3 1/2 DIGIT SINGLE CHIP A/D CONVERTER

GENERAL DESCRIPTION

The MMC 7106 and 7107 are high performance, low power 3–1/2 digit A/D converters containing all the necessary active devices on a single CMOS I. C. Included are seven-segment decoders, display drivers, reference, and a clock. The MMC 7106 is designed to interface with a liquid crystal display (LCD) and includes a backplane drive; the MMC 7107 will directly drive an instrument-size light-emitting diode (LED) display.

The MMC 7106 and MMC 7107 bring together an unprecedented combination of high accuracy, versatility, and true economy.

The versatility of true differential input and reference is useful in all systems, but gives the designer an uncommon advantage when measuring load cells, strain gauges and other bridge-type transducers. And finally the true economy of single power supply operation (MMC 7106), enabling a high performance panel meter to be built with the addition of only 7 passive components and display.

FEATURES

- Guaranteed zero reading for 0 volts input on all scales.
- True polarity at zero for precise null detection.
- Direct display drive — no external components required
  — LCD MMC 7106
  — LED MMC 7107
- On chip clock and reference.
- Low power dissipation — typically less than 10 mW.
- No additional active circuits required.

ABSOLUTE MAXIMUM RATINGS

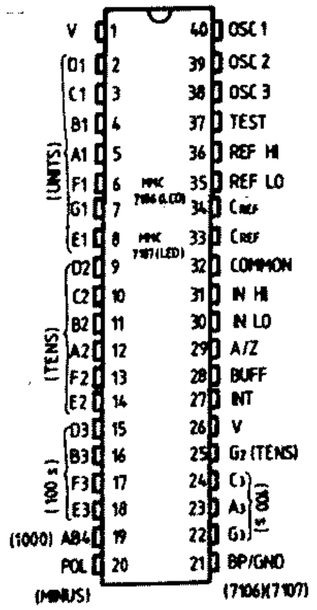
Supply Voltage (V^+)	
MMC 7106	15 V
MMC 7107	+6 V
Supply Voltage (V^-)	
MMC 7106	0V
MMC 7107	−9 V
Analog Input Voltage (either input) (Note 1)	V^+ to V^-
Reference Input Voltage (either input)	V^+ to V^-
Clock input	
MMC 7106	Test to V^+
MMC 7107	Gnd to V^+
Power dissipation (MMC 7106 Note 2; MMC 7107 Note 1)	
Ceramic package	1000 mW
Plastic package	800 mW
Operating Temperature	0° C to + 70° C
Storage Temperature	−65° C to 85° C

Stresses above those listed under Absolute Maximum Ratings may cause permanent damage to the device. These are stress ratings only and functional operation of the devices at these or any other conditions above those indicated in the in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

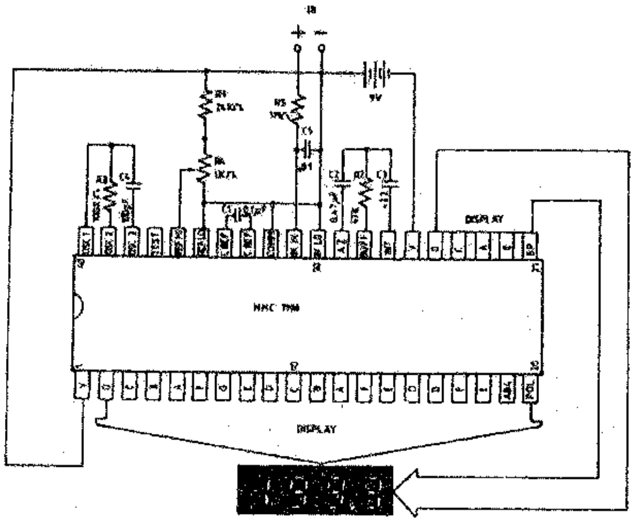
Note 1: Input voltages may exceed the supply voltages provided the input current is limited to ± 100 μA

Note 2: Dissipation rating assumes device is mounted with all leads soldered to printed circuit board.

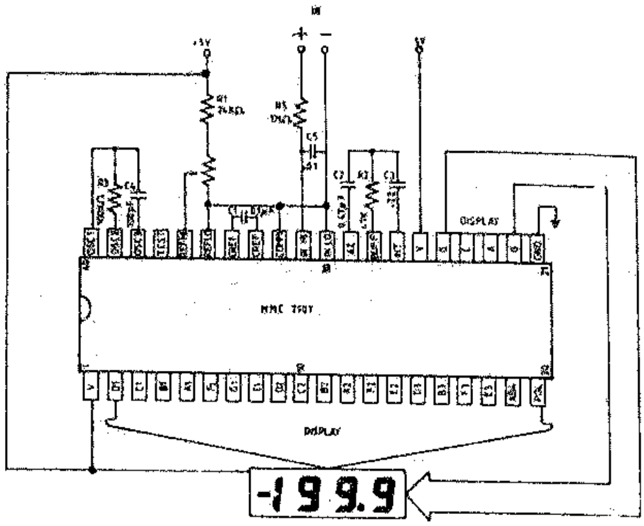
PIN CONFIGURATION



CONNECTION DIAGRAM



MMC 7106 with Liquid Crystal Display



MMC 7107 with LED Display

ELECTRICAL CHARACTERISTICS (note 3)

PARAMETER	TEST CONDITIONS	VALUES			UNIT
		MIN	TYP	MAX	
Zero Input Reading	V_{IN} = 0.0V Full Scale = 200.0 mV	−000.0	±000.0	+000.0	Digital Rading
Ratiometric Reading	$V_{IN} = V_{REF}$ V_{REF} = 100 mV	999	999/1000	1000	Digital Reading
Rollover Error (Difference in reading for equal positive and negative reading near Full Scale)	$V_{IN} = V_{IN}$ = 200.0 mV	−1	±.2	+1	Counts
Linearity (Max. deviation from best straight line fit)	Full scale = 200 mV or full scale = 2.000 V	−1	±.2	+1	Counts
V^+ Supply Current (Does not include LED current for 7107)	V_{IN} = 0		0.8	1.8	mA
V^- Supply Current (7107 only)			0.6	1.8	mA
Analog Common Voltage (With respect to Pos. Supply)	25 kΩ between Common & Pos. Supply	2.4	2.8	3.2	V
7106 Only Pk—Pk Segment Drive Voltage Pk—Pk Backplane Drive Voltage (Note 4)	V^+ to V^- = 9 V	4	5	6	V
7107 Only Segment Sinking Current (Except Pin 19)	V^+ = 5.0 V Segment voltage = 3 V	5	8.0		mA
Pin 19 only		10	16		mA

Note 3: Unless otherwise noted, specifications apply to both the MMC 7106 and 7107 at T_A = 25° C, f_{clock} = 48 kHz. MMC 7106 is tested in the circuit of Figure 1. MMC 7107 is tested in the circuit of Figure 2.

Note 4: Back plane drive is in phase with segment drive for „off" segment, 180° out of phase for „on" segment. Frequency is 20 times conversion rate. Average DC component is less than 50 mV.

TEST CIRCUITS

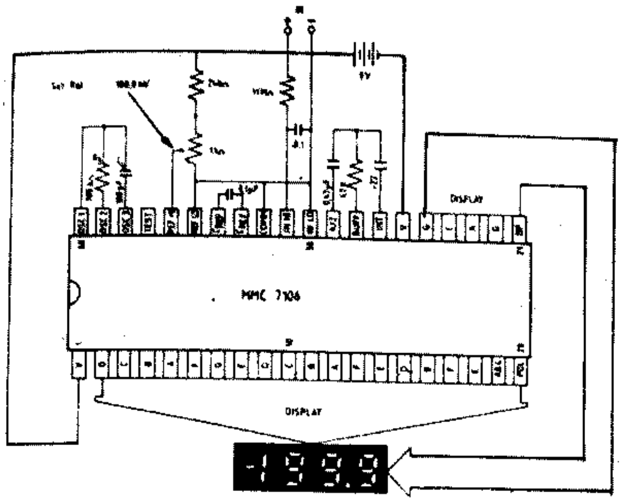


Figure 1: 7106

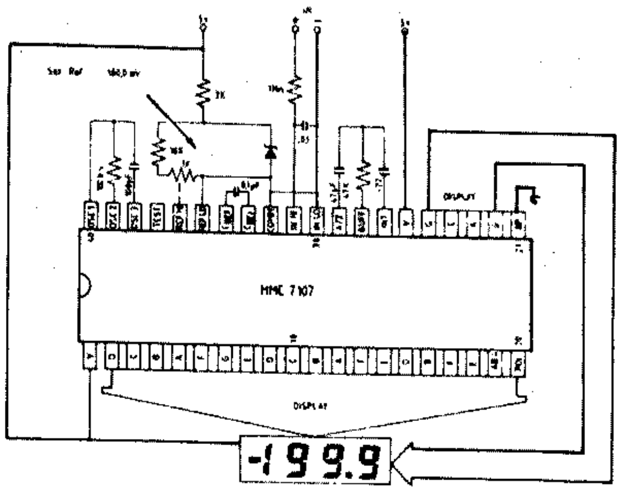


Figure 2: 7107

DETAILED DESCRIPTION

ANALOG SECTION

Figure 3 shows the Block Diagram of the Analog Section for the MMC 7106 and 7107. Each measurement cycle is divided into three phases. They are (1) auto-zero (A—Z), (2) signal integrate (INT) and (3) deintegrate (DE).

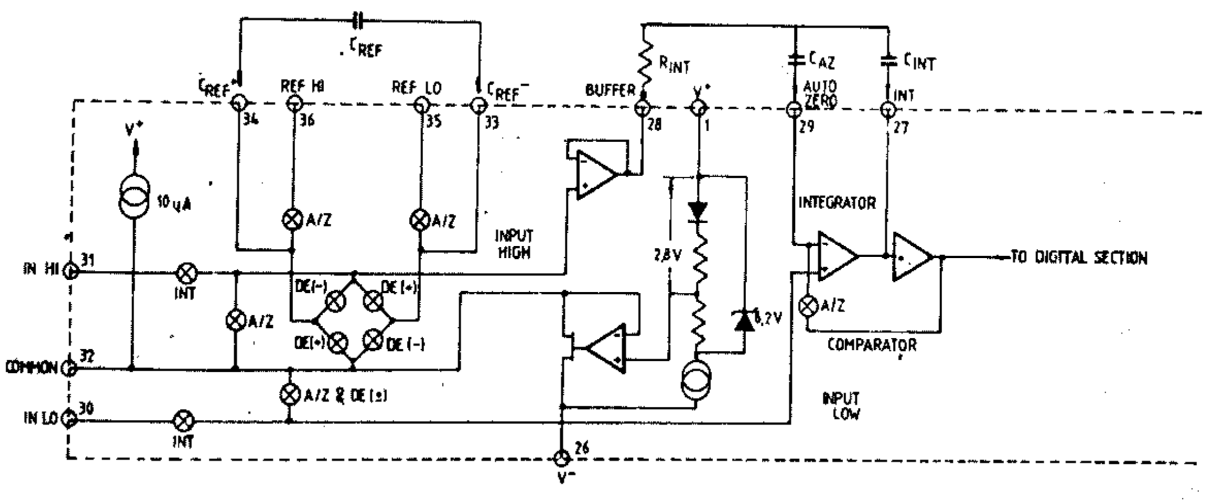


Figure 3: Analog Section of 7106/7107

1. AUTO-ZERO PHASE

During auto-zero three things happen. First, input high and low are disconnected from the pins and internally shorted to analog COMMON. Second, the reference capacitor is charged to the reference voltage. Third, a feedback loop is closed around the system to charge the autozero capacitor C_{AZ} to compensate for offset voltages in the buffer amplifier, integrator, and comparator. Since the comparator is included in the loop, the A—Z accuracy is limited only by the noise of the system. In any case, the offset referred to the input is less than 10 μV.

2. SIGNAL INTEGRATE PHASE

During signal integrate, the auto-zero loop is opened, the internal short is removed, and the internal input high and low are connected to the differential voltage between IN HI and IN LO for a fixed time. This differential voltage can be within a wide common mode range; within one volt of either supply. If, on the other hand, the input signal has no return with respect to the converter power supply, IN LO can be tied to analog COMMON to establish the correct common-mode voltage. At the end of this phase, the polarity of the integrated signal is determined.

3. DE-INTEGRATE PHASE

The final phase is de-integrate, or reference integrate. Input low is internally connected to analog COMMON and input high is connected across the previously charged reference capacitor. Circuitry within the chip ensures that the capacitor will be connected with the correct polarity to cause the integrator output to return to zero. The time required for the output to return to zero is proportional to the input signal.

Specifically the digital reading displayed is $1000 \left(\frac{V_{IN}}{REF} \right)$.

DIFFERENTIAL INPUT

The input can accept differential voltages anywhere within the common mode range of the input amplifier; or specifically from 0.5 volts below the positive supply to 1.0 volt above the negative supply. However, since the integrator also swings with the common mode voltage, care must be exercised to assure the integrator output does not saturate. A worst case condition would be a large positive common mode voltage with a near full-scale negative differential input voltage. The negative input signal drives the integrator positive when most of its swing has been used up by the positive common mode voltage. For these critical applications the integrator swing can be reduced to less than the recommended 2 V full scale swing with little loss of accuracy. The integrator output can swing within 0.3 volts of either supply without loss of linearity.

DIFFERENTIAL REFERENCE

The reference voltage can be generated anywhere within the power supply voltage of the converter. The main source of common mode error is a roll-over voltage caused by the reference capacitor losing or gaining charge to stray capacity on its nodes. If there is a large common mode voltage the reference capacitor can gain charge (increase voltage) when called up to de-integrate a positive signal but lose charge (decrease voltage) when called up to deintegrate a negative input signal. This difference in reference for (+) or (−) input voltage will give a rollover error. However, by selecting the reference capacitor large enough in comparison to the stray capacitance, this error can be held to less than 0.5 count for the worst case condition. (See Component Values Selection below).

ANALOG COMMON

This pin is included primarily to set the common mode voltage for battery operation (MMC 7106) or for any system where the input signals are floating with respect to the power supply. The COMMON pin sets a voltage that is approximately 2.8 volts more negative than the positive supply. This is selected to give a minimum end-of-life battery voltage of about 6 V. However, the analog COMMON has some of the attributes of a reference voltage. When the total supply voltage is large enough to cause the zener to regulate (> 7 V), the COMMON voltage will have a low voltage coefficient and low output impedance.

The limitations of the on-chip reference should also be recognized, however. With the MMC 7107, the internal heating which results from the LED drivers can cause some degradation in performance. Due to their higher thermal resistance, plastic parts are poorer in this respect than ceramic. The combination of reference Temperature Coefficient (TC) internal chip dissipation, and package thermal resistance can increase noise near full scale. Also the linearity in going from a high dissipation count such as 1000 (20 segments on) to a low dissipation count such as 1111 (8 segments on) can suffer by a count or more. Devices with a positive TC reference may require several counts to pull out of an overload condition. This is because overload is a low dissipation mode, with the three least significant digits blanked. Similarly, units with a negative TC may cycle between overload and a non-overload count as the die alternately heats and cools. All the problems are of course eliminated if an external reference is used.

The MMC 7106, with its negligible dissipation, suffer from none of these problems. In either case, an external reference can easily be added, as shown in Fig. 4.

Analog COMMON is also used as the input low return during auto-zero and de-integrate. If IN LO is different from analog COMMON, a common mode voltage exists in the system and is taken care of by the excellent CMRR of the converter. However, in some applications IN LO will be set at a fixed known voltage (power supply common for instance). In this application, analog Common should be tied to the same point, thus removing the common mode voltage from the converter. The same holds true for the reference voltage. If reference can be conveniently referenced to analog COMMON, it should be since this removes the common mode voltage from the reference system.

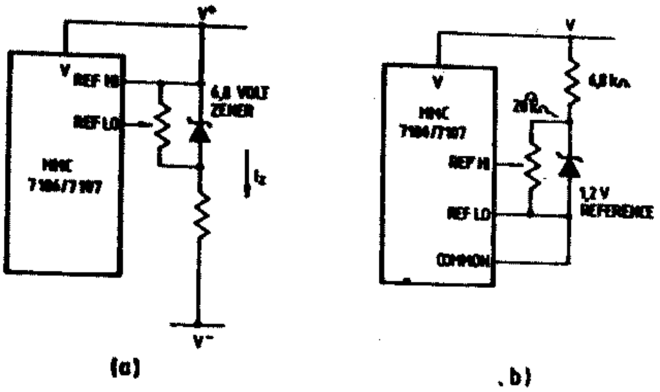


Fig.4 : Using an External Reference

Within the IC, analog COMMON is tied to an N channel FET that can sink 30mA or more of current to hold the voltage 2.8 volts below the positive supply (when a load is trying to pull the common line positive). However, there is only 10 μA of source current, so COMMON may easily be tied to a more negative voltage thus over-riding the internal reference.

TEST

The TEST pin serves two functions. On the MMC 7106 it is coupled to the internally generated digital supply through a 500 Ω resistor. Thus it can be used as the negative supply for externally generated segment drivers such as decimal points or any other presentation the user may want to include on the LCD display. Figures 5 and 6 show such an application. No more than a 1 mA load should be applied.
The second function is a „lamp test". When TEST is pulled high (to V⁺) all segments will be turned on and the display should read — 1888. The TEST pin will sink about 10 mA under these conditions.

Caution: on the MMC 7106, in the lamp test mode, the segments have a constant d-c voltage (no square-wave) and may burn the LCD display if left in this mode for several minutes.

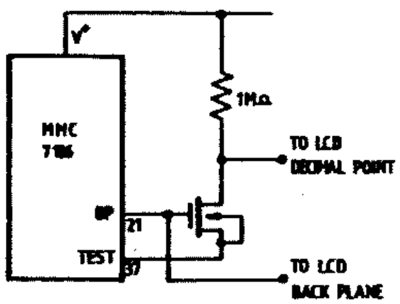


Figure 5: Simple Inverter for Fixed Decimal Point

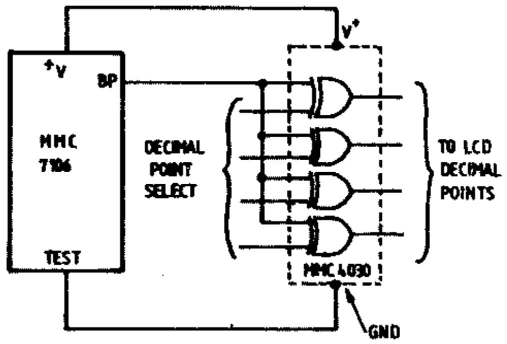


Figure 6: Exclusive 'OR'Gate for Decimal Point Drive

DIGITAL SECTION

Figures 7 and 8 show the digital section for the MMC 7106 and MMC 7107, respectively. In the MMC 7106, an internal digital ground ia generated from a 6 volt Zener diode and a large P channel source follower. This supply is made stiff to absorb the relative large capacitive currents when the back plane (BP) voltage is switched. The BP frequency is the clock frequency divided by 800. For three readings/second this is a 60 Hz square wave with a nominal amplitude of 5 volts. The segments are driven at the same frequency and amplitude and are in phase with BP when OFF, but out of phase when ON. In all cases negligible d-c voltage exists across the segments.

Figure 8 is the Digital Section of the MMC 7107. It is identical to the MMC 7106 except that the regulated supply and back plane drive have been eliminated and the segment drive has been increased from 2 to 8 mA, typical for instrument size common anode LED displays. Since the 1000 output (pin 19) must sink current from two LED segments, it has twice the drive capability or 16 mA.

In both devices, the polarity indication is „on" for negative analog inputs. If IN LO and IN HI are reversed, this indication can be reversed also, if desired.

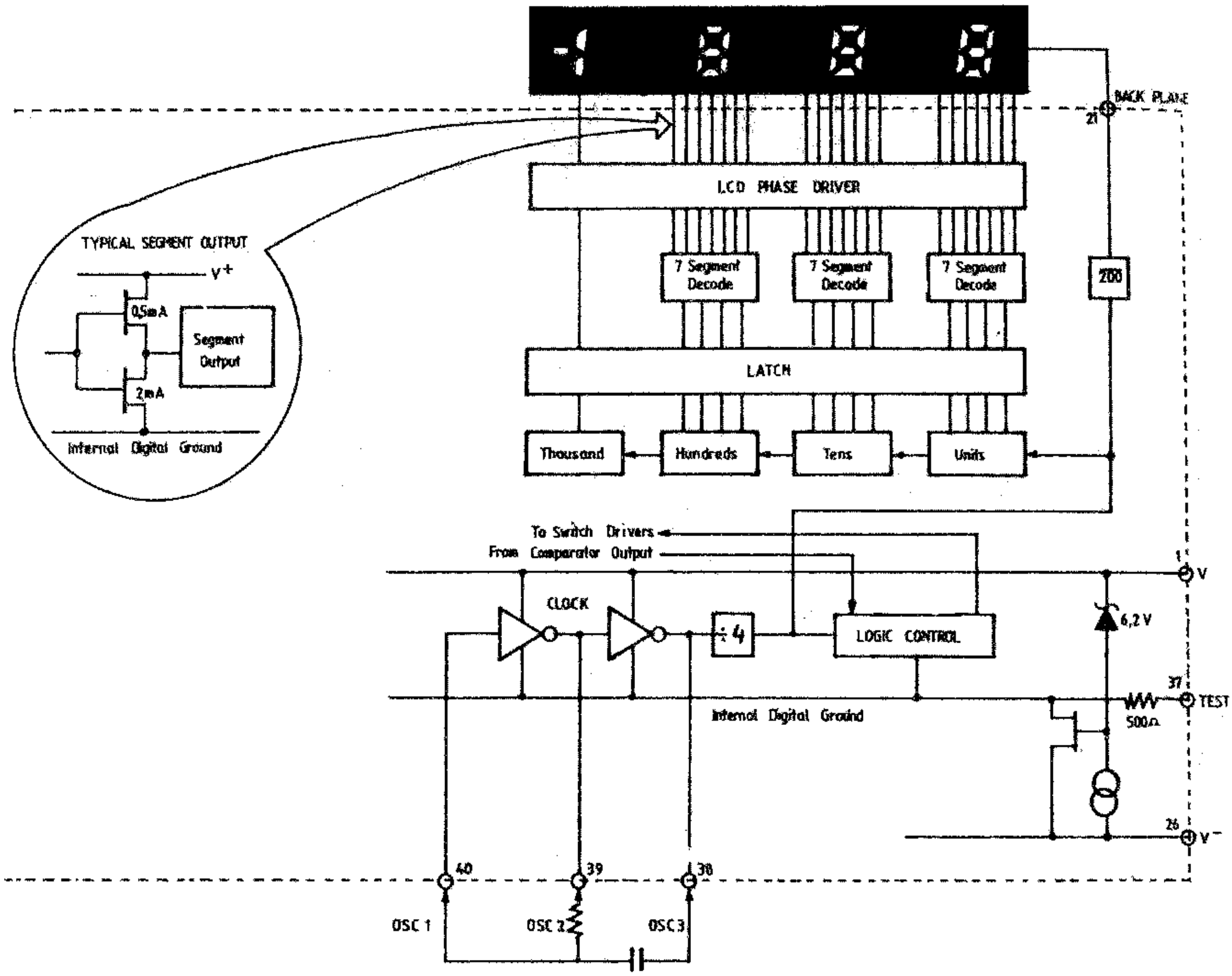


Figure 7: Digital Section 7106

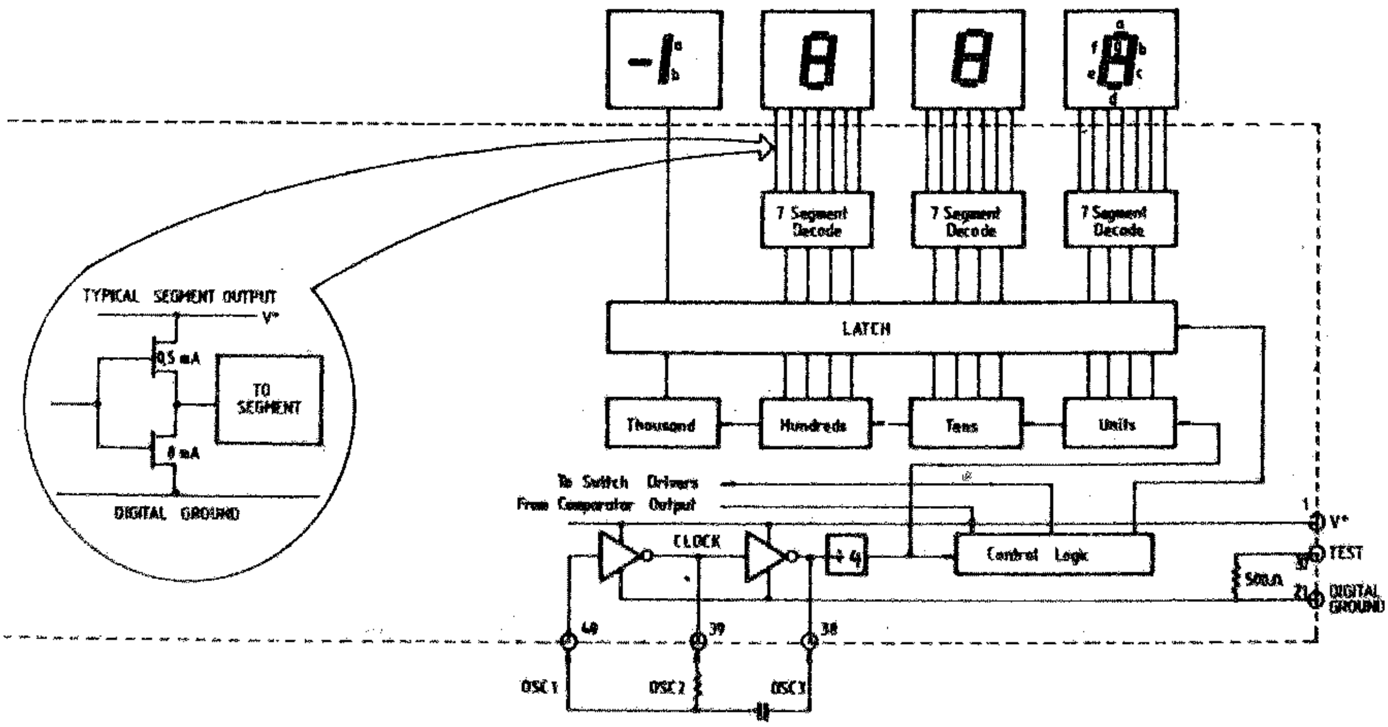
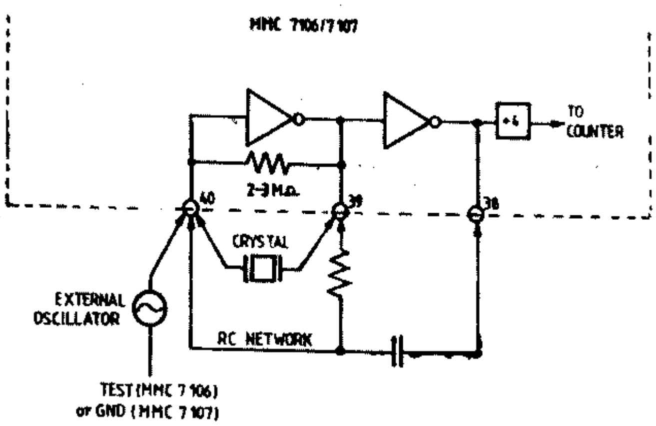


Figure 8: Digital Section 7107

SYSTEM TIMING

Figure 9 shows the clocking arrangement used in the 7106 and 7107. Three basic clocking arrangements can be used:

1. An external oscillator connected to pin 40.
2. A crystal between pins 39 and 40.
3. An R—C oscillator using all three pins.



The oscillator frequency is divided by four before it clocks the decade counters. It is then further divided to form the three convert-cycle phasess. These are signal integrate (1 000 counts), reference deintegrate (0 to 2 000 counts) and auto-zero (1 000 to 3 000 counts). For signals less than full scale, auto-zero gets unused portion of reference deintegrate. This makes a complete measure cycle of 4 000 (16 000 clock pulses) independent of input voltage. For three readings/secod an oscillator frequency of 48 kHz would be used.

To achieve maximum rejection of 50 Hz pickup, the signal integrate cycle should be a multiple of 50 Hz. Oscillator frequencies of 200 kHz, 100 kHz, 66 2/3 kHz, 50 kHz, 40 kHz etc. should be selected. Note that 40 kHz (2.5 readings/second) will reject both 50 and 60 Hz (also 400 and 440 Hz).

COMPONENT VALUE SELECTION

1. INTEGRATING RESISTOR

Both the buffer amplifier and the integrator have a class A output stage with 100 μA of quiescent current. They can supply 20 μA of drive current with negligible non-linearity. The integrating resistor should be large enough to remain in this very linear region over the input voltage range, but small enough that undue leakage requirements are not placed on the PC board. For 2 volt full scale, 470 KΩ is near optimum and similarly a 47 KΩ for a 2000 mV scale.

2 INTEGRATING CAPACITOR

The integrating capacitor should be selected to give the maximum voltage swing that ensures tolerance build-up will not saturate the integrator swing (approx. 0.3 volt from either supply). In the MMC 7106 or the MMC 7107, when the analog COMMON is used as a reference, a nominal ±2 volt full scale integrator swing is fine. For the MMC7107 with ±5 volt supplies and analog COMMON tied to supply ground, a ±3.5 to ±4 volt swing is nominal. For three readings/second (48 kHz clock) nominal values for C_{INT} are 0.22 μF and 0.10 μF, respectively. Of course, if different oscillator frequencies are used, these values should be changed in inverse proportion to mentain the same output swing. An additional requirement of the integrating capacitor is it have low dielectric absorbtion to prevent rollover errors. While other types of capacitors are adequate for this application, polypropylene capacitors give undetectable errors at reasonable cost.

3. AUTO-ZERO CAPACITOR

The size of the auto-zero capacitor has some influence on the noise of the system. For 200 mV full scale where noise is very important, a 0.47 μF capacitor is recommended. On the 2 volt scale a 0.047 μF capacitor increases the speed of recovery from overload and is adequate for noise on this scale.

4. REFERENCE CAPACITOR

A 0.1 μF capacitor gives good results in most applications. However, where a large common mode voltage exists (i.e. the REF LO pin is not at analog COMMON) and a 200 mV scale is used, a large value is required to prevent roll-over error. Generally 1.0 μF will hold the roll-over error to 0.5 count in this instance.

5. OSCILLATOR COMPONENTS

For all ranges of frequency a 100 kΩ resistor is recommanded and the capacitor is selected from the equation $f = \frac{.45}{RC}$. For 48 kHz clock (3 readings/second), C = 100 pF.

6. REFERENCE VOLTAGE

The analog input reequired to generate full-scale output (2 000 counts) is: $V_{IN} = 2\ V_{REF}$. Thus, for the 2.000 mV and 2 000 volt scale, Vref should equal 100.0 mV and 1.000 volt, respectively. However, in many applications where the A/D is connected to a transducer, there will exist a scale factor other than unity between the input voltage and the digital reading. For instance, in a weighing system, the designer might like to have a full scale reading when the voltage from the transducer is 0.682 V. Instead of dividing the input down to 200.0 mV, the designer should use the input voltage directly and select $V_{REF} = .341$ V. Suitable values for integrating resistor and capacitor would be 120 kΩ and 0.22 µF. This makes the system slightly quieter and also avoids a divider network on the input. The MMC 7107 with ±5 V supplies can accept input signals up to ± 4V. Another advantage of this system occurs when a digital reading of zero is desired for $V_{IN} \neq 0$.

Temperature and weighing systems with a variable tare are examples. This offset reading can be conveniently generated by connecting the voltage transducer between IN HI and COMMON and the variable (or fixed) offset voltage between COMMON and IN LO.

7. MMC 7107 POWER SUPPLIES

The MMC 7107 is designed to work from ±5 V supplies. However, if a negative supply is not available, it can be generated from the clock output with 2 diodes, 2 capacitors, and an inexpensive I.C. In fact, in selected applications no negative supply is required. The conditions to use a single + 5 V supply are:

1. The input signal can be referenced to the center of the common mode range of the converter.
2. The signal is less than ± 1.5 volts.
3. An external reference is used.

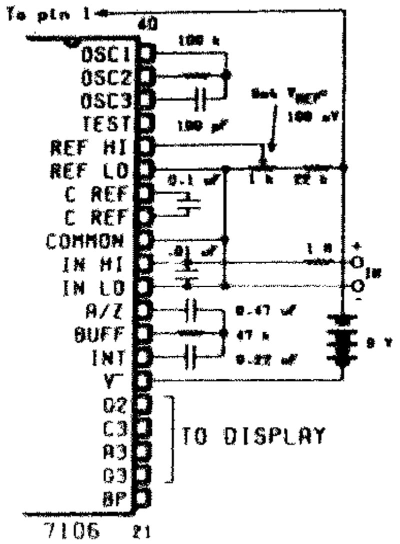


Fig.1 7106 using the internal reference. Values shown are for 200.0 mV full scale, 3 readings per second, floating supply voltage(9V battery)

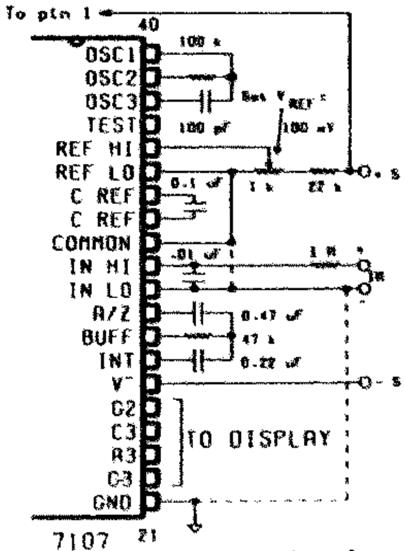


Fig.2 7107 using the internal reference. Values shown are for 200.0 mV full scale, 3 readings per second. INLO may tied to either COMMON for inputs floating with respect to supplies, or GND for single ended inputs. (See discussion under Analog COMMON.)

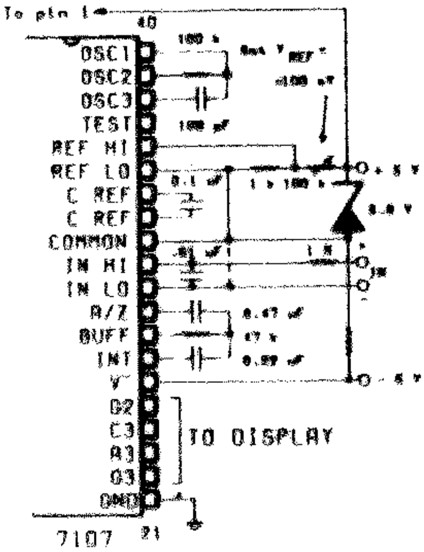


Fig.3 7107 with Zener diode reference. Since low T. C. Zeners have breakdown voltage 6.8 V. diode must be placeed across the total supply (10V). IN LO may be tied to either COMMON or GND

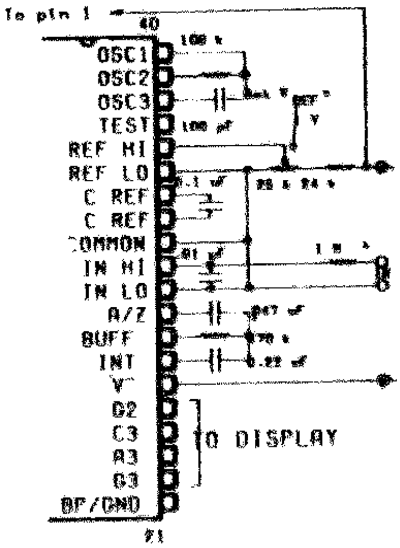


Fig.4 7106/7107 Recommended component values for 2.000 V full scale