Users Manual

National Semiconductor

SC/MP-II Microprocessor Retrofit Kit

Publication Number 420305365-001A

SC/MP-II Microprocessor

Retrofit Kit

Users Manual

January 1977

2900 Semiconductor Drive
Santa Clara, California 95051

PREFACE

This manual shows how the SC/MP Kit (Order No. ISP-8K/200) and the SC/MP INTROKIT (Order No. ISP-8K/200E) – each using the P-channel microprocessor chip – can be retrofitted to use the N-channel (SC/MP-II) microprocessor chip. Once the retrofit changes are incorporated, the power-up procedures, the reset circuits, and the Teletype® interface connections for the retrofitted kit are identical to those procedures and circuits pertaining to either the SC/MP Kit or the SC/MP INTROKIT. (*Note: If, instead of a Teletype, the SC/MP Keyboard Kit is used for an input/output peripheral, some additional minor changes are required for proper interface with either the retrofitted SC/MP Kit or the retrofitted SC/MP INTROKIT; these changes are detailed in 7.0.*)

Retrofit procedures are presented assuming that the user is familiar with basic techniques and tools of electronic assembly; refer to chapter 2 of the SC/MP Kit Users Manual or the SC/MP INTROKIT Users Manual, as applicable, if additional information is required.

For those that need or would like more information on the SC/MP family of microprocessors, the following documents are available.

- Data Sheet, ISP-8A/500 Single-Chip 8-bit Microprocessor (SC/MP) – publication number 420305227-001. Provides electrical characteristics and functional overview of SC/MP chip.
- Data Sheet, ISP-8A/600 Single-Chip N-Channel 8-bit Microprocessor (SC/MP-II) – Publication Number 426305290-001A. Provides electrical characteristics and functional overview of SC/MP-II chip.
- SC/MP Technical Description – Publication Number 4200079. Comprises comprehensive descriptions of functional details, general interfacing characteristics, supporting hardware, and systems information.
- SC/MP Applications Handbook – Publication Number 420305239-001A. Provides general design data and a host of bench-proven applications – Analog-to-Digital/Digital-to-Analog Systems, Keyboard/Display Systems, Multiprocessor Systems, and so on.
- SC/MP Assembly Language Programming Manual – Order Number ISP-8S/994Y. Contains comprehensive overview of the SC/MP Microprocessor as it relates to assembly language programming and detailed descriptions of the assembly language, sundry source statements, programming techniques, and assembly input/output formats.

®Registered trademark of the Teletype Corporation

CONTENTS

LIST OF ILLUSTRATIONS

1.0 INTRODUCTION

This manual describes how the SC/MP Kit and the SC/MP INTROKIT (each using a P-channel "SC/MP" microprocessor chip) can be converted so that each kit uses an N-channel "SC/MP-II" microprocessor chip. Both the SC/MP and SC/MP-II chips are object-code compatible; thus a qualitative and quantitative comparison between the two microprocessors can be easily made. If the user so desires, the SC/MP-II Kit can be adapted for higher-speed operation. Using a 2-megahertz crystal, SC/MP-II operates at the same frequency of SC/MP, whereas, with a 4-megahertz crystal, the operating frequency of SC/MP-II can be extended up to twice that of SC/MP. The higher operating speed together with clocking simplicity, better interface capabilities, and lower power requirements makes SC/MP-II a valuable addition to the ever-growing SC/MP family of application tools. Typical interface and software modifications required by changes in the CPU speed are provided in 6.1 and 6.2. Once modified to use the SC/MP-II microprocessor chip, both the SC/MP Kit and the SC/MP INTROKIT can be interfaced with the SC/MP Keyboard Kit; refer to 7.0 for interfacing details.

Refer to the preface for referenced publications.

2.0 OPERATIONAL DIFFERENCES OF SC/MP-II

The differences between SC/MP and SC/MP-II can be summarized as follows:

- SC/MP-II requires only a single +5-volt power supply; this feature provides a substantial reduction in power dissipation – thus, lower power supply cost. (*Note: Even though the chip operates with a single +5-volt supply, the SC/MP-II Retrofit Kit still requires an additional –12-volt supply to service the power requirements of the MM5214 (ROM).*) Because of +5-volt operation, SC/MP-II can be easily interfaced with TTL devices, NMOS devices, and, by using pullups, with CMOS devices.
- The ENIN, ENOUT, and BREQ signals of SC/MP are active-high; these same signals for SC/MP-II are active-low and are preceded by a negative designator (NENIN, NENOUT, and NBREQ).
- SC/MP-II can be operated at up to twice the speed of SC/MP. Depending upon user needs, this capability can broaden the spectrum of practical applications.
- If SC/MP-II is operated with an external clock, the input requirements are much less demanding; furthermore, only one input is required to drive the internal chip clocks of the SC/MP-II chip, whereas two inputs are required for the SC/MP chip. The X_{in} input of SC/MP-II is fully TTL-compatible; the clock output from X_{out} is likewise TTL-compatible. It should be noted that one microcycle for SC/MP-II is $4T_x$ ($T_x = 1/f_{xtal}$), whereas one microcycle for SC/MP is $2T_x$ – that is, to run the two microprocessors at the same frequency, the crystal used in SC/MP-II must be twice the frequency of that used in SC/MP. (For greater timing detail, refer to the appropriate data sheet referenced in the Preface.)

3.0 CODE AND INTERFACE COMPATIBILITIES

Both SC/MP and SC/MP-II are object-code compatible. This compatibility allows the user to take advantage of SC/MP-II features (excluding the higher-speed operation) as soon as the retrofit procedures are completed. No software changes are required so long as the retrofitted CPU runs at the

same speed; likewise, no changes to ROM, RAM, or KITBUG are required. With minor modifications, the SC/MP Keyboard Kit can also be interfaced to either the retrofitted SC/MP Kit or the retrofitted SC/MP INTROKIT – see 7.0.

4.0 RETROFITTING SC/MP KIT TO USE SC/MP-II CPU

4.1 GENERAL INFORMATION

Procedural detail and nomenclature used in the following paragraphs assumes familiarity with basic techniques and tools of electronic assembly; refer to chapter 2 of the SC/MP Kit or INTROKIT Users Manual if additional information is required. The retrofit instructions required to make the conversion are organized in functional groups: – V_{CC} Changes, V_{SS} Changes, Control-Line Changes, Crystal and Crystal-Component Changes, Address Pullups, and, last of all, the Chip Change (Replacing SC/MP with SC/MP-II).

4.2 RETROFIT PARTS LIST

The SC/MP-II Retrofit Kit includes the following items:

Description	Quantity
SC/MP-II CPU (ISP-8A/600)	1
Crystal (2-Megahertz)	1
Resistor Array (RA15 – 10KN)	1
Resistor (100K – ¼W)	1
Resistor (1K – ¼W)	1
Capacitor (56-Picofarad)	1
Wire-Wrap Wire (30 AWG)	Several inches
Plastic Tubing	1 inch

4.3 RETROFIT PROCEDURES

Step-by-step procedures for retrofitting printed circuit board #5514879/B to use the SC/MP-II CPU are as follows:

V_{CC} Changes (figure 1)

1. Remove voltage regulator (LM 320MP) and 1-microfarad capacitor, as indicated.
2. Add wire jumper between terminals 1 and 2 – previously occupied by the regulator.

V_{SS} Changes (figure 2)

1. Cut trace in two places as indicated.
2. Add new connections in two places as shown.

ENIN/NHOLD/CONT Changes (figure 2)

1. Add jumper wire from pins 6 and 8 of the SC/MP chip to +5-volts as shown.
2. Add jumper wire from pin 3 of SC/MP to ground as shown.

Crystal and Crystal-Component Changes (figures 1 and 2)

1. Cut trace between pin 37 of SC/MP and J1 as shown in figure 1; add 1-kilohm resistor as indicated.
2. Remove 1-megahertz crystal for P-channel SC/MP and replace with 2-megahertz crystal for SC/MP-II.
3. Refer to figure 2; add 100-kilohm resistor and 56-picofarad capacitor as shown – use plastic tubing to insulate each lead of capacitor.

Address Pullups (figure 2)

1. Position resistor array (RA15–10KN) between the MM5214 (ROM) pins on the solder side of PC board.
2. Solder wire between pin 12 of MM5214 and pin 16 of RA15–10KN.
3. In turn, solder a wire between each address pin of the MM5214 and a resistor in the array as shown.

Chip Change – Replacing SC/MP with SC/MP-II (figure 1)

CAUTION

Before replacing SC/MP with SC/MP-II, make certain that the "V_{CC}" and "V_{SS}" changes are complete. If the chips are interchanged and power is applied before these changes are made, SC/MP-II *will be permanently damaged.*

1. Carefully remove SC/MP chip from its 40-pin socket.
2. Replace with SC/MP-II microprocessor chip.

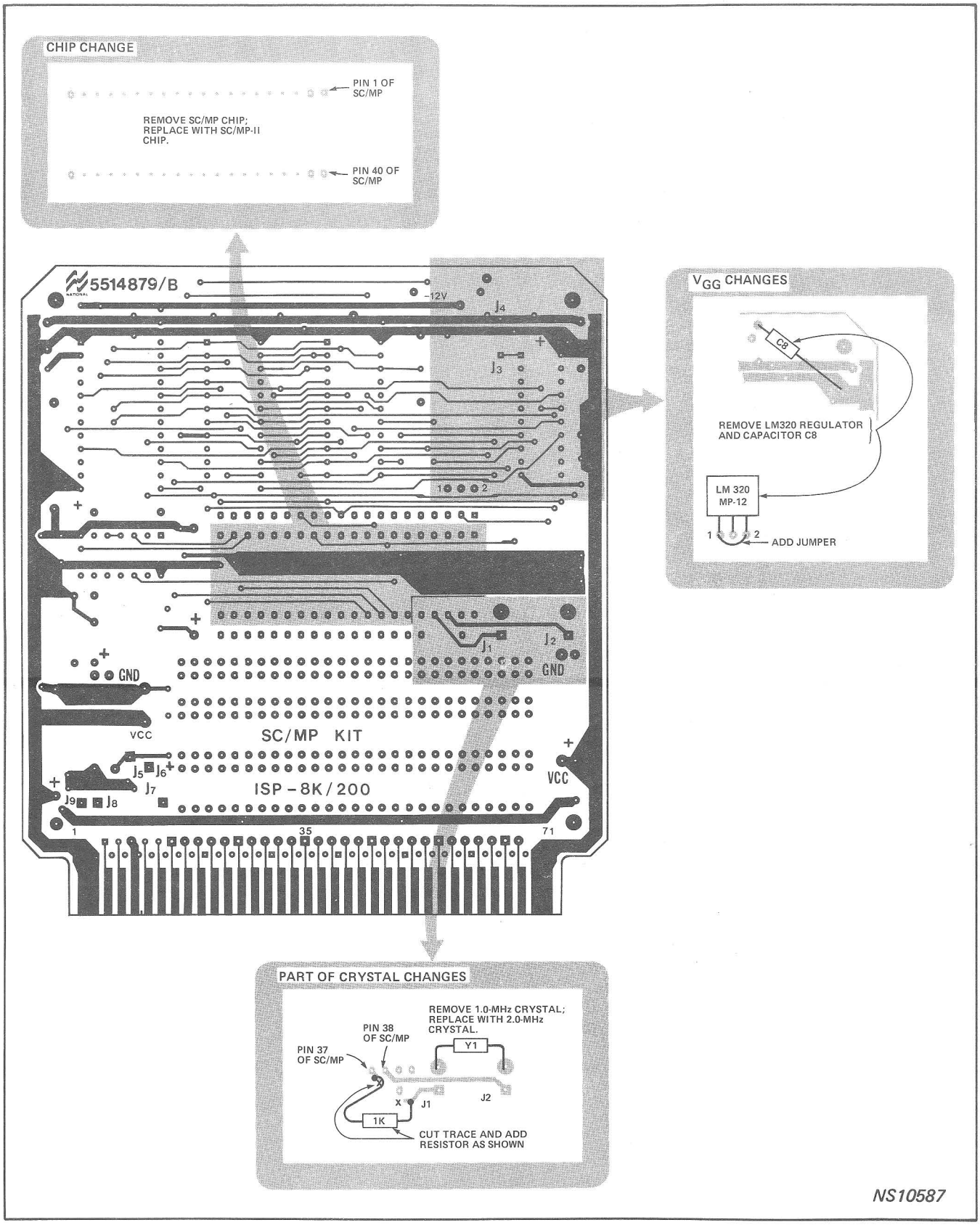


Figure 1. Retrofitting Component Side of PC Board #5514879/B for SC/MP-II Microprocessor Chip

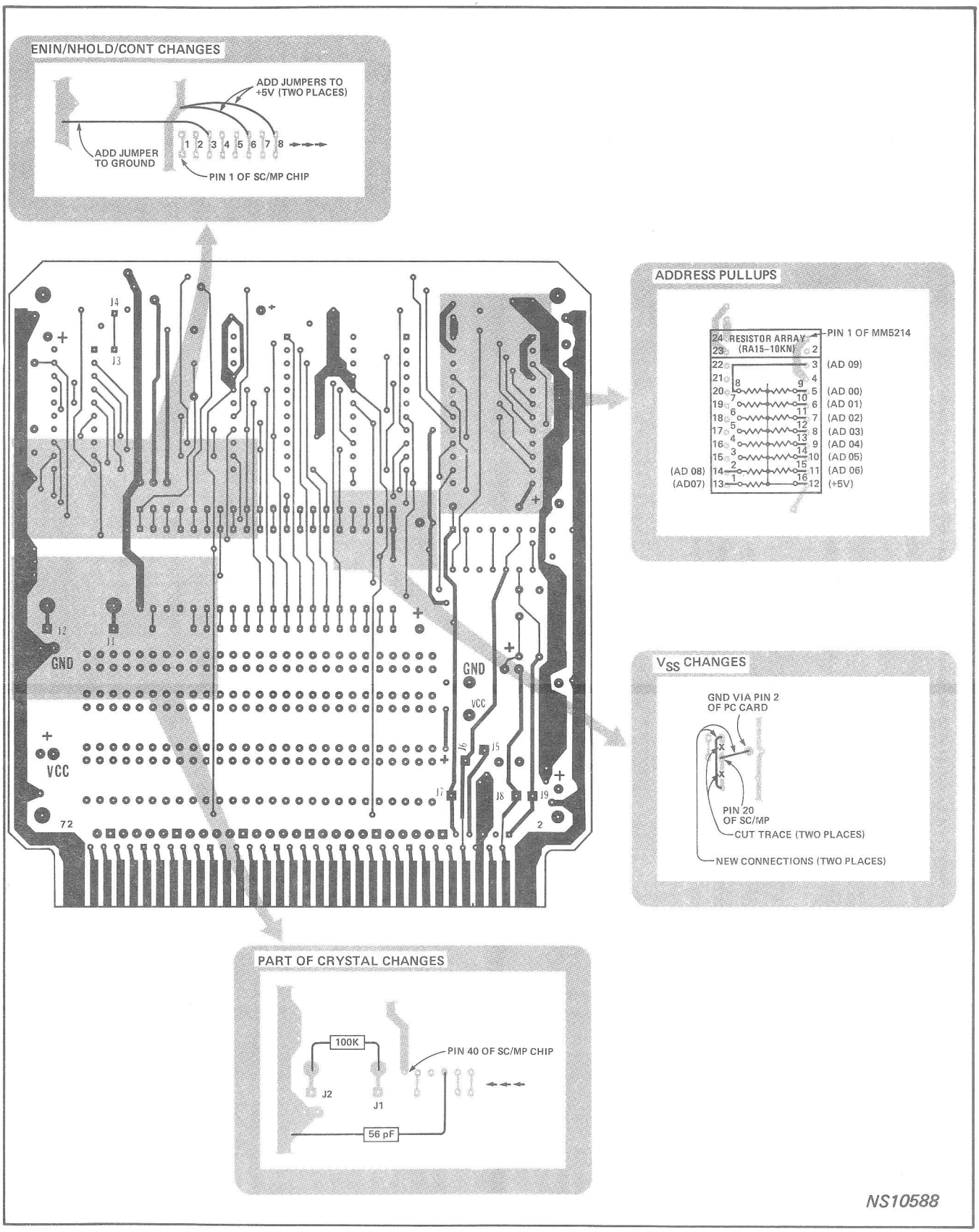


Figure 2. Retrofitting Solder Side of PC Board #5514879/B for SC/MP-II Microprocessor Chip

4.4 VERIFICATION AND CHECKOUT

Once the preceding changes are completed, the retrofitted PC board should agree with the layouts shown in figures 3 and 4; the chip schematic should agree with that shown in figure 5.

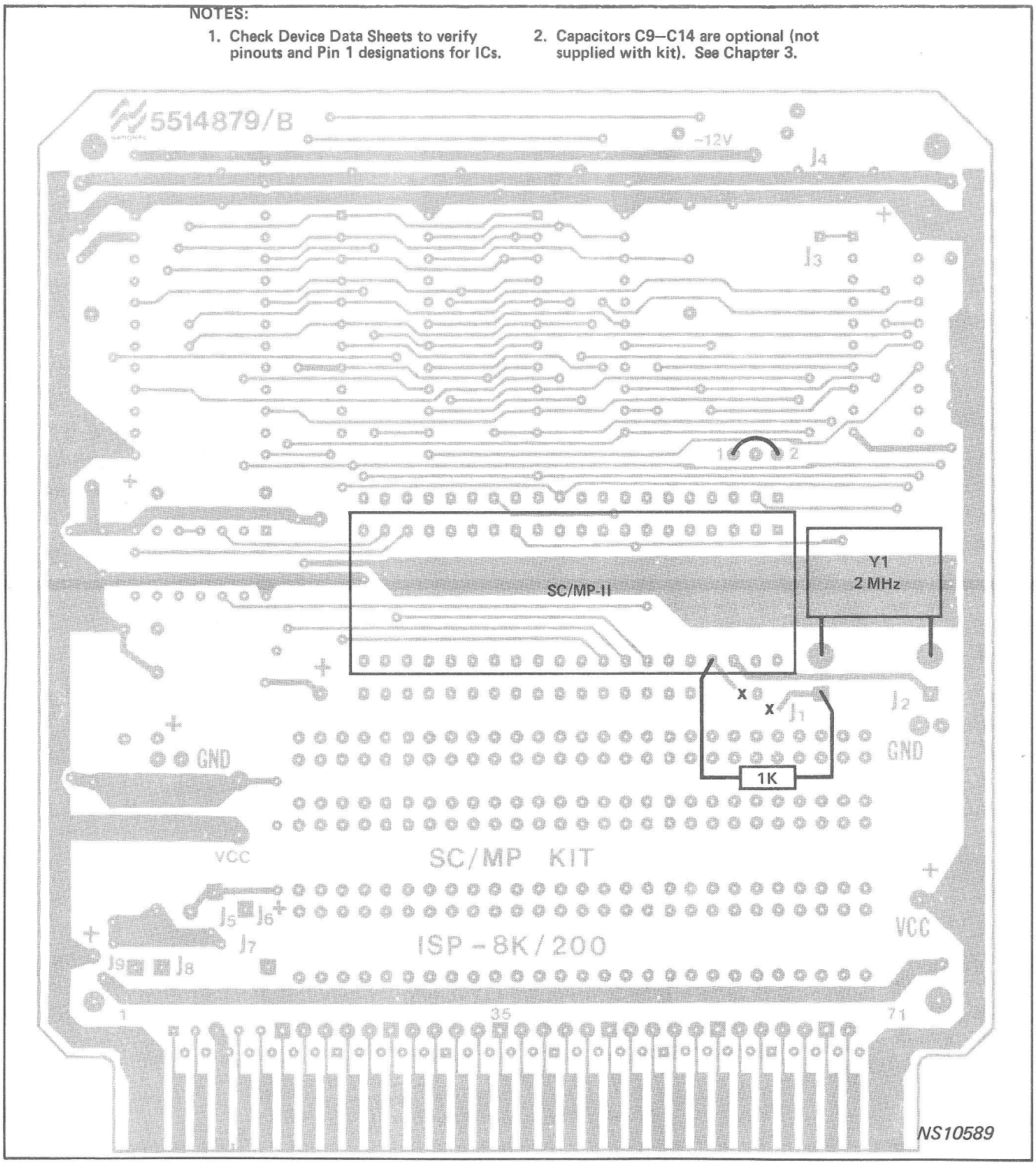


Figure 3. Component Side of PC Board #5514879/B Retrofitted for SC/MP-II Microprocessor Chip

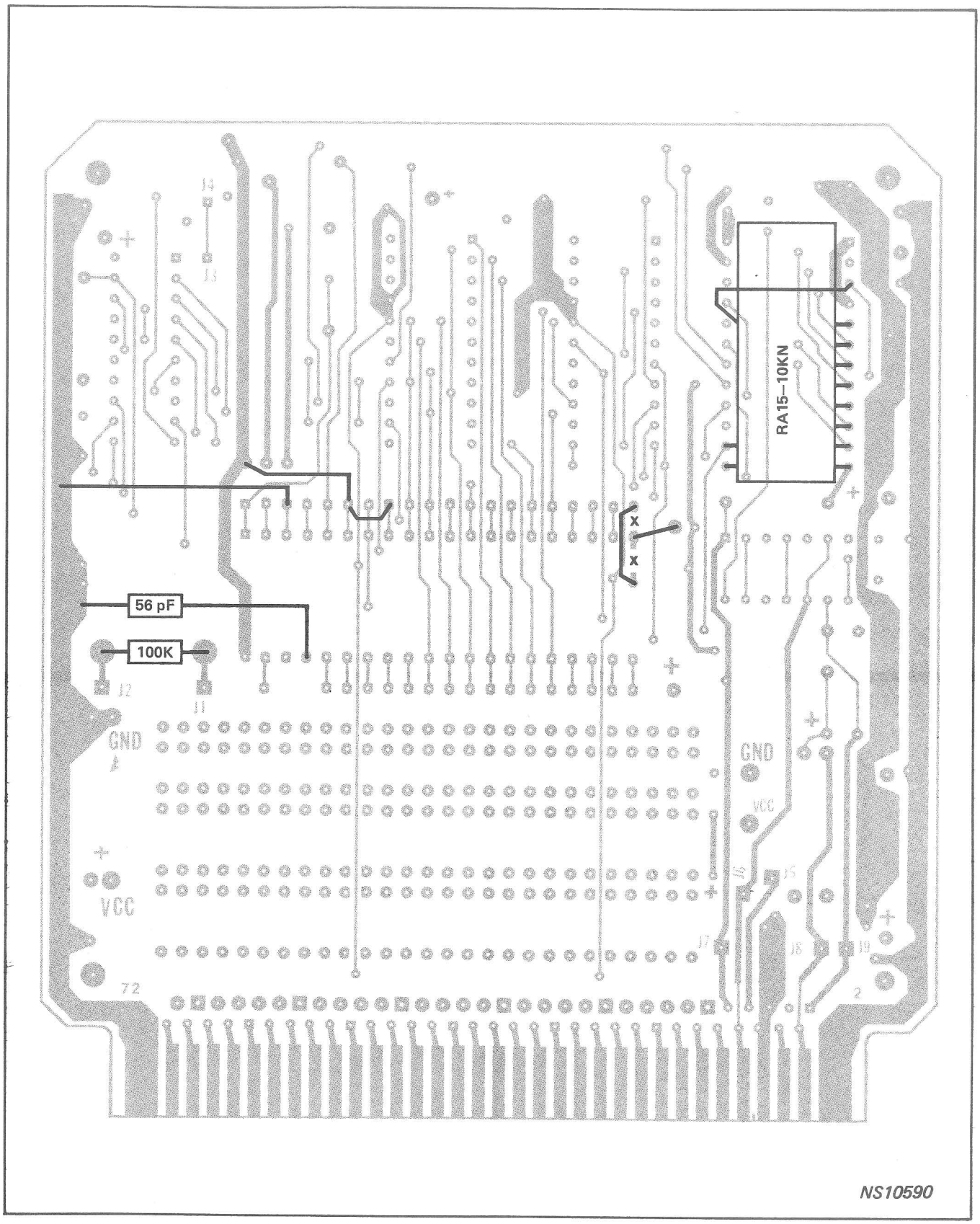


Figure 4. Solder Side of PC Board #5514879/B Retrofitted for SC/MP-II Microprocessor Chip

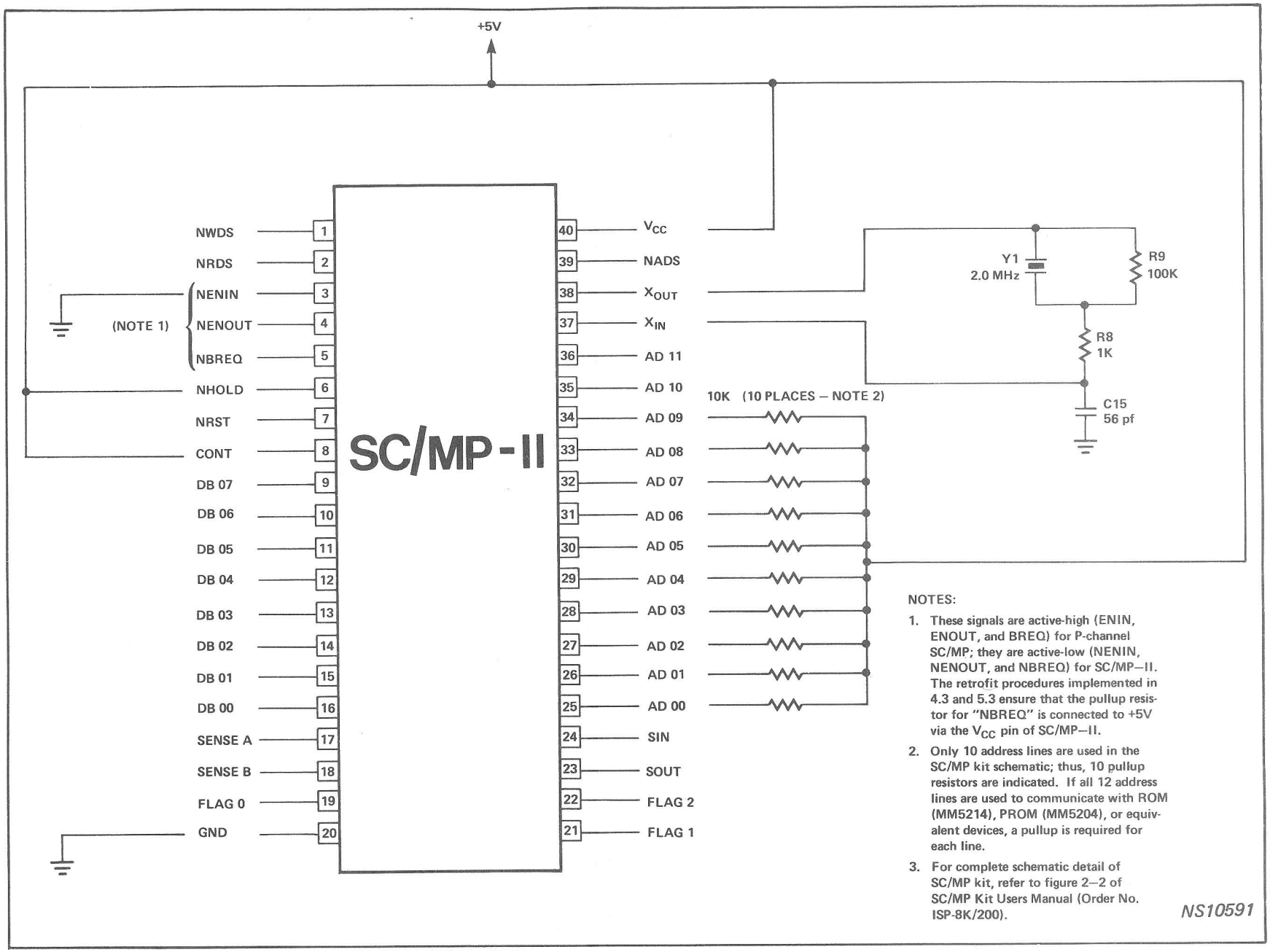


Figure 5. SC/MP-II Operating at P-Channel SC/MP Frequency – Partial Schematic Diagram

5.0 RETROFITTING SC/MP INTROKIT TO USE SC/MP-II CPU

5.1 GENERAL INFORMATION

Procedural detail and nomenclature used in the following paragraphs assumes familiarity with basic techniques and tools of electronic assembly; refer to chapter 2 of the SC/MP INTROKIT Users Manual if additional information is required. The retrofit instructions required to make the conversion are organized in functional groups: – V_{CC} Changes, V_{SS} Changes, Control-Line Changes, Crystal and Crystal-Component Changes, Address Pullups, and last of all, the Chip Change (Replacing SC/MP with SC/MP-II).

5.2 RETROFIT PARTS LIST

The SC/MP-II Retrofit Kit includes the following items:

Description	Quantity
SC/MP-II CPU (ISP-8A/600)	1
Crystal (2-Megahertz)	1
Resistor Array (RA15–10KN)	1
Resistor (100K–¼W)	1
Resistor (1K–¼W)	1
Capacitor (56-Picofarad)	1
Wire-Wrap Wire (30 AWG)	Several inches
Plastic Tubing	1 inch

5.3 RETROFIT PROCEDURES

Step-by-step procedures for retrofitting printed circuit board #551305229–001A to use the SC/MP-II CPU are as follows.

V_{CC} Changes (figure 6)

1. Remove voltage regulator (LM 320MP) and 1-microfarad capacitor as indicated.
2. Add wire jumper between terminals 1 and 2 – previously occupied by the regulator; this connects pin 40 (V_{CC}) of SC/MP to +5-volts.

V_{SS} Changes (figure 6)

1. Cut trace from pin 20 of SC/MP to +5-volts as shown.
2. Add jumper from pin 20 to ground as shown.

ENIN/NHOLD/CONT Changes (figure 7)

1. Add jumper wires from pins 6 and 8 of SC/MP chip to pin 40 (+5-volts) as shown.
2. Add jumper wire from pin 3 of SC/MP chip to ground as shown.

Crystal and Crystal-Component Changes (figures 6 and 7)

1. Cut trace as shown in figure 7; add capacitor and two resistors as indicated – insulate each lead of capacitor with plastic tubing.
2. Refer to figure 6; remove 1-megahertz crystal for P-channel SC/MP and replace with 2-megahertz crystal for SC/MP-II.

Address Pullups (figure 7)

1. Position resistor array (RA15–10KN) between the MM5214 (ROM) pins on the solder side of PC board.
2. Solder wire between pin 12 of MM5214 and pin 16 of RA15–10KN.
3. In turn, solder a wire between each address pin of the MM5214 and a resistor in the array as shown.

Chip Change – Replacing SC/MP with SC/MP-II (figure 6)

CAUTION

Before replacing SC/MP with SC/MP-II, make certain the "V_{CC}" and "V_{SS}" changes are complete. If the chips are interchanged, and power is applied before these changes are made, SC/MP-II *will be permanently damaged.*

1. Carefully remove SC/MP chip from its 40-pin socket.
2. Replace with SC/MP-II microprocessor chip.

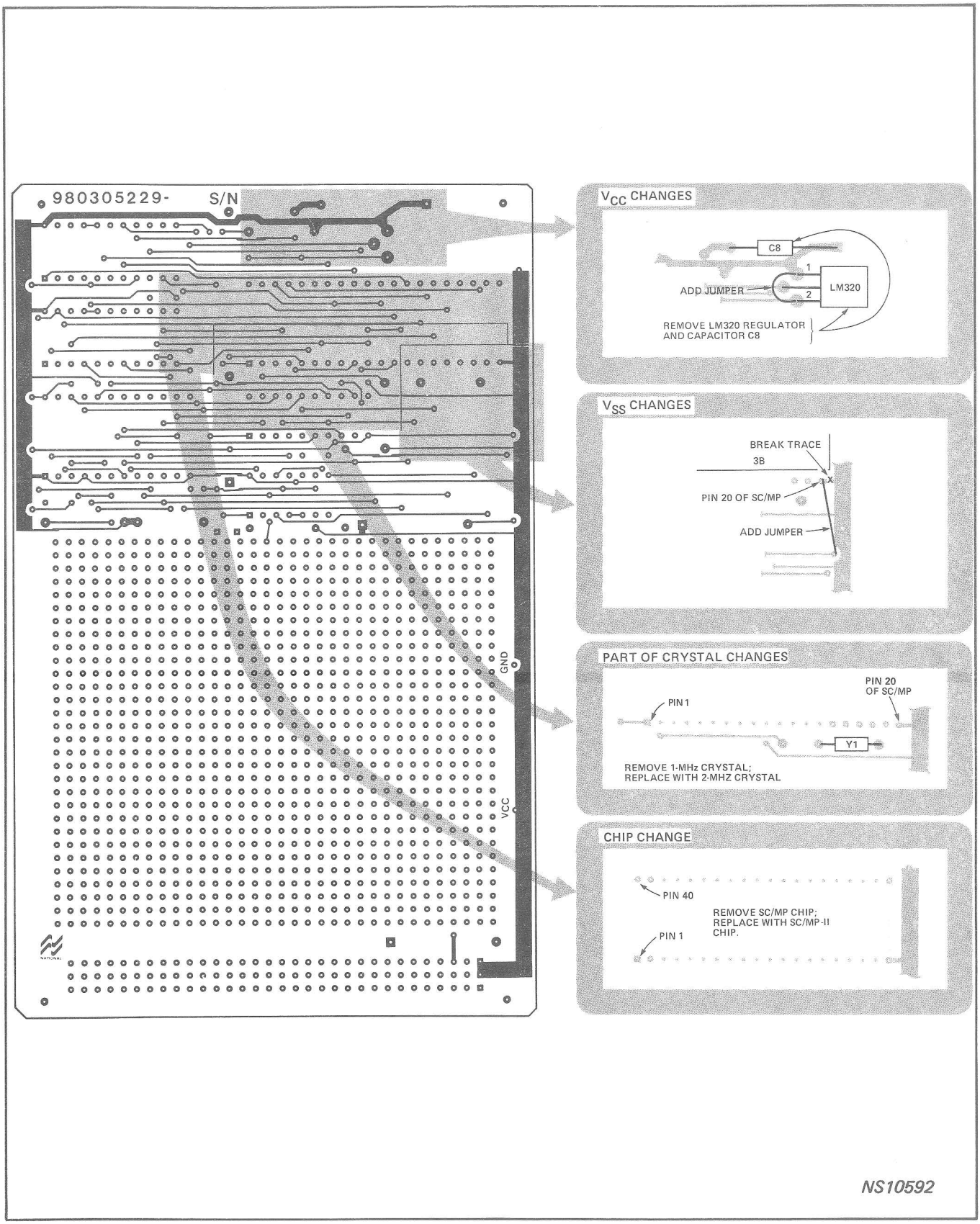


Figure 6. Retrofitting Component Side of PC Board #551305229-001A for SC/MP-II Microprocessor Chip

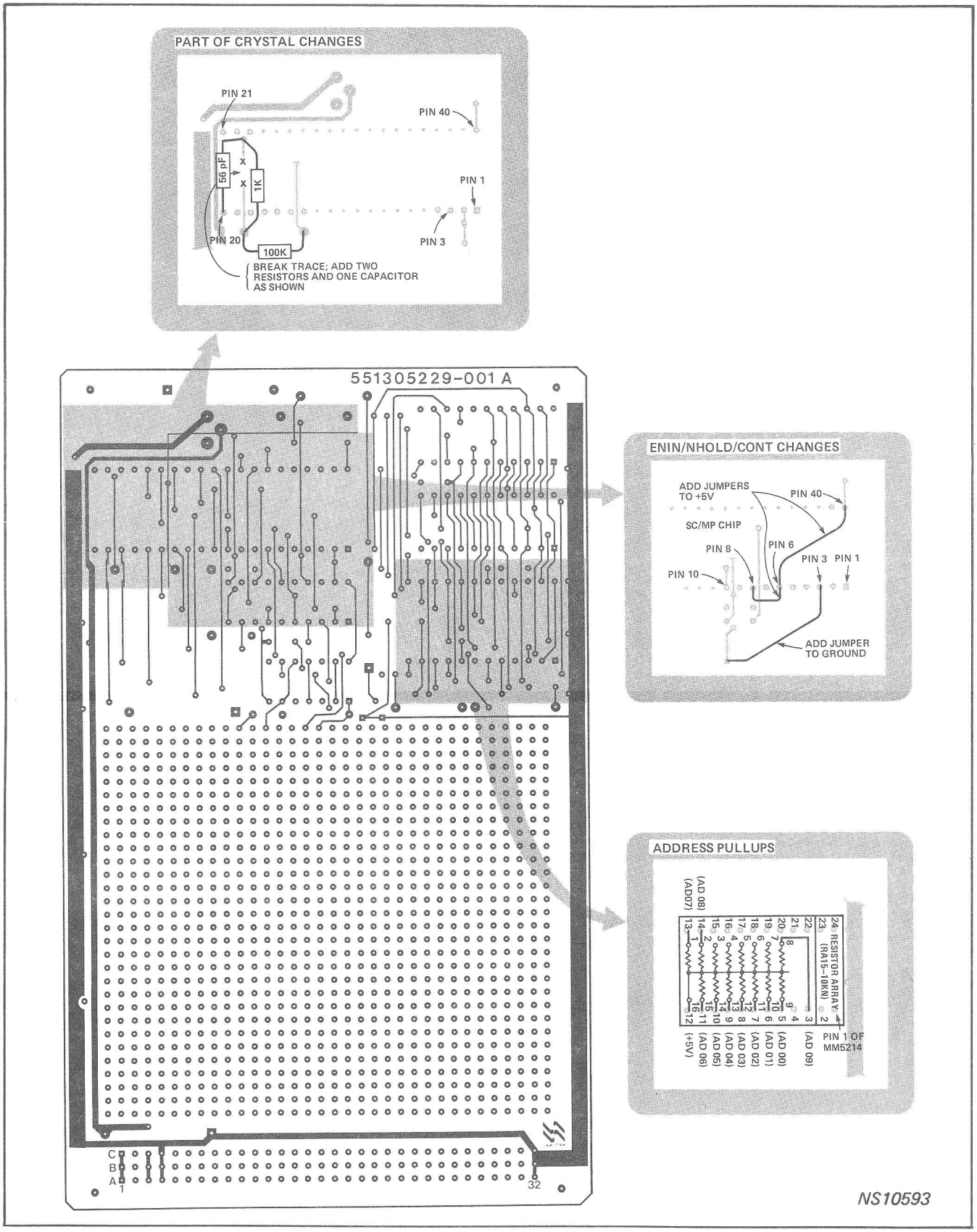


Figure 7. Retrofitting Solder Side of PC Board #551305229-001A for SC/MP-II Microprocessor Chip

5.4 VERIFICATION AND CHECKOUT

Once the preceding changes are completed, the retrofitted PC board should agree with the layouts shown in figures 8 and 9; the chip schematic should agree with that shown in figure 5.

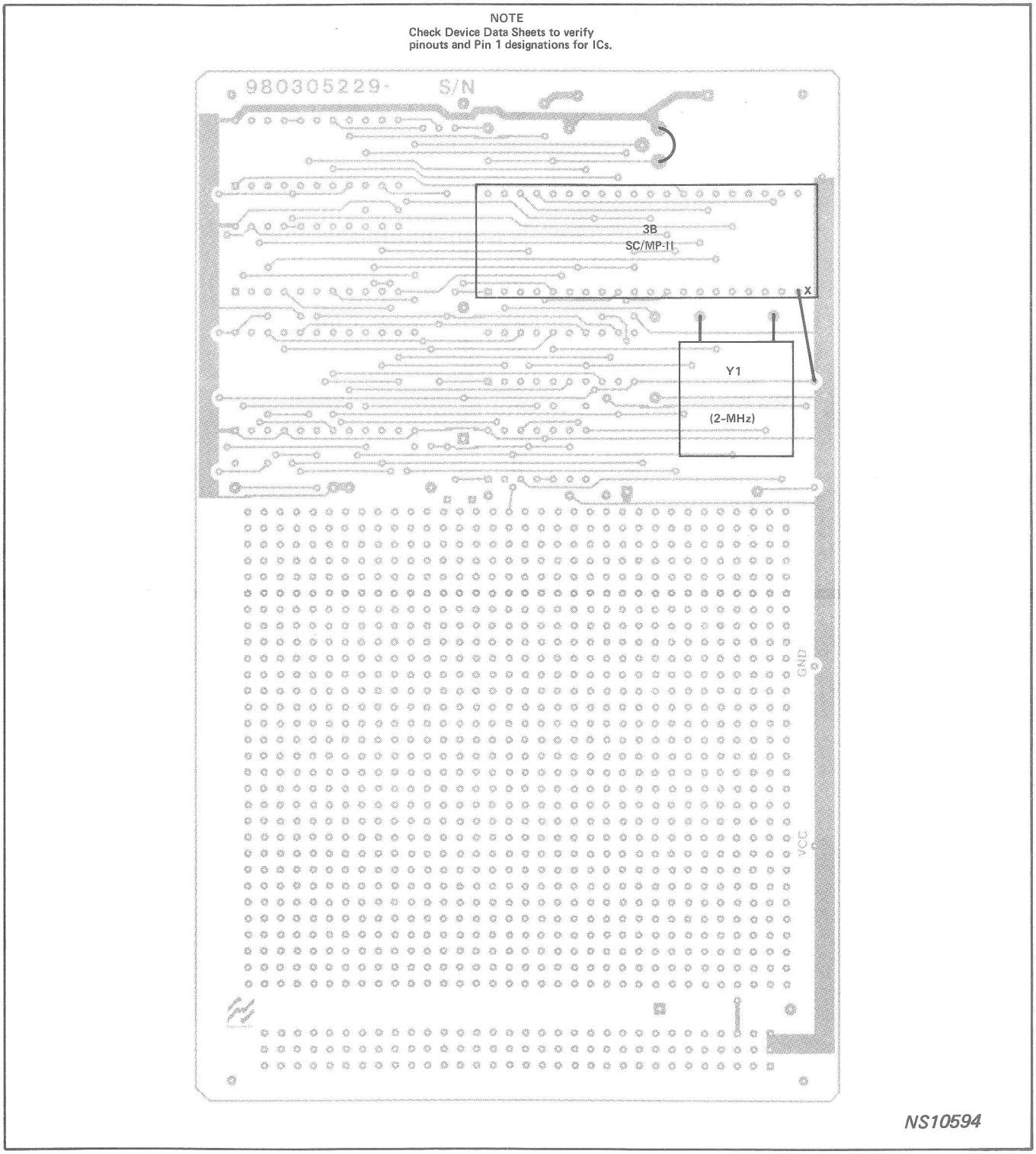
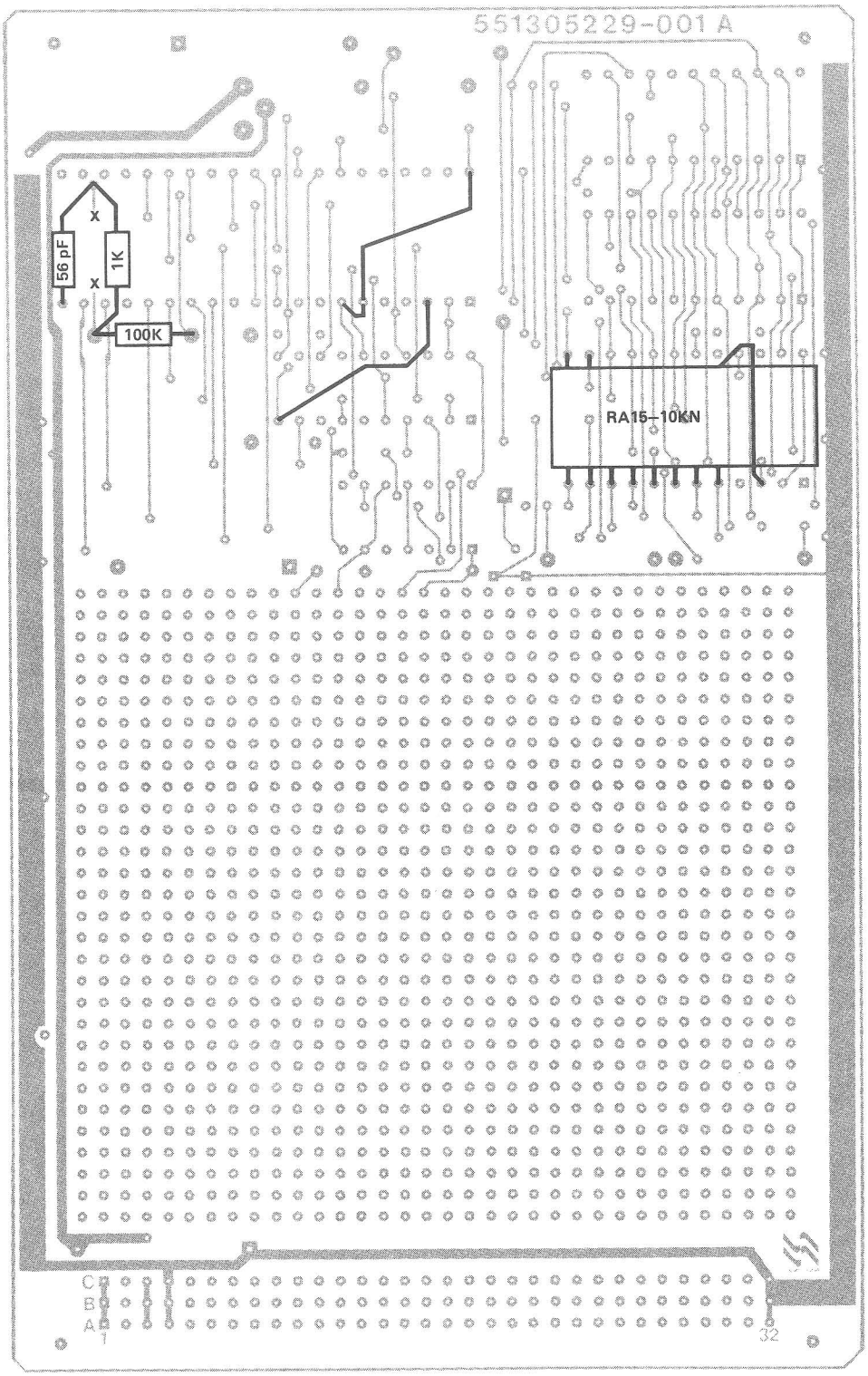


Figure 8. Component Side of PC Board #551305229-001A Retrofitted for SC/MP-II Microprocessor Chip



NS10595

Figure 9. Solder Side of PC Board #551305229-001A Retrofitted for SC/MP-II Microprocessor Chip

6.0 OPERATION AT HIGHER SPEEDS

Once the SC/MP Kit or the SC/MP INTROKIT is modified to use the SC/MP-II CPU, the user can, if desired, take advantage of higher operating speeds. To realize maximum operational speed (twice the operating frequency of SC/MP), a 4-megahertz crystal is used – see figure 10. Except for the new crystal and the 27-picofarad capacitor, all components in figure 10 are identical to those shown in figure 5.

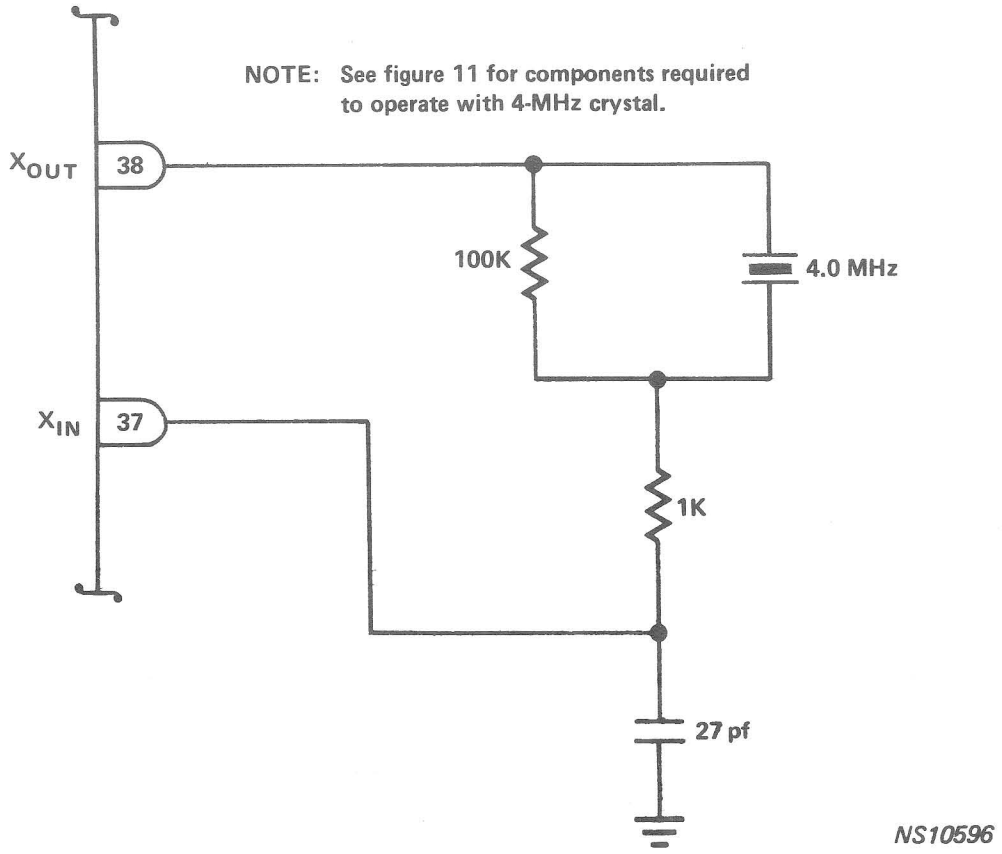


Figure 10. Using 4.0-MHz Crystal to Double Operating Speed of SC/MP-II

When the operating speed of SC/MP-II is doubled, an extended input/output cycle is required for proper memory interface and KITBUG must be appropriately modified to provide adequate control for serial communication with the teletype peripheral. The KITBUG program is stored in a 512-by-8 bit ROM (MM5214) in which the programmed data cannot be altered. However, a programmable read only memory device (MM5204 PROM) that is pin compatible with the MM5214 ROM can be used; the program modifications required for maximum operating speed (as shown in figure 10) can be made using an appropriate PROM programmer. The user must have the means for programming his PROM himself; National Semiconductor does not provide this service for this particular application. *(Note: Pins 1, 2, 4, and 24 are not used in the MM5214 (ROM); however, they are used in the MM5204 and must be connected, respectively, to +5V (V_{BB}), 0V(Power Saver), +5V (Program), and 0V (V_{LL}) for proper operation of the PROM.)*

6.1 MEMORY INTERFACE

When SC/MP-II is operated with a 4-megahertz crystal (T_X = 250 nanoseconds), the circuit shown in figure 11 can be used to extend the input/output cycle for operation with standard MM2101 memories – see SC/MP-II data sheet. By programming the eight parallel inputs of the DM74165, the input/output cycle can be extended to $3T_C/2$ (750 nanoseconds). (*Note: When the cycle is extended by this amount, the execution time of each instruction is increased by* $2T_C$ *times the number of input/output cycles required by a particular instruction.*)

6.2 SOFTWARE MODIFICATIONS

The program execution time in most microprocessors can be established by the number of microcycles it takes to execute the sequence of instructions in the program. The number of microcycles usually varies from instruction to instruction, and, to a large extent, the number depends on the internal architecture of the processor and the microprogram. The length of the microcycle is determined by the number of clock cycles required by each microinstruction; therefore, execution time of the processor is affected directly by the clock frequency. Accordingly, any program that establishes time loops based on a fixed baud (such as in Teletype communication) and on a given CPU speed must be altered when the CPU speed is changed. If the program were not tied to specific input/output data rates of peripherals and there were no interface timing considerations, the program would not need to be altered – even though the CPU speed were changed.

Since KITBUG software is designed for Teletype communication at a fixed CPU speed of 2 microseconds per microcycle and 110 baud, doubling the CPU speed (operating SC/MP-II with 4.0-megahertz crystal) requires changes in the KITBUG program. Also, extending the input/output cycle as shown in figure 11 increases the instruction execution time. Changing the contents of the accumulator and respecifying the displacement value with a "delay instruction" can provide delays of 13 to 131,593 microcycles. With a 4.0-megahertz crystal, 1 microcycle is executed in 1 microsecond – as contrasted with a 2-microsecond microcycle with a 2.0-megahertz crystal. Thus, KITBUG *must be altered by the user if the 4-megahertz crystal is used.* This means that the user must have the capability for doing this.

The following changes to the contents of the appropriate address locations modify KITBUG so SC/MP-II may be used with a 4.0-megahertz crystal. (Refer to the KITBUG listing in appendix B of either the SC/MP Kit or INTROKIT Users Manual.)

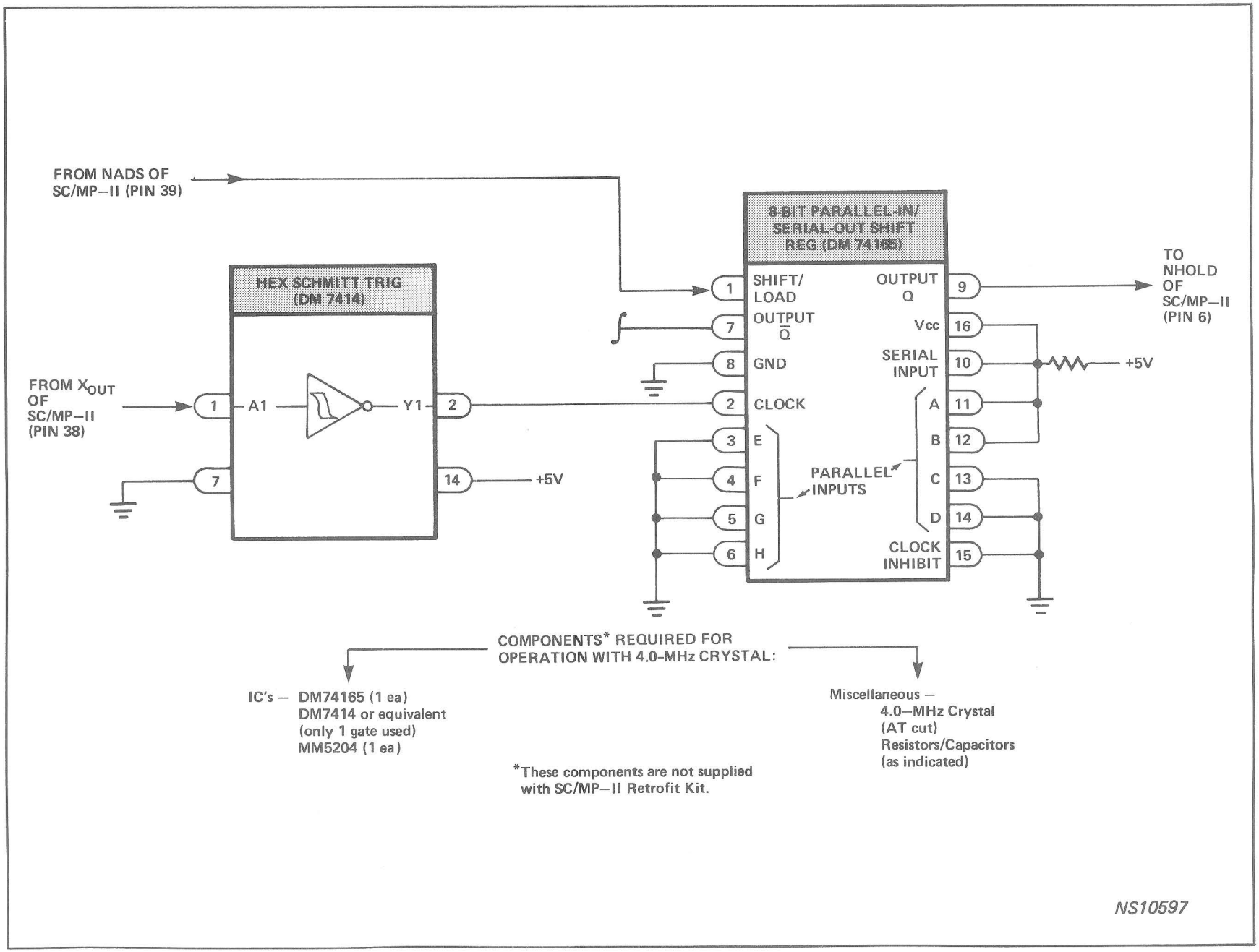


Figure 11. Extending Memory Input/Output Cycle of SC/MP-II CPU

Program Line Number	Address Location	Old Contents	New Contents	Comments
338	0190	57 (LDI)	B5 (LDI)	Change displacement value of Accumulator
339	0192	04 (DLY)	08 (DLY)	Change delay
346	019D	7E (LDI)	45 (LDI)	Change displacement value of Accumulator
347	019F	08 (DLY)	11 (DLY)	Change delay
366	01BC	08 (DLY)	11 (DLY)	Change delay
382	01C9	17 (DLY)	2E (DLY)	Change delay
388*	01D3	8A (LDI)	54 (LDI)	Change displacement value of Accumulator
389*	01D5	08 (DLY)	11 (DLY)	Change delay

*For changes to these locations, see calculations in following example.

For an example, the calculations for determining the delay time required for altering KITBUG lines 388 and 389 of the KITBUG listing (appendix B of either the SC/MP Kit or the SC/MP INTROKIT Users Manual) are given. Starting with the constant of 110 baud (as required for communicating with the Teletype), the transfer time for 1 bit is 9.09 milliseconds (1000 ÷ 110) or 9090 microseconds. The total delay time in microcycles using the 2.0-megahertz crystal is

9090 microseconds ÷ 2 microseconds/microcycle = 4545 microcycles

The execution time for all other instructions in the delay loop (between lines 388 and 402) is 144 microcycles. Thus, the DLY instruction execution is

4545 microcycles – 144 microcycles = 4401 microcycles

The total delay time using a 4.0-megahertz crystal (based on the 110 baud, resulting in a bit transfer time of 9090 microseconds) is calculated as follows:

Execution time for other instructions	= 144 microcycles
Execution time due to input/output extensions	= 28 microcycles
Total execution time other than DLY	= 172 microcycles

Execution time for DLY = 9090 – 172 = 8918 microcycles

The delay of 8912 microcycles may be achieved by the combination of changes where the accumulator contents (line 388) is changed to X'54 and the displacement value (line 389) of the DLY instruction, to X'11 – refer to preceding table.

Refer to appendix E of the SC/MP Applications Handbook for additional information on implementing program delays.

7.0 INTERFACING SC/MP RETROFIT KIT WITH SC/MP KEYBOARD KIT

If, instead of a Teletype, the SC/MP Keyboard Kit is used for an input/output peripheral, some additional minor changes are required for proper interface with the SC/MP-II Retrofit Kit. Referring to figure 2-1 in the SC/MP Keyboard Kit Users Manual, note that the keyboard matrix is decoded by selecting one of four columns and then looking at each key in the column. Thus, only four of the SC/MP data lines (DB 4–DB 7) are used to decode the matrix. Since each of the other four data lines (DB 0–DB 3) have an on-chip pullup, these data lines will assume a 'logic 1' value. Using SC/MP-II, these pullups are not required for conventional N-channel interfacing; however they must be added to avoid having to change ROM for the SC/MP Keyboard Kit. The pullup resistors are readily available from those not used on the RA15–10KN; figure 12 shows how the pullup resistors can be added.

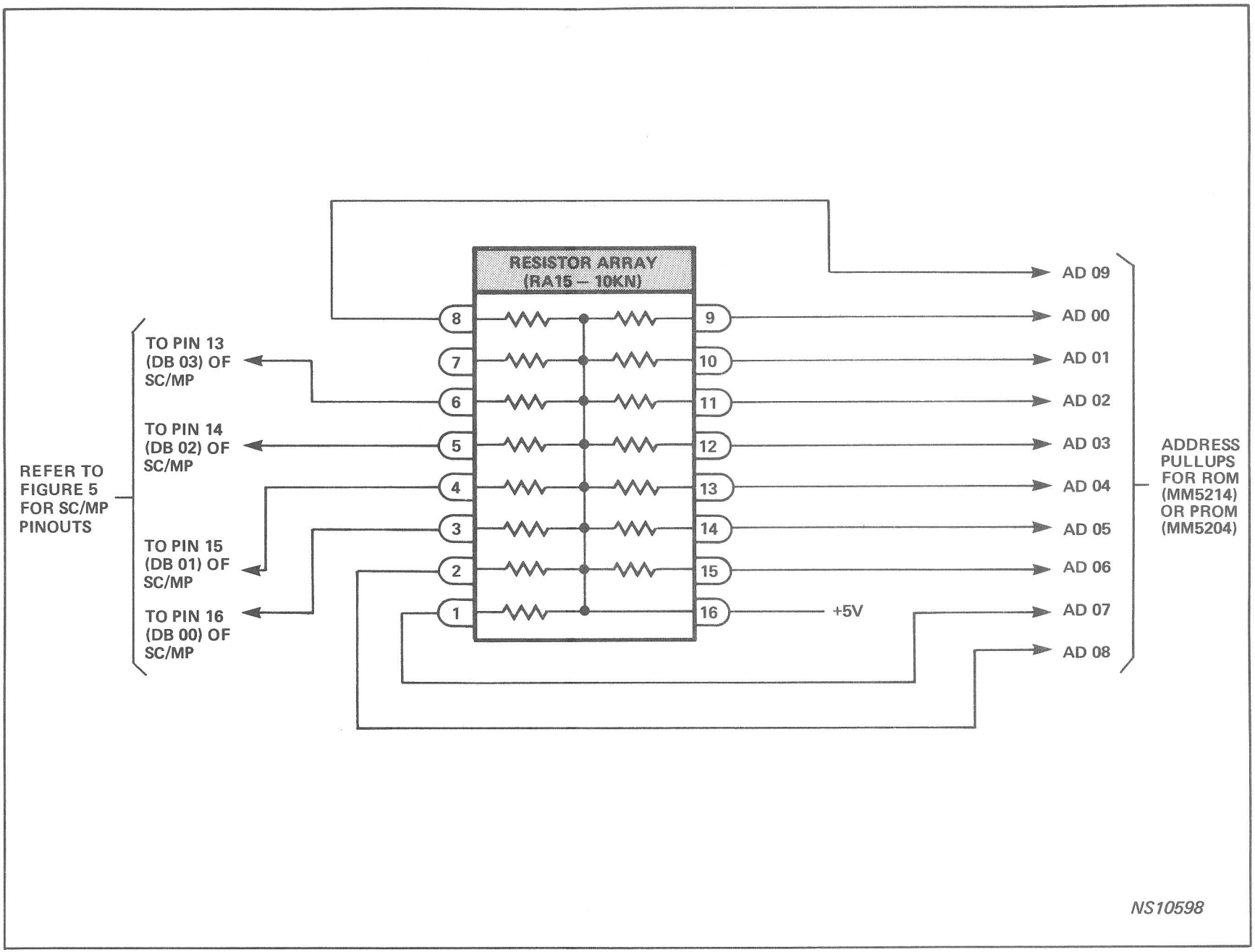


Figure 12. Interfacing SC/MP Retrofit Kit with SC/MP Keyboard Kit

National Semiconductor Corporation
2900 Semiconductor Drive
Santa Clara, California 95051
(408) 737-5000
TWX: 910-339-9240

National Semiconductor GmbH
808 Fuerstenfeldbruck
Industriestrasse 10
West Germany
Telephone: (08141) 1371
Telex: 05-27649

NS Electronics (HK) Ltd.
4 Hing Yip Street, 11th Floor
Kwun Tong
Kowloon, Hong Kong
Telephone: 3-411241-8
Telex: 73866 NSE HK HX

NS International Inc.
Miyake Bldg. 6F, 1-9 Yotsuya
Shinjuku-Ku
Tokyo 160, Japan
Telephone: 03-355-3711
Telex: J28592

NS Electronics Pty. Ltd.
CNR-Stud Road & Mountain Highway
Bayswater, Victoria 3153, Australia
Telephone: 03-729-6333
Telex: 32096

Publication No. 420305365-001A