX |
| AD584XXXXXX | M38510/12802XXX |
| AD584TH/QMLVR | 5962R3812802VGA |

## Appendix A

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# Operational Amplifier

| Generic/Supplier Number | Specification |
|---|---|
| HSX-5104ARH-X | 5962R9569001XXX |
| HS1-1245RH-Q, HS1B-1245RH-Q | 5962F9683201XXX |
| LT1124XXXXX, LT1125XXXXX | 5962-932380XXXX |
| LM124AXXXXXXX | 5962R9950401XXX |
| LM124XXXXXX | 770430XXX |
| XX124XXX | M38510/11005XXX |
| XX124AXXX | M38510/11006XXX |
| LM158XXXX, LM158AXXXXX | 5962-877100XXXX |
| OP07XXXX, MM4807XXXX | M38510/13501XXX |
| OP27BRC/883C | 5962-9468001M2A |
| OP27XXXXXXX | 5962R9468002XXX |
| OP-27A, OP27XXXX, OPO27XXXX | M38510/13503XXX |
| LMC6462XXXXXXX, LMC6464XXXXXX | 5962-956030XXXX |
| OP37XXXXXX | 5962-885370XXXX |
| OP43AJ/QMLV | 5962-9763701XXX |
| OP-200AXXXXX, OP200AXXXXXX | 5962-8859301XXX |
| CLC200A8C, KH200HXX | 5962-8991001XX |
| EL2002XXXXXX | 5962-905090XXXX |
| EL2001XXXXXX | 5962-915340XXXX |
| OP400AXX | 5962-8777101XXX |
| XX26C31XXXXXX | 5962-9163901XXX |
| CS5101A-XXXX | 5962-916910XXXX |
| LM101AXXXXXX | 5962R9951501XXX |
| XXX108XXXX | M38510/10104XXX |
| LM6118XXXX | 5962-9156501XXX |
| LT118AJ8/883 | 5962-9451601MPX |
| LM118XXXXXXX | 5962P9853901XXX |
| 118, XXX118XXX | M38510/10107XXX |
| 2101AJJAN, MM2101ADMA | M38510/10105XXX |
| LM148 ,JL148XXX, MM148DCA | M38510/11001XXX |
| JL155XXX, LF155XX, PM155XXX | M38510/11401XXX |
| LF155AXX, PM155SAXX | M38510/11404XXX |
| MC1558XXX | 5962-9760301XXX |
| 1558, JL1558BGA | M38510/10108XXX |
| JL156XXX, LF156XX, PM156XXX | M38510/11402XXX |
| LF156AXX, PM156AXX | M38510/11405XXX |
| 157, LF157 | M38510/11403XXX |
| 157A, LF157A | M38510/11406XXX |
| JL411/BGA, JL411BPA | M38510/11904XXX |
| HA1-4741/883 | 5962-9864501QCA |
| 741, 741A, XX741XXXX | M38510/10101XXX |
| MM4156 | M38510/11003XXX |
| 747, 747A, XX747XXX | M38510/10102XXX |
| TLV2772XXXXX | 5962-985880XXXX |
| HI1-774T/883 | 5962-9958201QXC |

# Operational Amplifier

| Generic/Supplier Number | Specification |
|---|---|
| HA2500, HA2-2500 | M38510/12204XXX |
| HSXX-2510RH-Q | 5962D9568601XXX |
| HA2-2510, HA7-2510 | M38510/12205XXX |
| HAX-2520/883, HAX-2522/883 | 5962-898800XXXX |
| HSXX-2520RH-Q | 5962D9568501XXX |
| HA2-2520, HA7-2520 | M38510/12206XXX |
| HSXX-2600RH-Q | 5962D9567101XXX |
| 2600, HA2-2600, HA7-2600 | M38510/12202XXX |
| HSXX-2620RH-Q, HSXX-2622 | 5962D956880XXXX |
| HS0-22620RH-Q, HS9-22620RH-Q | 5962F9751201XXX |
| 2620, HA2-2620, HA7-2620 | M38510/12203XXX |
| LH2108A, MM2108ADMA, PM2108AQ5 | M38510/10106XXX |
| 4136, MM4136XXX, PM4136XX | M38510/11004XXX |
| TLE2071XXXX,TLE2072XXXX,TLE2074XXX | 5962-946020XXXX |
| TL06XMXXX, TL07XMXXX, LF147D/883 | 810230XXX |
| HAX-5127/883,HAX-5137/883,HAX-5147 | 5962-896270XXX |
| 074, JL147BCA | M38510/11906XXX |
| 35074/BCAJC, 35074A/BCAJC | 5962-899690XXXX |
| 5532A | M38510/13102BCA |
| AD811SE/883B, AD811SQ/883B | 5962-9313101MXX |
| MM5534AXXX | M38510/13101XXX |
| AD797SQ/883B | 5962-9313301MPA |
| XX148XXX | M38510/11001XXX |

# Pulse Width Modulator

| Generic/Supplier Number | Specification |
|---|---|
| XX1524XXXXXX | 5962-876450XXX |
| XX1524X/883B | 7802801EA |
| 1524JJAN, UC1524J | M38510/12601XXX |
| 1846 | M38510/70201XXX |
| XX1846XXXXX, XX1847XXXXX | 5962-868060XXXX |
| XX1525XXXXX, XX1527XXXXX | 5962-895110XXXX |
| 1525AJJAN, UC1525AJ | M38510/12602XXX |
| 1526BJJAN | M38510/12603XXX |
| XX1526XXXXX | 8551501XX |
| 1527AJJAN, UC1527J | M38510/12604XXX |

## Appendix A

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# Linear Converter (A/D)

| Generic/Supplier Number | Specification |
|---|---|
| AD976ASD | 5962-9756401QXA |
| HSX-9008RH-X | 5962F9669601XXX |
| XXX574XXXXXX | 5962-851270XXXX |
| IDT54FCT574XXX | 5962-895130XXXX |
| ADC-908XX, XX7574XXXXX | 5962-896160XXXX |
| XXX54FCT574XXXX | 5962-922220XXXX |
| XXXX574XXXXXXX | 5962-851270XXXX |
| AD574AUD | M38510/14001XXX |
| AD574ATD | M38510/14002XXX |
| 574AU | M38510/14003XXX |
| 574AT | M38510/14004XXX |

# Linear Converter (D/A)

| Generic/Supplier Number | Specification |
|---|---|
| DAC08 Q5, DAC08S Q5, MM4818ADMA | M38510/11301XXX |
| AHV2815SF/CH | 5962-9211301XXX |
| DAC08A Q5, MM4818, DAC08SA Q5 | M38510/11302XXX |
| 562 | M38510/12101XXX |
| AD565SD | M38510/12103XXX |
| AD561SD | M38510/13301XXX |
| HSX-565ARH-X | 5962R9675501XXX |
| 7521 | M38510/12703XXX |

# Sample and Hold Amplifier

| Generic/Supplier Number | Specification |
|---|---|
| 198,JL198BGA,LF198H,JL198SGA | M38510/12501XXX |

# Timer

| Generic/Supplier Number | Specification |
|---|---|
| 555, SE555, JL555XXX | M38510/10901XXX |
| SE556 | M38510/10902XXX |