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\section{Introduction}
This section describes the motivation, context, and objectives of the work. We aim to explore how atmospheric electric potentials can be harvested, modeled, and converted, and propose a circuit model for such a system.

\section{Technical Background}
We consider the known parameters of atmospheric electric fields and amplifier behavior:
\begin{itemize}
  \item The amplifier LMC6001 has an input bias current up to about 25 fA at 25 °C, and under adverse conditions possibly up to ~2 pA.
  \item Noise, offset, drift specifications from the datasheet serve as anchor points.
  \item Typical atmospheric electric field strengths are ~100 V/m in calm conditions; air conductivity is extremely low, so harvested currents over electrode areas on the order of 1 m² are in pico- to nanoampere ranges.
\end{itemize}

\section{System Architecture and Circuit Topology}
The envisioned system architecture consists of:
\begin{itemize}
  \item A resonant electrode (antenna) that “listens” to atmospheric potential gradients.
  \item A Transimpedance Amplifier (TIA) stage that converts the extremely small current into a voltage.
  \item A feedback network comprised of a high-value resistor \(R_f\) and compensation capacitor \(C_f\).
  \item A rectifier / detector, then a storage stage (e.g., supercapacitor + battery) for buffering.
  \item Protective and shielding structures: guard rings, driven shields, isolation, protections against surges.
\end{itemize}

\section{Pseudo-SPICE Modeling}
We propose a SPICE subcircuit for LMC6001 with example experimental parameter estimates:
\begin{verbatim}
.SUBCKT LMC6001_EXPERIMENTAL non_inv inv out VCC VEE
  I_bias_noninv non_inv 0 DC 1e-14
  I_bias_inv inv 0 DC 2.5e-14
  G_leak inv non_inv VALUE = { V(inv,non_inv)*1e-12 }
  E_offset inv non_inv voff 1
  E_gain out 0 VALUE = {1e6*(V(non_inv,inv))}
  R_out out out_node 50
```

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  E_out out_node 0 VALUE = { V(out)*0.999 }
  R_load out_node out 20
.ENDS LMC6001_EXPERIMENTAL
\end{verbatim}
```

Additionally, the netlist template is:

```
\begin{verbatim}
I_in Electrode 0 DC 1e-11
R_path Electrode inv 1e6
R_fb out inv 1e9
C_fb out inv 1e-12
X1 non_inv inv out VCC VEE LMC6001_EXPERIMENTAL
VCC VCC 0 DC 5.0
VEE VEE 0 DC -5.0
.options abstol=1e-15 reltol=1e-6 gmin=1e-16
\end{verbatim}
```

We also include SPICE options directives to assist simulation in the ultra-low current regime.

\section{Simulation Estimates \& Performance}
With a current source of ~10 pA and \(R_f = 1\,\text{G}\Omega\), the output voltage may reach tens of millivolts under ideal conditions. At lower currents (in the femto / picoampere domain), the signal is extremely vulnerable to noise, offset, and leakage paths.
The interaction of parasitic capacitances, PCB leakage, amplifier input leakage, and offset could substantially erode the useful signal. To realize milliwatt-level output, substantial advancements in electrode area, materials, circuit losses, and possible active amplification are required.

\section{Risks \& Limitations}
Key risk factors:
\begin{itemize}
  \item Surface leakage and parasitics may dominate the signal chain unless suppressed with guard rings and extremely clean isolation.
  \item Amplifier noise, offset drift, and power supply coupling can overwhelm femto- to picoampere signals.
  \item Instability or oscillations may arise in high-gain loops if \(C_f\) (compensation) is inadequately chosen.
  \item Parasitic capacitance and inductance in traces degrade signal integrity and bandwidth.
  \item Scaling up to meaningful power requires dramatically larger electrodes, better isolation, and stricter environmental control.
\end{itemize}

\section{Recommendations \& Roadmap}
\begin{enumerate}
\item Execute simulations with the provided netlist and model, sweeping source current, \(R_f\), leakage parameters to assess sensitivity.
\item Build a prototype of the TIA with guard ring, shielding, ultra-low leakage components to measure input currents, offset, noise.
\item Calibrate the SPICE model using empirical data: refine leakage, offset, parasitics.
\item Include realistic parasitic elements in subsequent simulations: electrode capacitance, PCB leakage pathways, stray coupling.
\item Explore electrode materials (e.g. graphene + Au, nanostructures) to maximize harvesting sensitivity.
\item Optimize compensation networks \(C_f\), ensure loop stability, and consider multi-stage amplification.
\item Scale up electrode area gradually, integrate protective measures, and test under atmospheric conditions.
\end{enumerate}

\section{Conclusion}
This technical content establishes a foundation for modeling, simulating, and prototyping an atmospheric energy harvester. While fundamental limits (noise, leakage, parasitics) present strong challenges, the structure of circuitry and modeling is in place. The next phase is prototyping, measurement calibration, and iterative refinement.