

BRIEF COMMUNICATION

# An Inexpensive Rotary Infusion Pump for Delivering Microliter Volumes of Fluids to Animal Subjects

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KASHINSKY, W. M., L. W. ROZBORIL, S. R. ROBINSON AND W. P. SMOTHERMAN. *An inexpensive rotary infusion pump for delivering microliter volumes of fluids to animal subjects.* *PHYSIOL BEHAV* 47(6) 1279-1281, 1990.—The study of chemosensory responsiveness in developing animals often involves experimental designs in which fluid stimuli are infused into the mouth of the subject. In this report we describe an inexpensive alternative to commercially available syringe pumps for automatically delivering intraoral infusions on a programmed schedule.

Infusion pump    Sensory development    Fluid stimuli    Intraoral cannulation

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EXPERIMENTS that probe the sensory responsiveness of fetal and neonatal animals often employ paradigms that involve intraoral infusion of chemosensory solutions in microliter amounts. The typical technology for delivering these solutions involves the use of relatively expensive automated infusion pumps, which typically employ standard disposable syringes. As an inexpensive alternative to the use of infusion pumps, we have employed a manually operated micrometer syringe (Gilmont Instruments Incorporated, Gilmont, CA), which permits delivery of a test solution with precise control over the time of infusion and the volume delivered. This kind of syringe comes in two sizes (0.2 or 2.0 ml capacity) and is described by the manufacturer as having accuracy of delivery of  $\pm 0.5\%$ . In this report we describe an inexpensive device for automatically delivering infusions on a programmed schedule from a micrometer syringe.

#### DESCRIPTION OF UNIT

The pump was designed with a stepper motor to produce a rotary motion to drive the micrometer syringe, which employs a screw mechanism to deliver an infusion. The stepper is a 12 VDC, 0.5 A per phase, 1.8° per step motor. The torque value of a motor of this type is sufficient to infuse chemosensory fluids with viscosity approximately that of water. The shaft of the motor is

connected through a flexible coupler to a variable length spring-tension coupler, which is secured to the ribbed knob on the end of the syringe with a thumbscrew adapter. The flexible coupler permits easy removal of the syringe from the clamp that anchors it. As the syringe is turned, its total length decreases, necessitating the use of the variable length coupler. This coupler is constructed from an inner shaft and an outer sleeve joined by a guide pin that travels within a slot. The length of the slot provides a fail-safe mechanism limiting the maximum travel of the syringe and protecting it from being overdriven (Fig. 1).

The reliability of this system in driving the syringe is due to the use of the stepper motor. The motor is controlled by SAA1027 controller chip or equivalent with appropriate circuits to provide buffering and level shifting. The result is that a single pulse transmitted from an external source steps the motor once, turning the shaft through  $\frac{1}{200}$  of a complete rotation (1.8°). With the motor coupled to a 2.0-ml micrometer syringe, each pulse results in an infusion of 0.5  $\mu$ l of the test solution. The external pulses can be generated by a microcomputer that is ultimately responsible for controlling the rate, volume and schedule of infusions during an experiment. However, the addition of a relatively simple timer circuit to the pump would provide an internal source for control pulses and created a stand-alone unit. In our laboratory, the

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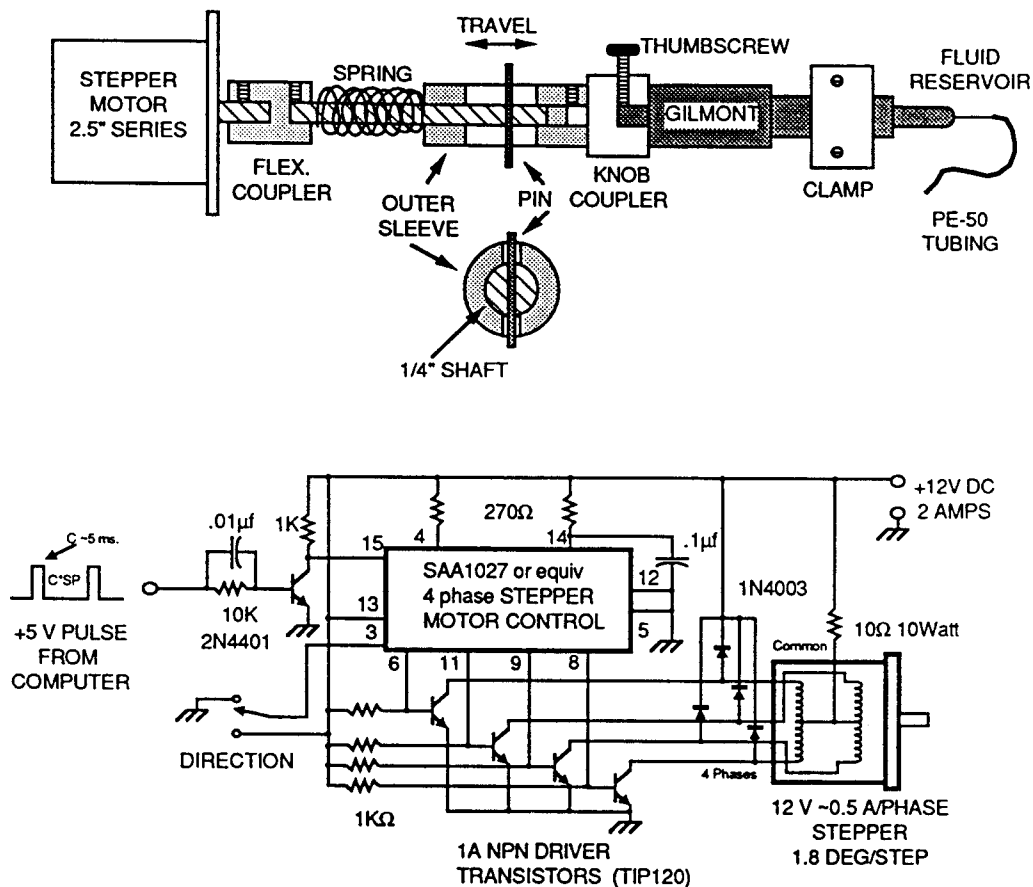


FIG. 1. Schematic diagram of micrometer syringe, rotary infusion pump and circuit for controlling the stepper motor. The diagram is drawn only approximately to scale; the Gilmont syringe is about 12 cm long.

infusion pump is connected to an Apple II series microcomputer through the game port. The game port is provided with annunciator outputs, one of which can be turned on and off (producing a pulse to the controller chip) with a pair of POKE commands imbedded in a simple BASIC subroutine (Table 1, line 500). The pulse comes from AN0 at address -16295 (on) and -16296 (off). Because this system provides a simple means of controlling the pump, a single computer can be used to drive multiple pumps, each with a unique schedule of fluid delivery.

Delivery of the test solution to an animal subject is accomplished by attaching a blunted 23-ga needle to the tip of the micrometer syringe and slipping a length of PE-50 polyethylene tubing over the tip of the needle. The inner diameter of the PE-50 tubing accommodates insertion of a narrower cannula fashioned from PE-10 tubing. The cannula may be installed in the jaw or cheek of the animal subject (2,6).

#### APPLICATION

This infusion system was designed and programmed to automate experiments involving repeated delivery of a fixed volume of a test solution through a cannula into the mouth of a rat fetus or neonate (4,5). Infusion of test stimuli through an intraoral cannula is a technique that is widely employed in the experimental study of sensory development and learning in fetal and neonatal rodents

[e.g., (1,4)]. Automation of protocols involving intraoral infusion can reduce the number of persons required for the conduct of experiments and promote the use of experimental designs involving blind observers.

As a specific example, we have adapted this infusion pump to facilitate experiments on habituation to a repeated chemosensory stimulus in the fetal rat (3). Intraoral infusions (10 or 20  $\mu$ l) are scheduled to occur at regular intervals during an exposure phase (e.g., nine infusions at 60-sec intervals), followed by a delay phase (e.g., 6 min) during which no infusions occur and a test phase (e.g., 1 min) that commences with a single infusion. The algorithm listed in Table 1 presents one method for programming the activation of the infusion pump to deliver infusions on this schedule.

#### COST

The cost for a rotary infusion pump of this design comes from the principle components of the stepper motor (about \$50) and the Gilmont micrometer syringe (about \$60). The remaining electronic and mechanical components total less than \$150.

#### DISCUSSION

The advantage of the infusion system described in this report

TABLE 1  
ALGORITHM FOR DELIVERING INFUSIONS ON A  
PROGRAMMED SCHEDULE

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BEGIN PROGRAM
CLEAR SCREEN
INPUT "INFUSION VOLUME CONSTANT"; UL : REM - e.g., 10 = MULTIPLE OF 10 µl
INPUT "NUMBER OF SECONDS PER BLOCK"; NS : REM - e.g., 15 = 15-s BLOCKS
INPUT "PRESS RETURN TO START EXPERIMENT"; Z$
READ P$ : REM - READ PROTOCOL FROM DATA STATEMENT (LINE 900)
I = 1 : REM - INITIALIZE INSTRUCTION COUNTER
RESET TIMER TO 0 sec

100 BS = MID$(P$,I,1) : REM - READ DIGIT FOR NEXT BLOCK FROM PROTOCOL
IF I > LEN(BS) THEN STOP : REM - STOP AFTER LAST DIGIT IN PROTOCOL
FLAG = 0

200 READ TIME
IF FLAG = 0 THEN GOSUB 400 : REM - EXECUTE NEW-BLOCK SUBROUTINE
FLAG = FLAG + 1
IF TIME < NS THEN GOTO 200 : REM - LOOP TO CHECK TIME
RESET TIMER TO 0 sec : REM - BEGINNING OF NEXT BLOCK
I = I + 1
GOTO 100 : REM - LOOP TO EXECUTE NEXT INSTRUCTION

400 REM - SUBROUTINE TO DO THINGS AT BEGINNING OF BLOCK
IF BS = "0" THEN RETURN : REM - DO NOTHING
IF BS = "0" THEN GOSUB 500 : REM - EXECUTE INFUSION SUBROUTINE
RETURN FROM BLOCK ROUTINE

500 REM - SUBROUTINE TO STEP INFUSION PUMP
C=100 : REM - DELAY CONSTANT FOR APPROXIMATE 5 ms PULSE
SP=10 : REM - DETERMINES RATE OF INFUSION
FOR I = 1 TO UL*2 VAL(BS) : REM UL*2 DIGIT = µl PER PULSE
POKE -16295,0 : REM - OUTPUT ON
FOR J = 1 TO C : NEXT J : REM - DELAY LOOP FOR PULSE
POKE -16295,0 : REM - OUTPUT OFF, THUS A PULSE
FOR J = 1 TO C*SP : NEXT J : REM - DELAY LOOP FOR PULSE
AND INFUSION RATE

NEXT I
RETURN FROM STEP ROUTINE

900 DATA 0000 1111 1111 1000 0000 0000 0000 0000 0000 2000
REM - EACH DIGIT, MULTIPLIED BY UL, DETERMINES THE VOLUME PER BLOCK
    
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stems from its cost and flexibility for use in different experimental settings. The total cost of this system is approximately 10% or less of the cost of commercially available conventional syringe pumps of comparable accuracy. The flexibility of this system is due to the use of a general purpose microcomputer, which is likely to be available in all modern laboratory environments, to control the schedule and volume of infusions delivered by the rotary pump. Modification of the schedule requires rewriting just one line in the program (the DATA statement in Table 1); variation of infusion volume similarly requires change of just one variable (UL). Moreover, the program shell described here may be simply augmented to provide control over variable intervals between successive infusions and variable volumes of infusion both within and between experiments. Thus, this automated system should be generally useful in research programs employing intraoral infusion of small volumes of chemosensory fluids to animal subjects. However, owing to the simplicity of design and lack of redundancy in control, we would recommend against use of this device with human subjects.

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