DS1227

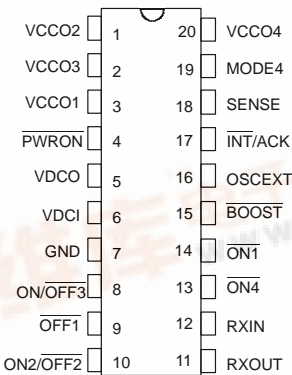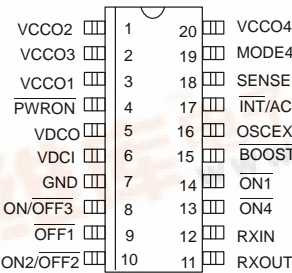# DALLAS
SEMICONDUCTOR

DS1227
KickStarter Chip

FEATURES

- Provides step-up regulation and microenergy management for battery-operated systems
- Converts +3V to +6V DC input power source to +5V DC out for system power
- "Kickstarts" system power upon detection of external stimuli:
    - Clock/calendar alarm
    - Sensor trip; such as from a photo diode
    - Incoming activity to a serial port
    - Any low-level signal transition
- Shuts down microcontroller power under software control when operation complete
- Provides 3 auxiliary power outputs for independent powering of system functions
- Allows design of "power on demand" systems
- Insures maximum life of main power source
- Ideally suited for DS5000-based systems
- Available in 20-pin DIP or SOIC packages
- Operating temperature range of −40°C to +85°C

PIN ASSIGNMENT

VCCO2	1	20 VCCO4
VCCO3	2	19 MODE4
VCCO1	3	18 SENSE
$\overline{PWRON}$	4	17 $\overline{INT/ACK}$
VDCO	5	16 OSCEXT
VDCI	6	15 $\overline{BOOST}$
GND	7	14 $\overline{ON1}$
ON/$\overline{OFF3}$	8	13 $\overline{ON4}$
$\overline{OFF1}$	9	12 RXIN
ON2/$\overline{OFF2}$	10	11 RXOUT

20-Pin DIP (300 Mil)
See Mech. Drawing - Sect. 16, Pg. 1

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20-Pin SOIC (300 Mil)
See Mech. Drawing - Sect. 16, Pg. 6

ORDERING INFORMATION
DS1227:   20-Pin DIP
DS1227S: 20-Pin SOIC

DESCRIPTION

The DS1227 Kickstarter is a unique CMOS circuit which combines power conversion and microenergy management functions for battery operated systems. Using its integral DC-DC converter, the DS1227 supplies +5V on demand from either a 3– or 6–volt battery input. The primary +5V output, typically tied to the microcontroller's V_{CC} pin, is "kickstarted" on in response to any one of several possible momentary, external signal transitions. Two auxiliary +5V power supply outputs can then be independently enabled or disabled under software control. When the primary power supply output is disabled, also under software control, the auxiliary power supply outputs remain in the state selected. In this manner, individual portions of the system can be powered only

when they are required, minimizing the energy consumption of the system.

The Kickstarter activates or kickstarts the primary V_{CC} output in response to external momentary low-going signals. Examples of such signals include a clock/calendar alarm from a DS1283 Watchdog Timekeeper, or an incoming asynchronous serial data word from a host PC via the DS1275 Line Powered Transceiver, or a simple pushbutton switch.

In addition, the DS1227 kickstarts primary system power in response to activity detected by an external sensor circuit. In this case, the Kickstarter can be signalled at regular intervals, typically from a DS1283 Watchdog Timekeeper, to momentarily apply power to the sensor and monitor an input for an active response.

An application using the Kickstarter has the capability to wake-up from an ultra-low power state, perform a task using minimum energy, and then go back to sleep until the DS1227 is signalled to kickstart system operation once again.

PIN DESCRIPTION

PIN	I/O	DESCRIPTION
$\overline{BOOST}$	Input	Regulation mode control.
V_{DCO}	Output	Main DC supply voltage output.
V_{DCI}	Input	Main DC supply voltage input.
GND	-	System ground.
V_{CCO1}	Output	Primary switched supply voltage output.
$\overline{ON1}$	Input	On control for V_{CCO1}. $\overline{ON1}$ is negative edge triggered and internally pulled high via a weak resistor.
$\overline{INT}$/ACK	Input/Output	Interrupt output/input; internally pulled low via a weak resistor during output; level activated via strong high voltage for input.
$\overline{OFF1}$	Input	Off control for V_{CCO1}; edge-triggered active low.
$\overline{PWRON1}$	Output	V_{CCO1} Power On signal output; Indicates when V_{CCO1} is powered on; Sometimes required for controlling external tri-state buffers in systems where micro-energy management techniques are employed.
V_{CCO2}	Output	Auxiliary switched supply voltage outputs.
ON2/$\overline{OFF2}$	Input	On/Off controls for V_{CCO2}/V_{CCO3}; level activated.
ON3/$\overline{OFF3}$	Input	
V_{CCO4}	Output	Momentarily switched VCC output.
$\overline{ON4}$	Input	V_{CCO4} trigger; edge activated; active low.
SENSE	Input	Sense input sampled just prior to V_{CCO4} off; turns on V_{CCO1} if active; active high.
MODE4	Input/Output	Selects V_{CCO4} on time; level sensitive input/current source output.
RXIN	Input	Serial I/O input; On control for V_{CCO1} when serial activity detected; edge activated.
RXOUT	Output	Serial I/O output; Echos incoming serial data from RXIN when V_{CCO1} is turned on.
OSCEXT	Output	Oscillator Signal Output; Gated by internal comparator when $\overline{BOOST}$ is enabled. Continuous when $\overline{BOOST}$ is disabled.

INPUT SUPPLY VOLTAGE

The Kickstarter is capable of operating either in a regulated step-up DC-to-DC conversion (boost) mode or in a non-regulated supply voltage Pass-Through mode.

In boost mode, the Kickstarter is designed to provide a regulated +5V output on the V_{CCO1}, V_{CCO2}, or V_{CCO3} voltage supply output pins from a +3V lithium source. Figure 1 illustrates the standard configuration for use of this mode. The $\overline{BOOST}$ pin should be tied low in order to enable step-up DC-to-DC conversion. V_{DCI} is used for the DC power supply input and is tied through an inductor (270 µH typical) to a +3V lithium cell. V_{DCO} is the main DC output which is switched to the V_{CCO1}, V_{CCO2}, and V_{CCO3} outputs. This pin requires a large capacitor (typically 100 µF) to ground for the boost regulation low pass output network. Further details of the boost voltage regulator operation are given in the "Boost Mode Operation" section of this data sheet.

Figure 2 and Figure 3 illustrate the required configurations to select the supply voltage Pass-Through mode of operation. In both of these configurations the $\overline{BOOST}$ pin should be strapped directly to the V_{DCO} pin. This connection causes the $\overline{BOOST}$ pin to remain at a high level at all times that a battery is connected. As a result, the internal boost regulator will be disabled when kick-starting occurs. When a +5V supply is used as the input DC power source, it should be directly connected to the V_{DCO} in parallel with a filter capacitor as shown in Figure 2. The V_{DCI} input itself should be grounded in this configuration.

If a +6V supply is used, then it should be connected to the V_{DCI} pin. A filter capacitor should still be connected to V_{DCO}. The voltage on V_{DCO} and subsequently on V_{CCO1}, V_{CCO2}, and V_{CCO3} (when they are enabled following kickstarting) will be a diode drop below the V_{DCI} voltage.

In both the Boost and Pass-Through modes, the DS1227 uses the voltage on V_{DCO} as its own internal supply.

DS1227 BOOST MODE CONFIGURATION Figure 1
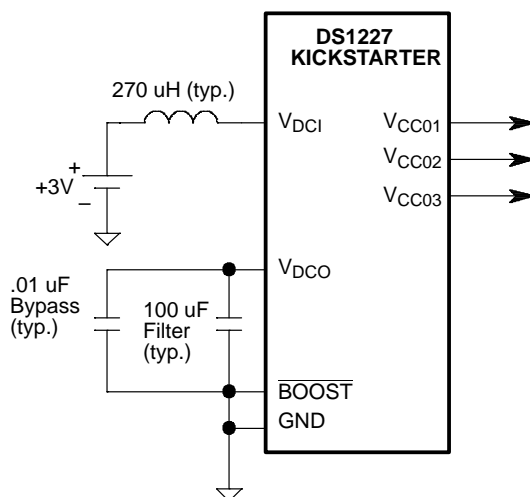
DS1227 +5V PASS-THROUGH MODE CONFIGURATION Figure 2
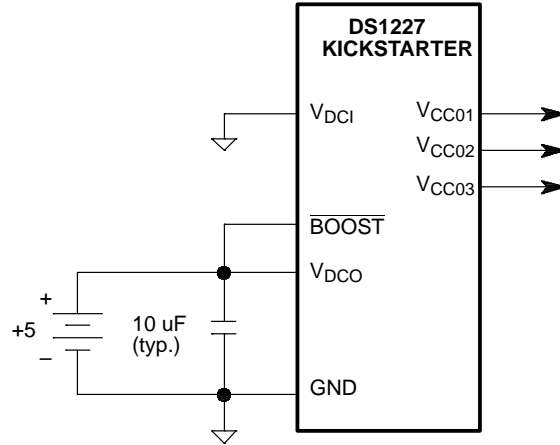
DS1227 +6V PASS-THROUGH MODE CONFIGURATION Figure 3
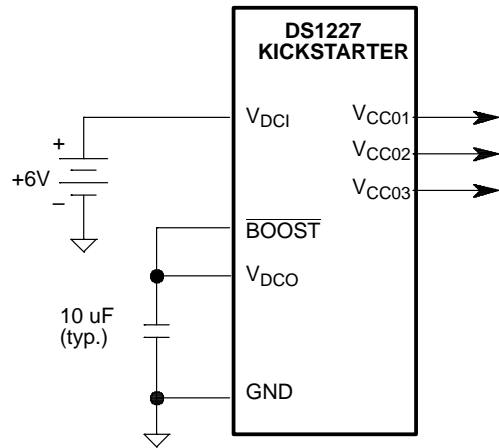
KICKSTARTER OPERATION

A conceptual block diagram of the internal circuitry of the DS1227 is illustrated in Figure 4 for reference. While in an initial power down state, the DS1227 will sense activity from an external stimulus applied to one of three input pins and kickstart system power by applying voltage from the input power source to the primary V_{CCO} output (V_{CCO1}). Activity detected on any of the $\overline{ON1}$, RXIN, and SENSE pins initiates the kickstarting action.

When kickstarting occurs and the DS1227 is configured for boost operation, the on-chip, step-up DC-to-DC converter is started and the voltage on V_{DCO} will be boosted from its initial V_{BAT} level to V_{DCON} before V_{CCO1} is turned on. If the DS1227 is configured for voltage Pass-Through operation, then the DC-to-DC converter will remain disabled and voltage on the V_{DCO} line will be switched to the V_{CCO1} pin immediately following the detection of an active transition on a stimulus input.

Initially, when V_{CCO1} is off, the $\overline{INT}$/ACK pin is collapsed to ground. At the time that voltage is switched to the V_{CCO1} output pin during kickstarting, the $\overline{INT}$/ACK pin will be latched such that it will remain in a low state. This signals the microcontroller that a power on reset has occurred. The OFF1, ON2/$\overline{OFF2}$, and ON3/$\overline{OFF3}$ inputs are all ignored until the microcontroller acknowledges this power on reset condition. This acknowledgement is performed via the same $\overline{INT}$/ACK pin, which also performs the function of an interrupt acknowledge input. This is made possible due to the fact that the pin has a weak NMOS pulldown which forms a latch. When $\overline{INT}$/ACK is externally driven with a sufficiently strong high signal (as described in the "Electrical Characteristics" section) the state of the latch will be switched and as a result the interrupt condition will be reset.

After the power on reset interrupt has been acknowledged and the DS1227 is in a power on condition, the $\overline{INT}$/ACK pin will be again taken low to signal the detection of active signalling on the $\overline{ON1}$ or SENSE inputs. Further activity on the RXIN input will not cause a subsequent interrupt condition. The $\overline{INT}$/ACK can be returned to its high (reset) state again by externally driving it with a sufficiently strong high signal.

The $\overline{OFF1}$ input is used to turn off the V_{CCO1} output under software control. It is typically interfaced to the system microcontroller via a port pin configured as an output. As noted above, it is active only when V_{CCO1} is on and $\overline{INT}$/ACK has been set high.

STIMULUS INPUTS

$\overline{ON1}$ is a simple TTL-level compatible input which is designed to detect a negative-going edge. V_{CCO1} is kickstarted whenever an active edge is detected on this pin.

The RXIN input can be used to initiate the kickstarting action in response to the detection of incoming serial data. In this configuration, the RXIN pin is interfaced to an incoming serial data line, typically from an RS232 transceiver. RXOUT is the corresponding output and is used to route the serial data to the microcontroller. RXIN remains internally disconnected from RXOUT until V_{CCO1} is powered on. At that time, the two lines are connected and serial data is passed straight through the device to the microcontroller.

The SENSE pin is intended to be connected to an external sensor circuit which is powered from V_{CCO4}. This circuit is then momentarily powered from the Kickstarter's V_{CCO4} output in response to a negative going edge applied to the $\overline{ON4}$ input. V_{CCO4} will stay powered for an amount of time determined by the circuitry on the MODE4 pin. During the time that V_{CCO4} is on, the SENSE pin has an internal pulldown device which is activated. SENSE is sampled just prior to the V_{CCO4} output being disconnected. If SENSE is externally driven high (V_{IH}) at this time, it kickstarts V_{CCO1} power. Any time that V_{CCO4} power is off, the SENSE pin appears as a high impedance to external circuitry.

The amount of time that V_{CCO4} is on is determined by the configuration of the MODE4 pin. MODE4 is intended to either be tied high (typically to V_{DCO}) or tied to an external capacitor. The V_{CCO4} on time is thereby determined either by the amount of time between falling edges on $\overline{ON4}$ or by the value of the capacitor.

If the MODE4 pin is tied high at the time that $\overline{ON4}$ is activated, then V_{CCO4} will remain on until the next falling edge is detected on $\overline{ON4}$. Figure 5 illustrates the timing associated with this mode of operation. If the Kickstarter is also configured for boost regulation and V_{CCO1}, V_{CCO2}, and V_{CCO3} are turned off, the DC-DC converter will be briefly enabled so that +5V will be supplied on V_{CCO4} for the duration of the time that it is on.

The alternative MODE4 configuration is illustrated in Figure 6A. As shown in the figure, it is recommended for most applications that a large resistor also be connected between MODE4 and ground in addition to the capacitor. For the configuration shown, the MODE4 pin will be sensed low by the Kickstarter just following the negative-going edge at $\overline{ON4}$. Following this condition, a constant current specified as I_{M4ON} is supplied out of the MODE4 pin. This will cause the voltage on MODE4 to rise linearly. V_{CCO4} will remain on until the voltage on MODE4 reaches a threshold specified as VM4OFF (approximately 0.5 V_{DCO}). At this time, V_{CCO4} will be shut off. At the same time, the constant current source on the MODE4 pin will be disconnected and an internal resistive element (specified as R_{M4DIS}) will be connected between the MODE4 pin and ground. This internal resistive element along with any external resistance will cause the voltage on the capacitor to decay exponentially until it reaches a threshold specified as V_{M4DIS} (approximately 0.1 V_{DCO}). When this condition is reached, the internal resistive element will be disconnected, and the MODE4 pin will appear as a high impedance until the next active transition occurs on $\overline{ON4}$. The external re-

sistor (if present) will then cause the voltage on MODE4 to further decay until it reaches ground or until the next $\overline{ON4}$ negative transition, whichever comes first.

When MODE4 is initially grounded as described above, V_{CCO4} power is switched from the V_{DCO} pin, regardless of whether or not V_{CCO1}, V_{CCO2}, or V_{CCO3}, are powered on. This means that V_{CCO4} will be switched with the voltage present on V_{DCO}, which could be from +3V to +5V depending on the configuration, input battery voltage used, and whether or not V_{CCO1}, V_{CCO2}, or V_{CCO3} are switched on.

The above described sampling operation of V_{CCO4} and SENSE in response to $\overline{ON4}$ also takes place when a kickstart has already occurred and V_{CCO1} is on. If SENSE is found to be active in this condition, an interrupt will be signalled on the INT/$\overline{ACK}$ pin.

MICRO ENERGY MANAGEMENT
In addition to the kickstarting features described above, the DS1227 allows sections of system circuitry to be individually powered up or down under command of the microcontroller. This capability is referred to as the Micro Energy Management feature of the DS1227.

V_{CCO2} and V_{CCO3} are auxiliary power supply outputs which may be switched on or off via the ON2/$\overline{OFF2}$ and ON3/$\overline{OFF3}$ pins, respectively. The ON2/$\overline{OFF2}$ and ON3/$\overline{OFF3}$ control pins are intended for connection to two microcontroller's port pins configured as outputs. The corresponding V_{CCO} output pins can then be turned on or off as desired under control of the system application software.

The ON2/$\overline{OFF2}$ and ON3/$\overline{OFF3}$ inputs are level activated. The corresponding V_{CCO} output therefore turns on when the on/off pin is high and off when it is low. These inputs are active only if the V_{CCO1} output is on and the $\overline{INT}$/ACK output has been set to a high state signalling a power on reset condition.

When V_{CCO2} or V_{CCO3} are turned on, they will remain on until the corresponding control input is taken low by the software. This is true even if the $\overline{OFF1}$ input is taken to its active low state at the time that either ON2/$\overline{OFF2}$, ON3/$\overline{OFF3}$, or both, are high.

Once $\overline{OFF1}$ is activated, the current states of ON2/$\overline{OFF2}$ and ON3/$\overline{OFF3}$ are internally latched and further activity on these pins is ignored. If both of the corresponding outputs (V_{CCO2} and V_{CCO3}) are turned off at this time and boost operation has been selected, then the internal oscillator is killed and the DC-to-DC converter will be shut down. If either V_{CCO2} and/or V_{CCO3} are left switched on when $\overline{OFF1}$ is activated, they will remain switched on even after V_{CCO1} has been turned off. If the DS1227 has been configured for boost operation, the DC-to-DC converter will remain operational during the entire time that V_{CCO1} is turned off so that +5 volts will continue to be supplied on either or both of these output pins. These pins can be shut off only when kickstarting occurs once again and V_{CCO1} is switched on and $\overline{INT}$/ACK has been set high.
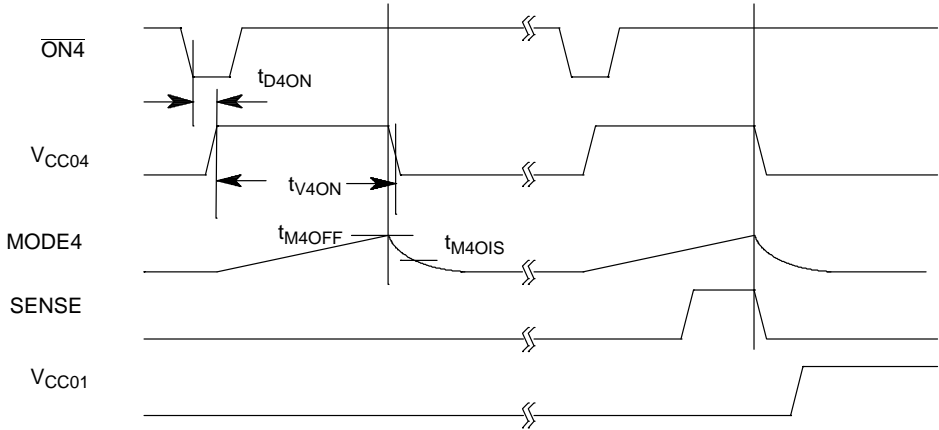
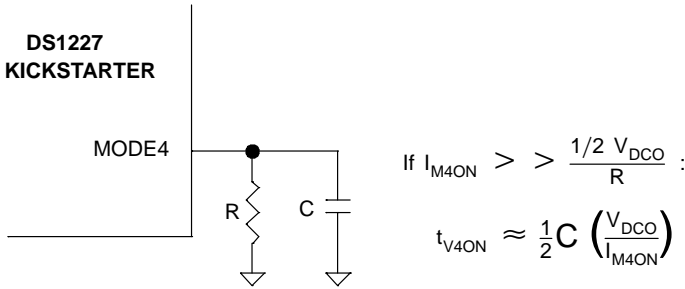**DS1227 KICKSTARTER BLOCK DIAGRAM** Figure 4
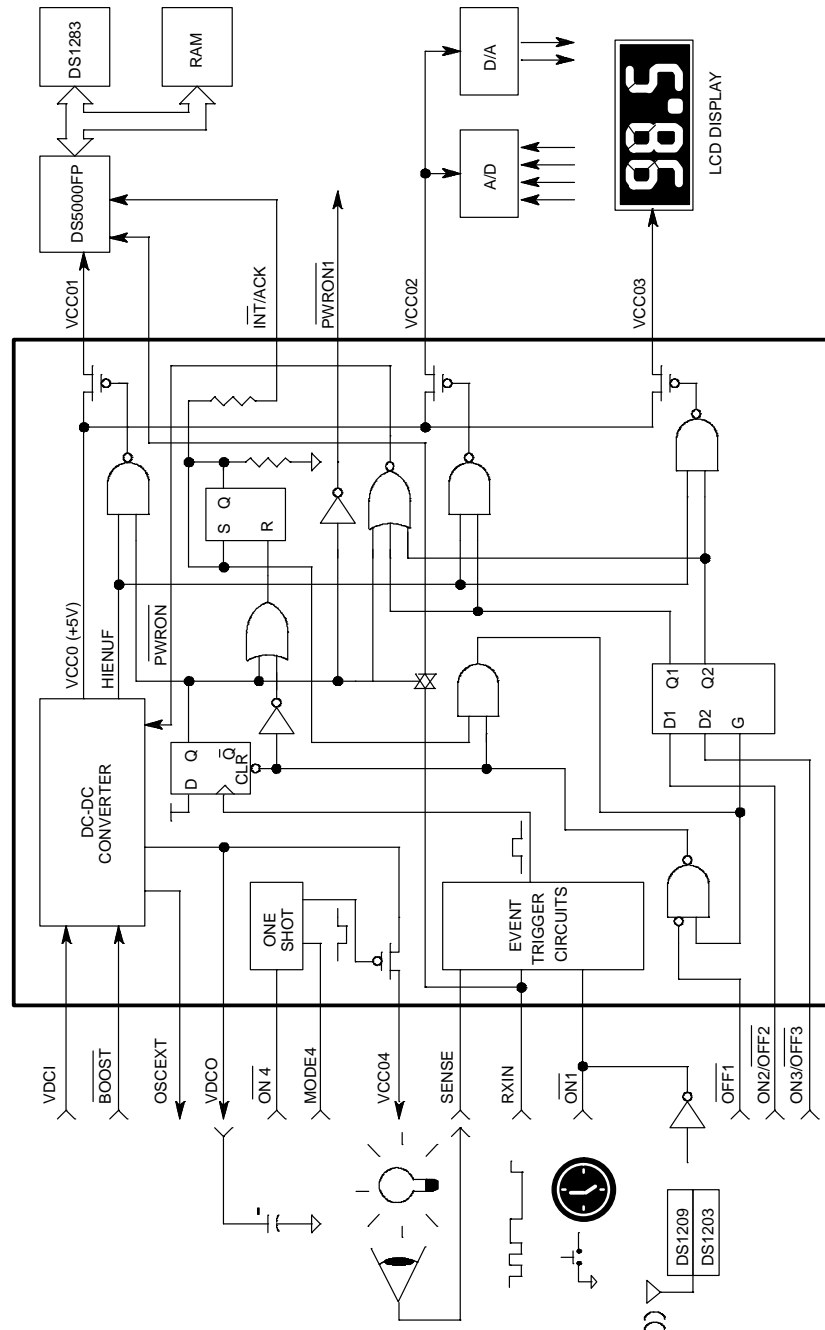
SENSE INPUT TIMING; MODE4 STRAPPED HIGH Figure 5
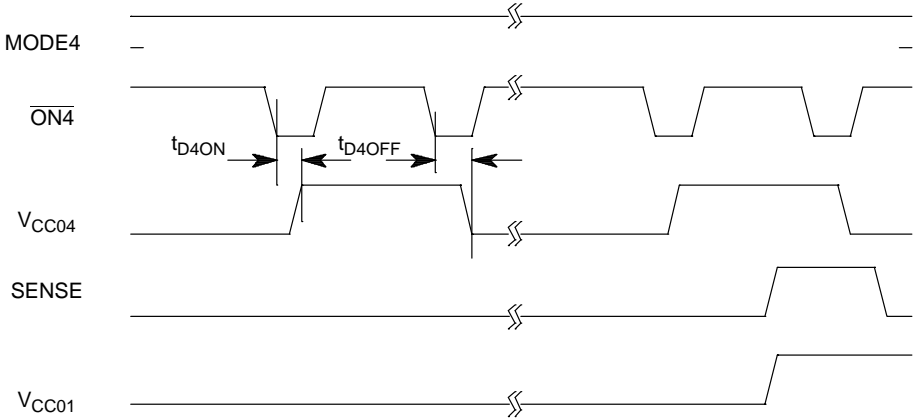
MODE4 RC NETWORK CONNECTION Figure 6A

SENSE INPUT TIMING; MODE4 WITH RC NETWORK Figure 6B

If $I_{M4ON} >> \dfrac{1/2\ V_{DCO}}{R}$:

$$t_{V4ON} \approx \frac{1}{2}C\left(\frac{V_{DCO}}{I_{M4ON}}\right)$$

BOOST MODE OPERATION

The DS1227 Kickstarter incorporates all of the necessary control and power switching functions required for its +3V to +5V step-up DC-to-DC converter. These functions include a bandgap reference, oscillator, voltage comparator, catch diode and an N-channel MOSFET. The only external components required are an output filter capacitor and a low cost inductor. The block diagram shown in Figure 7 illustrates the DC-to-DC converter.

When kickstarting occurs from an initial powered down state (i.e., V_{CCO1}, V_{CCO2}, and V_{CCO3} turned off), an internal start sequence is initiated within the DS1227. During this sequence, the V_{CCO1} output remains shut off and the $\overline{BOOST}$ pin is sampled in order to determine if the DS1227 is configured for boost mode operation. If $\overline{BOOST}$ is low, then boost mode operation is enabled and the DC-to-DC converter is started.

The internal DC-to-DC converter is started by enabling the on-chip 40 KHz oscillator. It then begins to build up the voltage on the V_{DCO} filter capacitor. Internal counter logic insures that the DC-to-DC converter stays in start mode for a minimum of six clock periods (nominally 150 µs @ 40 KHz). After this initial delay time, the V_{DCO} output is monitored by the internal Error Comparator as it slews up to V_{DCON}. As long as the V_{DCO} voltage remains below the preset value, the Error Comparator will be switched high and the internal 40 KHz oscillator will be connected to the gate of the V_{DCI} driver.

The V_{DCI} driver is a large N-channel MOSFET with a typical ON resistance of less than 4 Ohms and is capable of supplying a peak current of 450 mA. The output device is turned on during each ON half-cycle generated by the internal square-wave oscillator, and is turned off during each OFF half-cycle. During each ON half-cycle, the current through the inductor rises linearly, storing energy in the coil. When the output device is turned off, the external inductor's magnetic field collapses, and the voltage across the inductor reverses sign. The voltage at V_{DCI} then rises until the internal diode is forward biased, delivering power to the V_{DCO} output. The converter is thereby powered from its own V_{DCO} output. This is often referred to as "bootstrapped" operation, since the circuit figuratively "lifts" itself up. In order to guarantee that the Kickstarter can bootstrap itself up to operating voltage, the V_{DCI} voltage must be at the minimum level of V_{DCISU} as listed in the DC characteristics section of this data sheet.

When the voltage on V_{DCO} rises to the V_{DCON} threshold, the internal signal called "HIENUF" will be active and the V_{CCO1} PMOS device is switched on. As noted above, internal circuitry insures that this device will not be switched on for a minimum of 6 clock cycles from the time that the DC-to-DC converter is started. However, since the recommended values for the external LC components result in a time constant which is much longer than six cycles, the actual slew rate will in practice be much longer than this delay time.

If loading of the V_{CCO} outputs causes V_{DCO} to drop below V_{DCOFF} the DS1227 will deactivate HIENUF and the V_{CCO1} PMOS device as well as the other V_{CCO} PMOS devices will be switched off. The V_{DCO} voltage will then be monitored for the V_{DCON} trip point before reconnecting the load. As a result, the power control regulation loop could oscillate between these two states until the V_{CCO1} node had sufficient charge to remain above the V_{DCOFF} threshold. To prevent this from occurring, the value of the filter capacitor must be sufficiently large. For large capacitive loads on V_{CCO1} the output may dip below V_{DCOFF} as a result of charge sharing and a larger regulation capacitor at V_{DCO} may be required. For large resistive loads the inductance and capacitance values may need to be adjusted using a smaller inductor value and large capacitance. In order not to violate the peak V_{DCI} current it may be necessary to use the external oscillator OSCEXT to drive an additional switchmode boost regulator, as shown in Figure 8.

Following the above described start sequence, normal boost operation is performed by the converter. V_{DCO} output voltage is constantly monitored by the error comparator. When V_{DCO} voltage drops below the preset value, the error comparator switches high and connects the internal 40 KHz oscillator to the gate of the V_{DCI} output driver. When the output voltage reaches the desired level, the error comparator inhibits the V_{DCI} output driver until the load on V_{CCO1} discharges the output filter capacitor to less than the desired output level.

INDUCTOR SELECTION

The available output current from the Kickstarter's on-chip DC-DC boost converter is a function of the input voltage, external inductor value, output voltage and the operating frequency. For most applications, the inductor is the only design variable since the internal oscillator is preset to a fixed value of 40 KHz. The proper inductor must have the following characteristics:

1) the correct inductance value must be selected.

2) the inductor must be able to handle the required peak currents.

3) the inductor must have acceptable series resistance and must not saturate.

When the internal N-channel MOSFET turns on, the current through the inductor rises linearly since:

$$\frac{di}{dt} = \frac{V}{L} \quad \text{where L is the inductance value}$$

At the end of the on-time, t_{ON}, the peak current, I_{PK} is:

$$I_{PK} = \frac{V \, t_{ON}}{L} \quad \text{where : } t_{ON} = \frac{1}{2f_O}$$
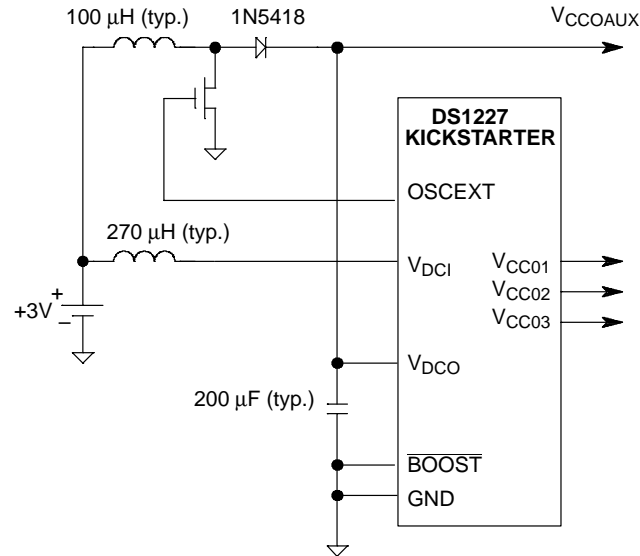
The energy in the inductor is:

$$E_L = \frac{L \, I_{PK}^{\,2}}{2}$$

At maximum load this cycle is repeated f_0 (typically 40 KHz) times per second, and the power transferred through the coil is $P_L = f_0 \times E_L$. Since the coil only supplies the voltage above the input voltage:

$$I_{OUT} = \frac{P_L}{V_{OUT} - V_{IN}}$$

DC-DC CONVERTER Figure 7

AUXILIARY BOOST SUPPLY CONFIGURATION Figure 8

The DC-DC converter's output current is provided both by the inductor and directly from the battery. If the load draws less than the maximum current, the V_{DCI} n-channel MOSFET is turned on only often enough to keep the output voltage at the desired level.

If the selected inductor has too high a value, the DS1227 will not be able to deliver the desired output power, even with the MOSFET turned on for every oscillator cycle. The available output power can be increased by either raising the input voltage or lowering the inductance. This causes the current to rise at a faster rate, and results in a higher peak current at the end of each cycle. The available output power increases since it is proportional to the square of the peak inductor current. The maximum inductance therefore is:

$$L_{MAX} = \frac{V_{IN}^2}{8\ f_O\ P_L}$$

$$\text{since}: \ P_L = \frac{L\ I_{PK}^2\ f_O}{2} \ \text{and}: \ I_{PK} = \frac{V_{IN}}{2}\ f_O\ L$$

The required output power must include what is dissipated in the forward drop of the catch diode and each of the V_{CCO1}, V_{CCO2}, and V_{CCO3} pass transistors. This can be expressed as follows:

$$P_{OUT} = V_F\ I_{OUT} + (I_{OUT12}\ R_{ON1} + I_{OUT2}^2\ R_{ON2} + I_{OUT3}^2\ R_{ON3} + I_{OUT42}\ R_{ON4}) + V_{OUT}\ I_{OUT}$$

where:

$$I_{OUT} = I_{OUT1} + I_{OUT2} + I_{OUT3} + I_{OUT4}$$

If the inductance value is too low, the current at V_{DCI} may rise above the maximum rating. The minimum allowed inductor value is expressed by:

$$L_{MIN} = \frac{V_{IN}}{2\ f_O\ I_{MAX}}\ (I_{MAX} + 450\ mA)$$

TYPES OF INDUCTORS
The following is a brief discussion of various types of inductors which may be typically used with the DS1227 Kickstarter to facilitate boost mode operation. Table 1 lists some typical manufacturers of these types of inductors. Table 2 summarizes performance of the circuit for various inductors.

Molded Inductors
These are cylindrically wound coils which look similar to 1-watt resistors. They have the advantages of low cost and ease of handling, but have higher resistance, higher losses, and lower power handling capability than other types of inductors.

Potted Toroidal Inductors
A typical 1 mH, 0.82 ohm potted toroidal inductor (Dale TE-3Q4TA) is 0.685 in diameter by 0.385 high and

mounts directly onto a printed circuit board by its leads. Such devices offer high efficiency and mounting ease, but at a somewhat higher cost than molded inductors.

Ferrite Cores (Pot Cores)

Pot cores are very popular as switch-mode power supply applications since they offer high performance and ease of design. The coils are generally wound on a plastic bobbin, which is then placed between two pot core sections. A simple clip to hold the core sections together completes the inductor. Smaller pot cores mount directly onto printed circuit boards via the bobbin terminals. Cores come in a wide variety of sizes often with the center posts ground down to provide an air gap. The gap prevents saturation while accurately defining the inductance per turn squared.

Pot cores are suitable for all DC-DC converters, but are usually used in the higher power applications. They are also useful for experimentation since it is easy to wind coils onto the plastic bobbins.

Toroidal Cores

In volume production, the toroidal core offers high performance, low size and weight, and low cost. They are, however, slightly more difficult for prototyping, in that manually winding turns onto a toroid is more tedious than on the plastic bobbins used with pot cores. Toroids are more efficient for a given size since the flux is more evenly distributed than in a pot core, where the effective core area differs between the post, side, top, and bottom.

Since it is difficult to gap a toroid, manufacturers produce toroids using a mixture of ferromagnetic powder (typically iron or Mo-Permalloy powder) and a binder. The permeability is controlled by varying the amount of binder, which changes the effective gap between the ferromagnetic particles. Mo-Permally powder (MFP) cores have lower losses and are recommended for the highest efficiency, while iron powder cores are lower cost.

COIL AND CORE MANUFACTURERS Table 1

TYPE	TYPICAL MANUFACTURER	PART #	DESCRIPTION
Molded	Dale	1HA-104	500 µH, 0.5 ohms
"	Cadell-Burns	7070-29	220 µH, 0.55 ohms
"	Gowanda	1B253	250 µH, 0.44 ohms
"	Nytronics	WEE-470	470 µH, 10 ohms
"	TRW	LL-500	500 µH, 0.75 ohms
Potted Toroidal	Dale	TE-3Q4TA	1 mH, 0.82 ohms
"	Gowanda	050AT1003	100 µH, 0.05 ohms
"	TRW	MH-1	600 µH, 1.9 ohms
"	Torotel Prod.	PT 53-18	500 uH, 5 ohms
Toroidal Core	Allen Bradley	T0451S100A	500 nH/T^2
"	Siemans	B64290-K38-X38	4 µH/T^2
"	Magnetics	555130	53 nH/T^2
Ferrite Core	Stackpole	57-3215	14 mm x 8 mm
"	Magnetics	G-41408-25	14 x 8, 250 nH/T^2

Note: This list does not constitute an endorsement by Dallas Semiconductor and is not intended to be a comprehensive list of all manufacturers of these components.

INDUCTOR SELECTION FOR COMMON DESIGNS Table 2

V_{IN}	V_{DCO}	I_{OUT}	EFF.	INDUCTOR		
(V)	(V)	(mA)	(%)	PART #	uH	Ohms
2	5	5	78	CB 6860-21	470	0.4
2	5	10	74	G 1B253	250	0.44
2	5	15	61	G 1B103	100	0.25
3	5	25	82	CB 6860-21	470	0.4
3	5	40	75	CB 7070-29	220	0.55

Note: CB = Cadell-Burns, NY (516) - 746 -2310
G = Gowanda Electronics Corp., NY (716) - 532-2234
Other manufacturers listed in Table 1.

OUTPUT FILTER CAPACITOR

In boost regulation mode, the DS1227's output voltage ripple on V_{DCO} has two components, with approximately 90° phase difference between them. One component is created by the change in the capacitor's stored charge with each output pulse. The other ripple component is the product of the capacitor's charge/discharge current and its ESR (Effective Series Resistance). With low cost aluminum electrolytic capacitors, the ESR produced ripple is generally larger than that caused by the change in charge.

$$V_{ESR} = I_{PK} \times ESR = \frac{V_{IN}}{2Lf_O} \times ESR \ (\text{Volts p} - \text{p})$$

Where V_{IN} is the coil input voltage, L is its inductance, f is the oscillator frequency, and ESR is the equivalent series resistance of the filter capacitor.

The output ripple resulting from the change in charge on the filter capacitor is:

$$V_{dQ} = \frac{Q}{C} \ \text{where,} \ Q = \frac{t_{DIS} \times I_{peak}}{2}$$

$$\text{and,} \ I_{peak} = \frac{t_{CHG} \times V_{IN}}{L}$$

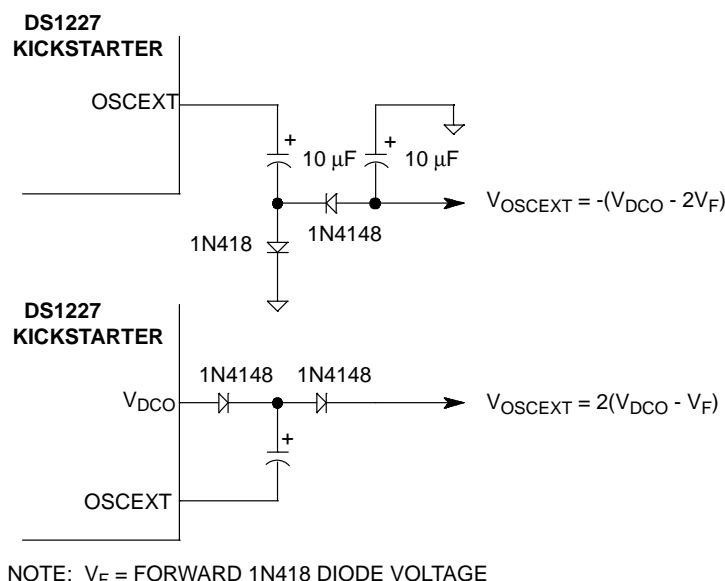$$V_{dQ} = \frac{V_{IN} \times t_{CHG} \times t_{DIS}}{2LC}$$

Where t_{CHG} and t_{DIS} are the charge and discharge times for the inductor $1/2 \ f_O$ can be used for nominal calculations).

High quality aluminum or tantalum filter capacitors will minimize output ripple, even if smaller capacitance values are used. Best results at reasonable cost are typically achieved in the 100 to 500 µF range, in parallel with a 0.1 µF ceramic capacitor.

OSCEXT FUNCTIONS

The OSCEXT pin is connected to the internal 40 KHz oscillator (nominal frequency). When Boost mode is enabled ($\overline{BOOST} = 0$) and the DC-to-DC converter is running, OSCEXT is active at the same time whenever the error comparator is switched high, i.e., whenever the internal oscillator is enabled to the gate of the V_{DCI} driver. In this configuration it may be used to drive an auxiliary switch mode boost regulator as shown in Figure 8. In this circuit, OSCEXT drives an external NMOS switch with its drain pin connected to an additional inductor and filter capacitor as well as an external catch diode. The amount of supply current which can be realized at the +5V output is determined by the power ratings of the external components. Through proper selection of the these components, increased supply current can be realized than is possible using the Kickstarter's internal V_{DCI} driver and catch diode.

When the Pass-Through mode is enabled ($\overline{BOOST} = 1$) and at least one of the V_{CCO} outputs is switched on, the OSCEXT pin will be continuously driven with the 40 KHz frequency. In this configuration this pin could potentially be used to generated negative or doubled voltages as shown in Figure 9.

VOLTAGE INVERTOR AND DOUBLER CONFIGURATIONS Figure 9

DS1227
KICKSTARTER

OSCEXT

10 µF   10 µF

1N418   1N4148

$V_{OSCEXT} = -(V_{DCO} - 2V_F)$

DS1227
KICKSTARTER

1N4148   1N4148

V_{DCO}

$V_{OSCEXT} = 2(V_{DCO} - V_F)$

OSCEXT

NOTE: V_F = FORWARD 1N418 DIODE VOLTAGE

APPLICATION BRIEF

The schematic shown in Figure 10 illustrates a typical application of the DS1227 Kickstarter in a microcontroller-based, battery powered system. Together with the Kickstarter, the system incorporates a DS5000FP Soft Microcontroller, a DS1283 Watchdog Timekeeper, and a DS1275 Line Powered RS232 Transceiver. Although the system is not designed to serve a specific application, this chip set could serve the majority of requirements for many types of hand-held instruments.

Using the illustrated configuration provides the following major features:

- Permanently powered operation from a +3V source for many applications
- Data and event logging with time stamp and date
- Reprogrammable through RS232 serial interface
- Buttonless (autonomous) operation for many tasks

COMPONENT DESCRIPTION

The DS5000FP is an 8-bit microcontroller which is instruction set-compatible with the industry standard 8051. It provides an embedded interface to 32 Kbytes of nonvolatile static RAM which can be dynamically partitioned for program and data storage, and may be loaded at any time via the on-chip serial port. With proper selection of RAM and the backup lithium source, nonvolatile storage can be maintained for over 10 years in the absence of V_{CC}. The DS5000FP offers the standard low power operating and standby modes (i.e., Idle, Stop). More importantly, sophisticated crashproof circuitry in conjunction with the lithium energy source allows it to retain its entire operating state for the duration of a power outage without drawing current from its V_{CC} line.

Timekeeping is provided by the DS1283 Watchdog Timekeeper. Incorporating a self-contained clock and calendar, the DS1283 tracks hundredths of seconds, seconds, minutes, hours, days, date of the month, month, and years. When its chip enable is inactive (no read or write), the DS1283 consumes extremely low current, typically 500 nA. Two alarm functions are provided: a time-of-day Alarm, and a watchdog alarm. The time-of-day Alarm can generate an interrupt pulse up to one week in advance of the current time. The watchdog alarm can produce an interrupt at regular intervals ranging from .01 seconds to 99.99 seconds. Both alarms function when the part is operating in low power standby mode.

The DS1275 Line Powered RS232 Transceiver allows the instrument to communicate with the RS232 port on a host computer (e.g., COM port on an IBM PC). It operates from a +5V supply and draws no power from the instrument's main energy source to create negative voltages. Instead, it steals power from the incoming RXD line to generate the negative voltages needed during transmission.

INSTRUMENT OPERATION

A common requirement of instruments is event logging with time stamp and date. The Dallas chip set provides this capability using the DS5000 and DS1283. The DS1283 interfaces directly to the DS5000FP embedded bus, and may be accessed by $\overline{CE2}$. In this way, valuable port pins are conserved. Events can be recorded by the microcontroller and logged in RAM with the date and time. In the absence of V_{CC}, the data will be retained in RAM by the backup lithium cell. The same energy cell provides backup to the DS1283, so that timekeeping is maintained in the absence of a primary energy source. Therefore, events may be time stamped and dated with confidence that the correct time has been maintained. Backup lithium current is managed by the DS5000FP and is distributed from the V_{CCO} line in the absence of V_{CC}.

PERMANENTLY POWERED OPERATION

In order to achieve permanently powered operation, Dallas Semiconductor uses several techniques which conserve the life of a primary energy source. First, the illustrated chip set operates at extremely low power. These components are also capable of very low power data retention. Second, the crashproof circuitry of the DS5000 allows V_{CC} to be removed and restored without disruption. This allows the energy management circuits of the Kickstarter to power down the microcontroller during periods when it is unused. Since the DS1227 can monitor external events and wakeup the DS5000 as necessary, the microcontroller and other circuitry may remain in low power data retention mode until needed. The DS5000, RAM, and DS1283 will be backed up via the button cell as show in Figure 1. Finally, the Kickstarter allows software-controlled powering of auxiliary circuits when tasks require them.

Low operating power is a basic requirement of battery-operated systems. The illustrated Dallas chip set can perform most instrument functions using minimal power. Using a 3.57 MHz crystal, the circuit in Figure 1 will draw approximately 8 mA during microcontroller operation. When the Kickstarter turns off the DS5000, the circuit draws approximately 5 µA from the primary energy source. If a similar configuration were created with an ordinary CMOS microcontroller in stop mode, the current could be as high as 55 µA. Idle mode operation would consume approximately 3 mA, which would excessively drain a primary power source over extended periods. The Dallas low power chip set provides a ten-to-one improvement over previously available alternatives.

Achieving the lowest power instrument requires the DS1227 Kickstarter. Using the Kickstarter, low power operation is achieved by powering down the microcontroller. When this occurs, the DS5000 effectively consumes zero power. RAM and key registers are backed by the lithium button cell, with no power draw from V_{CC}. When a task must be performed, the Kickstarter powers up the DS5000 to execute a function and powers it down when the function is complete (under software direction). The period for which power remains on is minimized in this way. Since most tasks require minimal processing time with long periods of waiting, the instrument may remain in a low power data retention mode for the majority of time. Therefore, even if an operator interface is necessary, the microcontroller can remain on for milliseconds (or microseconds) to perform a task, and remain off for the seconds between operations.

The ability to react to external stimuli allows the instrument to operate autonomously for many applications. Fundamental to this operation is the kickstart caused by external stimuli. The following section describes the operation of the Kickstarter with respect to four different stimuli.

KICKSTARTING OPERATION

The DS1227 receives primary power from a +3V lithium battery. Prior to a kickstart, battery voltage is present on V_{DCO}, which is the main voltage output. When the system receives a kickstart stimulus, an on-chip boost regulator raises V_{DCO} to +5V. Upon completion of power up, +5V is switched to the DS5000 on V_{CC01}. Prior to kickstart, no power was supplied to this line.

TYPICAL APPLICATION OF DS1227 KICKSTARTER Figure 10
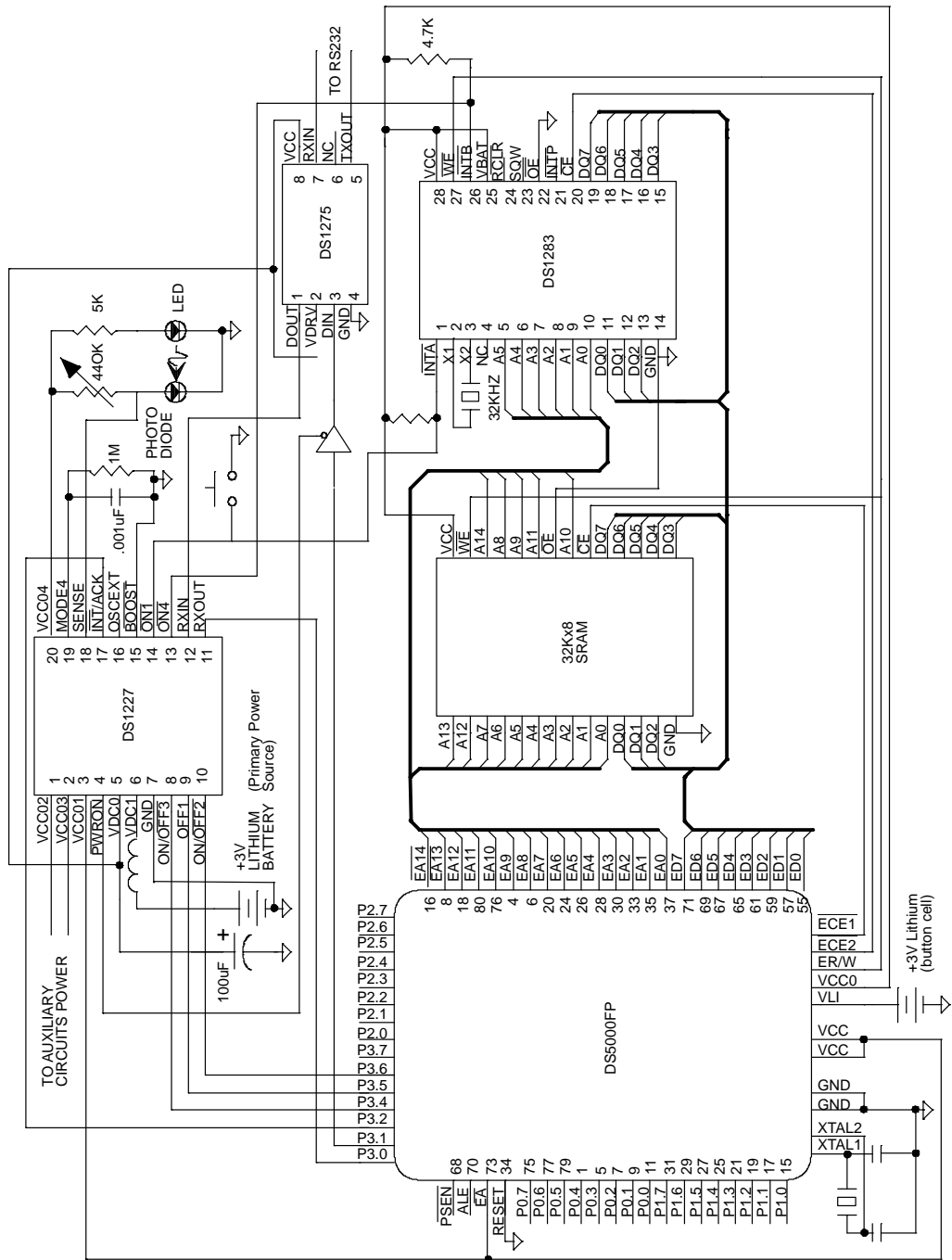
The schematic in Figure 1 demonstrates four kickstart stimuli. They are real time clock alarm, RS232 incoming data, a sensor input, and a user switch. During the low power standby prior to kickstart, V_{CCO} from the DS5000 provides battery power to the RAM and real time clock from the button cell. V_{DCO} supplies the RS232 transceiver. While operating on battery power, the RTC can still issue alarms. If a time of day alarm is programmed, $\overline{INTA}$ will be taken low by the RTC when the alarm occurs. Th is is connected to $\overline{ON1}$, and issues a Kickstart.

Incoming RS232 activity will allow the transceiver to Kickstart the DS1227. Following the initial interrupt, all additional RS232 data is passed through the RXIN/RXOUT pins of the DS1227 to the DS5000 without further action. In this way, the instrument can collect a table of data and dump it to a PC for analysis when necessary. Since the instrument will kickstart when it detects RS232 communication, it is unnecessary for an operator to take further action. Enough time should be allowed for the DS5000 to complete a power-on reset before sending meaningful data.

Two additional methods of kickstarting are illustrated. One method involves the use of a sampled sensor. A periodic pulse (the watchdog alarm) from the DS1283 causes V_{CC04} to be applied to the LED. For example, this might occur every 250 ms. It remains on for the time it takes to charge the capacitor on Mode4 to 1/2 V_{DCO} (1.5V). In this example, the on period is approximately 75 μsec. Just prior to removing V_{CC04}, the sense line is sampled. If the LED light path to the photodiode is blocked, the sense line will be high and the system will be kickstarted. If the light path is clear, the sense line will be low, and nothing will happen. This facilitates checking for the presence of an ID card in a reader. In the other method a user switch, which is momentarily closed, will start the system. This is tied to $\overline{ON1}$ in a wired-OR configuration. All of the above kickstart stimuli cause the boost regulator to raise V_{DCO} and turn on V_{CC01}. In summary, the four kickstart stimuli are:

1) Time of Day Alarm - $\overline{INTA}$ goes low and Kickstarts V_{CC01}.

2) RS232 Activity - Powers up V_{CC01} and routes all RS232 straight through to the DS5000.

3) $\overline{INTB}$ goes low periodically, V_{CC04} turns on, and the sense line is sampled. If high, a kickstart occurs. If low, no action.

4) A user switch momentarily pulls $\overline{ON1}$ low and kick starts.

Although the user switch is easily implemented, it may be unnecessary. By allowing the instrument to power up and determine the cause of the Kickstart, it is possible to achieve buttonless operation in many applications. Automatic response allows the instrument to function autonomously and save power by turning off unused circuits.

Once the DS5000 receives power, it must read the $\overline{INT}$/ACK line (tied to $\overline{INT0}$). A power-on condition causes this signal to be low. The DS5000 port pin should then acknowledge power up by driving this line high. This recognizes the interrupt and enables the kickstarter for further activity. The DS5000 may now turn on auxiliary loads V_{CC02} and V_{CC03} using ON/$\overline{OFF}$ 2 and 3 (tied to any port pins). These auxiliary supplies may supply circuits which are not always necessary (e.g. an A/D converter). Peripheral circuits remain powered down until needed. After an operation is complete, the DS5000 can turn off the auxiliary circuits. When processing of a task is complete, it may turn itself off using $\overline{OFF1}$. An application may require that an auxiliary circuit remain on when the microcontroller is off. This might occur with an LCD display or dual slope A/D converter. Since the dual slope A/D takes a relatively long period to convert (40-50 mS), the microcontroller may be powered down while waiting.

Since the INT/$\overline{ACK}$ line is tied to INT0, additional kickstart stimuli which occur while VCC01 is on will cause the DS5000 to receive an interrupt. This allows the DS5000 to take action for specific conditions.

Precautions against excessive current drain are taken in this application. For example, the data input to the DS1275 RS232 transceiver is tri-stated when VCC01 is off. This is necessary to prevent a high signal from driving the RS232 bus and consuming power while the DS5000 is off. Similar precautions should be taken by the user in designing systems with switched power supplies.

ABSOLUTE MAXIMUM RATINGS*

Input Voltage on any Pin Relative to Ground	-0.3 to 7.0V
V_{DCI} Peak Input Current	450 mA
Power Dissipation	
Plastic DIP (derate 7.41 mW/°C above +50°C)	- 555 mW
Small Outline (derate 12.5 mW/°C above +50°C)	- 937 mW
Operating Temperature	−40°C to +85°C
Storage Temperature	-55°C to +125°C
Lead Soldering Temperature	260°C for 10 seconds

* This is a stress rating only and functional operation of the device at these or any other conditions above those indicated in the operation sections of this specification is not implied. Exposure to absolute maximum rating conditions for extended periods of time may affect reliability.

ELECTRICAL CHARACTERISTICS $(t_A = -40°C \text{ to } +85°C)$

PARAMETER	SYMBOL	MIN	TYP	MAX	UNITS	NOTES
Startup Voltage	V_{DCISU}	1.8			V	1
V_{DCO} Voltage Threshold for V_{CCO} Turn-ON	V_{DCON}	4.20	4.30	4.62	V	
V_{DCO} Voltage Threshold for V_{CCO} Turn-OFF	V_{DCOFF}			4.00	V	
Operating Supply Current ($\overline{BOOST}$=0) ($\overline{BOOST}$=1)	I_{CC}		1.5 0.5	3.0 1.0	mA mA	4 2
Standby Supply	I_{SB}			200	nA	
V_{CCO1} DC Source Current ($V_{CCO1} = V_{DCO}$ -0.25V)	I_{CCO1}			100	mA	2, 7
V_{CCO2}, V_{CCO4} DC Source Current (V_{CCO2}, $V_{CCO4} = V_{DCO}$ - 0.25V)	I_{CCO2} I_{CCO4}			50	mA	2, 7
V_{CCO3} Source Current ($V_{CCO3} = V_{DCO}$ - 0.25V)	I_{CCO3}			10	mA	2, 7
V_{CCO1}, V_{CCO2}, V_{CCO3}, V_{CCO4} Voltage	V_{OUTB}	4.75	5.00	5.25	V	1, 4
V_{CCO1}, V_{CCO2}, V_{CCO3}, V_{CCO4} Voltage	V_{OUTP}	V_{DCO} -0.25			V	2
V_{CCO4} Voltage	V_{OUT4}	V_{DCO} -0.25			V	
V_{CCO1} ON Resistance	R_{VCCO1}			2.5	Ohms	
V_{CCO2}, V_{CCO4} ON Resistance	$R_{VCCO2,4}$			5.0	Ohms	
V_{CCO3} ON Resistance	R_{VCCO3}			25	Ohms	
Efficiency			80		%	1, 8

PARAMETER	SYMBOL	MIN	TYP	MAX	UNITS	NOTES
Line Regulation $+0.5V_{CCO} < +V_S < V_{CCO}$	V_{CCO}			0.4	%	1
Oscillator Frequency			40		KHz	
Oscillator Duty Cycle			50		%	
OSCEXT ON Resistance	R_{OSCEXT}		50	75	Ohms	
V_{DCI} Driver ON Resistance (@ I_{VDCI} = 100 mA)	R_{VDCION}		6	14	Ohms	1
V_{DCI} Driver OFF Leakage Current (t_A = 25° C)	I_{VDCIL}			30	μA	1
Catch Diode Forward Voltage	V_F			1.0	V	
Output Low Voltage, (OSCEXT, $\overline{PWRON1}$) I_{OL} = 1.6 mA	V_{OL}			0.45	V	
Output High Voltage (OSCEXT, $\overline{PWRON1}$) I_{OH} = -80 μA	V_{OH}	2.4			V	
Input Low Current ($\overline{INT}$, ON2/$\overline{OFF2}$, ON3/$\overline{OFF3}$, $\overline{ON4}$, $\overline{BOOST}$)	I_{IL1}	-1.0		1.0	μA	
Input Low Current ($\overline{ON1}$, RXIN)	I_{IL2}	-50			μA	6
Output High Current ($\overline{PWRON1}$)	I_{OH}	-400			μA	
Output Low Current ($\overline{PWRON1}$)	I_{OL}	2.0			mA	
RXIN Current ($V_{RXIN} - V_{RXOUT} \leq 500$ mV)	I_{RXIN}	10			mA	
$\overline{INT}$/ACK Input Transition Current	I_{ACKT}			± 2.0	mA	5
$\overline{INT}$/ACK Input Leakage Current $0.0 \leq V_{IN} \leq 0.1$, or V_{DCO} $- 0.1 \leq V_{IN} \leq V_{DCO}$	I_{ACKL}			± 200	μA	5
SENSE Resistance (V_{CCO4} ON)			250		KOhms	
MODE4 Source Current (MODE4 = 0 when $\overline{ON4}$ goes from 1 to 0)	I_{M4ON}	10	45	100	μA	
MODE4 Source Current Shutoff Voltage	V_{M4OFF}		$0.5V_{DCO}$			
MODE4 Discharge Resistance (Following current source shutoff)	R_{M4DIS}			2	KOhms	
MODE4 Discharge Resistance Shutoff Voltage	V_{M4DIS}			$0.1V_{DCO}$		

NOTES:

1. Applicable only when Boost mode operation is in effect.

2. Applicable only when Pass Through mode operation is in effect.

3. Valid when $2.5V \leq V_{DCO} \leq 5.0V$.

4. Measured with Boost Mode operation in effect; $I_{CCO1} = I_{CCO2} = I_{CCO3} = I_{CCO4} = 0$. This value represents the amount of current drawn by the DS1227 itself during and does not include current supplied on the I_{CCO} outputs nor does if boost operator includes inefficiencies of DC-to-DC conversion.

5. Input transition current on the INT/$\overline{ACK}$ pin is specified to indicate the amount of current required to switch the pin from a high to a low or from a low to a high condition. Once the pin has switched states, then the leakage current specification is applicable.

6. $\overline{ON1}$ and RXIN have internal weak p-channel pull-up devices.

7. When BOOST operation is in effect, the total combined current supplied out of V_{CCO1}, V_{CCO2}, V_{CCO3}, and V_{CCO4} is limited by the V_{DCI} peak current.

8. Actual efficiency is dependent on external discrete component characteristics.

9. Battery replacement in the boost mode requires the discharge of the capacitor attached to V_{DCO} (pin 5). The following, or similar, circuit is recommended (see Figure 11).

BATTERY DISCHARGE CIRCUIT Figure 11